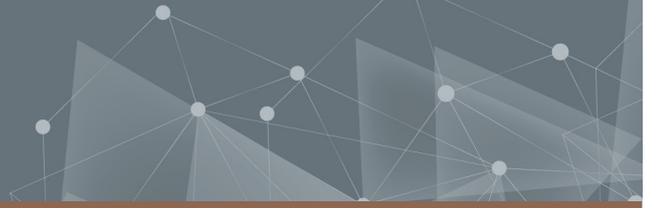




CHALMERS
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Optimizing product configuration processes

Master's thesis in Product Development

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2024

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MASTER THESIS 2024

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Typeset in LATEX
Gothenburg, Sweden 2024

Abstract

This thesis investigates the implementation of a new product configuration process and the key factors that determine the success of the new process. Through data collection methods and several analyses of the collected data, five key aspects were identified: Standardization of formats and processes, Streamlining data flow, Enhanced version control, Minimizing human errors, and Adapting to systems and external parties.

Comprehensive analyses revealed that standardization and streamlining significantly improve efficiency and reduce errors. The practical implementation of a new IT system within the configuration process at the collaborative company Polestar underscored the importance of establishing clear templates and workflows to enhance consistency and ease of use. Streamlining data flow through automated notifications and system integration minimized delays and gaps, increasing visibility and accountability. Enhanced version control systems facilitated accurate tracking of document revisions, promoting transparency and compliance for external and internal audits and regulations. Minimizing human errors involved automating repetitive tasks and implementing validation checks, improving accuracy and efficiency. Adapting to systems and external parties emphasized the importance of collaboration and alignment to ensure seamless data exchange. These findings align with the Lean methodology, which emphasizes continuous improvement and customer-centricity.

Analyses conducted in this project provided a profound understanding of data flow dynamics, overcoming challenges associated with stakeholder comprehension. Initial visual mapping clarified data flow, while subsequent process and information models offered nuanced insights into process dynamics and data integration, empowering stakeholders to identify areas for improvement. This clarity facilitated collaborative efforts, evident during the implementation of the new IT system with Polestar.

Moreover, the analysis of the new IT system underscored the significance of "Minimizing Human Errors" and "Enhanced Version Control" in mitigating information loss. Automated change logs and dedicated SharePoint folders streamlined document tracking, reducing errors and enhancing efficiency and compliance with regulations. Prioritizing these factors led to a smoother configuration process, minimizing information loss and enhancing user accountability.

Further research is recommended to validate these findings across diverse companies beyond Polestar, confirming the effectiveness of the identified framework in various industries. Additionally, refining the developed IT system to address bugs and expand its coverage within the configuration process could enhance its performance. Exploring the optimal configuration process structure, whether a single supersystem or multiple subsystems, would be valuable for future investigation, offering insights into associated benefits and challenges.

Acknowledgements

We would like to take the opportunity to thank Polestar and our supervisor Dag Henrik Bergsjö for all the help and guidance throughout this research project. We are also grateful for the collaboration with Polestar and how they have been trusting our process and decisions throughout the duration of the project.

List of Abbreviations

The following table explain some of the words employed in the report. The abbreviations covers both general concepts in the field but also specific that are utilized within Polestar and their external parties. The list is in alphabetical order:

DRM	Design Reasearch Methodology
Model year	A version of a product and the time it is released
Package structure	The optional packages and trim levels a customer can choose when configuring a car
Product Configuration	The process which is utilized to make new products
Powertrain	Specifies a vehicle's level of equipment or special features
Vehicle Binder (VB)	List of features specifying a car

Contents

1	Introduction	2
1.1	Background	2
1.2	Purpose	3
1.3	Boundaries	3
1.4	Clarification of the research question	3
1.5	Project plan	4
1.6	Overview of report	5
2	Theoretical framework	6
2.1	Configuration process	6
2.2	Vehicle binder	6
2.3	Offer-file	7
2.4	Process model	7
2.5	Information model	8
2.6	KJ-Analysis	8
2.7	IT-System	8
2.7.1	CPQ & PLM	9
2.7.2	Suppliers	9
3	Method	11
3.1	Method Theory	11
3.1.1	Research Clarification	11
3.1.2	Descriptive Study I	11
3.1.3	Prescriptive Study	12
3.1.4	Descriptive Study II	12
3.2	Applied Methodology	12
3.2.1	Research Clarification	12
3.2.2	Descriptive Study I	17
3.2.3	Prescriptive Study	23
3.2.4	Descriptive Study II	29
4	Results	30
4.1	Key aspects of a new configuration process	30
4.1.1	Theoretical key aspects	30
4.1.2	Implemented key aspects	31
4.2	Clarity of the configuration process	39

4.3	Minimize the risk of information loss	40
5	Analysis	42
5.1	Standardization of Formats and Processes	42
5.2	Streamlining Data Flow	43
5.3	Enhanced Version Control	43
5.4	Minimizing Human Errors	44
5.5	Adapting to Systems and External Parties	45
5.6	Resemblance to the Lean methodology	45
5.7	Conclusion of analysis	46
6	Discussion	47
6.1	Integration of the system	47
6.2	Internal development vs Super-system	48
6.3	Synergistic outcome from framework	49
6.4	Recommendations	51
7	Conclusion	52
	Bibliography	54
A	Appendices	I
A.1	First map of the data flow	I
A.2	Second map of the data flow	III
A.3	Process Model	V
A.4	Information Model	VII
A.5	Gantt chart	IX

1

Introduction

There is an excessive amount of data in businesses as a result of the quick development of Industry 4.0 technologies like automation and IoT (Internet of Things) devices. Because it is becoming more complex to navigate through all of the data, data management has become crucial for businesses to handle. The significance of being able to track data from the very beginning of the process all the way through to the very end. Coordinating many streams is difficult, especially when combining data from several departments. Organizations need to have access to cutting-edge technology and be ready for a data-driven approach in order to tackle these challenges. This introduction establishes the framework for talking about the difficulties in managing data flow in production companies and emphasizes the need for innovative solutions.

This master's thesis will be conducted with the car manufacturing company Polestar. Polestar is a company founded in 2017 that makes electric vehicles, focusing on design, innovation, and sustainability. The project will be conducted within the product management division. The following areas will be discussed in this chapter: the background of the project, purpose, boundaries, clarification of the research question, work procedure, as well as an outline of the time schedule.

1.1 Background

Every company has work processes to accomplish different tasks. In many cases, each process contains many subprocesses. These subprocesses can be connected to each other in different ways and can vary greatly in complexity. Changing parts of, or the whole process, can be very difficult since the function of the whole process needs to be understood and the inputs and outputs connecting each subprocess need to be compatible with each other. Processes are built to make sure they accomplish that specific task, which may result in a complex structure with suboptimal connectivity between subtasks. In the creation and production industry, it is extremely important to be able to track and have clear communication of information, especially when the product offer can vary. It can differ from company to company, but in some way, all companies that produce products have a process of product configuration. Product configuration is a critical aspect of modern manufacturing and sales strategies, enabling businesses to offer customized products tailored to individual customer needs and preferences, while minimizing errors in communication.

The project's collaboration partner, Polestar, is relatively young and has emerged

from another company named Volvo Cars. Polestar has therefore inherited many processes that are not optimized for their needs and organization. Many of the work methods are related to the previous company. Volvo Cars is a Swedish automotive manufacturer that produced its first car in 1927. Volvo Cars have become well known for its dedication to safety, innovation, and sustainability. A pioneer in automotive safety technology, introducing groundbreaking features like the three-point seatbelt and autonomous driving aids.

At Polestar, they are currently working with different R&D partners, to jointly develop new cars for the market. As a result, Polestar is using three different ordering systems where they list the features configuring a car, one for each company, that collectively define what should be developed by the different partner's R&D departments to create the wanted car. It also contains different variants to use as a base for financial systems to calculate the cost per car. Moreover, there are distinct specifications for each car designed for every continent due to customer features, legal demands, and rating features.

The objective of this project is to find a solution to improve the product configuration process. The focus should be centered around the beginning of the configuration process where features are set to explain all customer functions to all R&D partners. The improved process is meant to increase the quality and efficient of the data flow and minimize risks of combining wrong data further down the process.

1.2 Purpose

The project's purpose is to streamline the work and minimize the risks when specifying the cars that are to be created. The system should ease the flow of the data and be compatible with other sub-processes.

1.3 Boundaries

The project will create one system, which should be finished within the time-frame set for the thesis project. Therefore, the complexity level of the future system will match the time available. The project will not concern improvements to R&D partners user interface; the delivery will continue to be the standard format of today in Excel format.

1.4 Clarification of the research question

RQ1: What are the key aspects of implementing a successful new product configuration process?

RQ2: How can the challenges of the implementation be overcome by analyzing the information flow within the process?

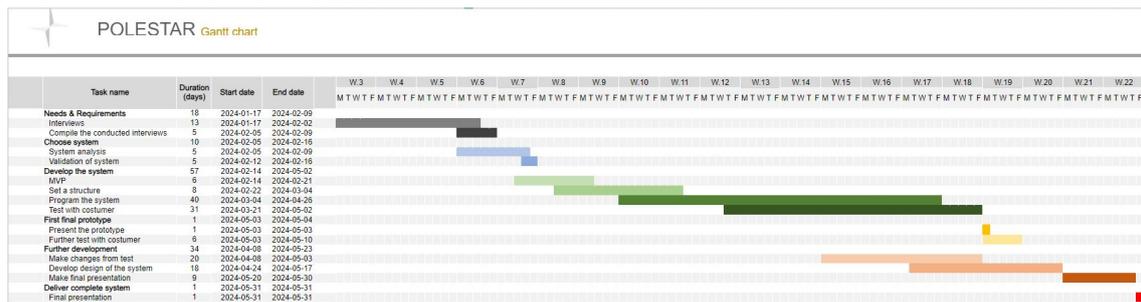
RQ3: Can factors be optimized to minimize the risk of information loss in the process?

To gather insights, the research team will utilize both experience-based knowledge, acquired through interviews and site visits with stakeholders across different phases of the organization, and data-based knowledge, extracted from a substantial dataset provided by Polestar. By adopting this dual approach, the study aims to elucidate both barriers and opportunities for optimizing the product configuration process. The findings from this study are expected to provide valuable insights into potential strategies for overcoming challenges associated with configuration processes in the industry. This research endeavor has the potential to enhance the efficiency and effectiveness of configuration processes within Polestar and potentially contribute to improvements within the broader automotive sector.

1.5 Project plan

In Table 1.1, a Gantt chart is presented, which illustrates the planning of this thesis's. The events are listed to the left, and the time period is visualized to the right. A full size of the Gantt chart is presented in Appendix A.5.

Table 1.1: *The thesis's Gantt chart*



1.6 Overview of report

The thesis comprises a theoretical framework, a methodological section, a qualitative segment, followed by results, which are subsequently analyzed, discussed, and concluded. The qualitative part encompasses interviews and workshops with stakeholders from various organizational sectors as described in the report. Table 1.1 presents a summary of the chapters and their corresponding contents.

Table 1.2: Thesis Structure

Introduction	Describes the background of the thesis, the purpose, boundaries and present the research questions for the project.
Work procedure	Divided in two parts, Theoretical framework, where previous studies regarding configuration processes, vehicle binder, process and information model, and CPQ & PLM will be included, and Methodology, which include the research approach, including the quantitative and qualitative methods.
Results	Presenting the results of the project and identifying the framework.
Analysis	Compares the results with previous studies and frameworks.
Discussion	Discussion about the project, and presenting recommendations of further development.
Conclusion	Conclusion of the project.

2

Theoretical framework

Theoretical frameworks are crucial in research, as they organize concepts and guide methodologies. The project have used existing theories to understand the study better, pinpoint gaps, and generate new insights. The used theories in this research are presented in the following section.

2.1 Configuration process

Configuration involves the strategic application of resources, processes and tools to create and maintain alignment between product requirements, the product itself and associated configuration information. Configuration Management (CM) is a key component in ensuring alignment throughout the project lifecycle, thereby reducing product development time, limiting costs and increasing overall product quality. By emphasising critical process capabilities and addressing key success factors and barriers, organisations can skillfully implement and evolve their CM processes to achieve optimal results. (Callum 2013)

Effective communication, customer awareness, and the creation of a favourable environment are fundamental factors contributing to configuration effectiveness, consequently, a organizational performance. Implementation of process controls at the supplier level and the fostering of a supportive organizational culture serve to fortify configuration management practices, mitigating risks associated with compromised product quality. Emphasizing consistency, flexibility, and a commitment to continuous improvement in configuration management processes is crucial for optimizing efficiency and effectively meeting project requirements. (Callum 2013)

2.2 Vehicle binder

In the automotive industry, the development of internal configurator tools has become essential for efficiently configuring new vehicles for production within companies. Among these tools, the vehicle binder serves as a comprehensive platform designed to streamline the configuration process and optimize production workflows. This theoretical exploration delves into the foundational principles and conceptual frameworks informing the functionality and effectiveness of the vehicle binder tool within the internal operations of automotive manufacturers.

Efficient production configuration is vital for optimizing manufacturing processes and ensuring cost-effectiveness within automotive companies. Rooted in theories of production optimization and lean manufacturing, the vehicle binder tool offers a

wide range functionalities. Enabling users to select features, materials, and specifications, streamlining data from project initiation to conclusion and enhancing overall operational efficiency throughout the organization. The tool enables the organization of features across various vehicles with different model years. A model year represents a new version of the same car, incorporating changes that can range from minor adjustments to significant modifications.

At the core of the vehicle binder's functionality lies the concept of product configuration, involving the systematic definition of specifications and attributes of new vehicles for production. Leveraging theories of product customization and modular design, the tool provides a comprehensive selection of customizable options, from engine specifications to interior features. Through an intuitive interface, users can experiment with different configurations and visualize their impact on production processes, facilitating informed decision-making and ensuring alignment with production requirements. (P.T Helo 2010)

2.3 Offer-file

In the context of product configuration, an offer file plays a pivotal role in facilitating the generation and presentation of customized product configurations to customers. The file serves as a comprehensive repository of detailed information regarding the configured product, encompassing specifications, features, pricing, and associated terms and conditions. One choice of feature could require another, or some features may not be compatible with others.

The offer file comprises several key components essential for accurate and personalized product configurations. It includes detailed product specifications, such as model variations, dimensions, materials, and optional features for all possible variation the customer could make. This ensures that the configured product accurately reflects the customer's preferences and requirements.

Additionally, the offer file incorporates algorithms or formulas for calculating the total price of the configured product based on the selected features and any applicable pricing rules or discounts. This ensures transparency and consistency in pricing, enabling the company to make more informed decisions.

2.4 Process model

Process modeling is a vital concept in data management, aimed at understanding, analyzing, and enhancing processes within an organization or system. A process model is essentially a visual or abstract representation of activities, tasks, or steps leading to a specific goal. It captures the flow of actions, resources, decisions, and interactions involved in process execution. These models simplify understanding complex systems, identifying bottlenecks, optimizing workflows, and fostering stakeholder communication.

The significance of process models lies in their ability to boost efficiency and transparency within organizations. By offering a structured framework for analysis, they present opportunities for identifying improvements, streamlining operations, opti-

mally allocating resources, and adapting to the environment. Furthermore, process models lay the groundwork for automation, enabling the implementation of workflow management systems and initiatives for business process re-engineering. (Marlon Dumas 2013)

2.5 Information model

The information model is defined as a conceptual framework that describes how data is organized, stored, and accessed during a product's lifecycle. It provides guidance for managing different types of data related to product development and management. By providing a structured approach to handling product information, it enhances communication, collaboration, and decision-making across various stages of the product lifecycle. This model encompasses dimensions such as lifecycle phases, information categories, and interrelationships to ensure traceability throughout the PLM process. Serving as the basis for effective PLM implementation, it allows organizations to streamline processes, boost productivity, and innovate in today's competitive market. (Immonen 2008)

2.6 KJ-Analysis

KJ Analysis, drawing its roots from the scholarship of Japanese anthropologist Jiro Kawakita, presents a structured approach to comprehending a large amount of data. The methodology entails a careful transcription of findings onto notes, with each note contains a singular data point. These notes are subsequently categorized into clusters based on thematic similarities, where each grouping receiving a descriptive designation. Employing a "bottom-up" strategy, KJ Analysis initiates its inquiry by analysing individual details, gradually put them together into a cohesive whole. A notable advantage of this approach is its capacity to allow for the emergence of data groupings naturally during analysis, sparing the need for predetermined classifications. The method is known as the "yellow sticky note method", given its wide use of adhesive notes. (Bligård 2015)

2.7 IT-System

In this section, we establish a theoretical market analysis and emphasize key concepts that will serve as the conceptual framework for the subsequent analysis and implementation. Central to the examination is the exploration of various Information Technology (IT) systems, each playing a vital role in the landscape of the project. Among these systems are Tacton, ConfigIT, Siemens, and Dassault, each renowned for its unique capabilities and contributions to the field.

2.7.1 CPQ & PLM

CPQ (Configure, Price, Quote) is a software solution that simplifies the configuration, pricing, and quoting processes for complex systems and services. The system is built from the configuration and the user perspective, then constructs the data structure. This facilitates customization and reduces time to market, enabling companies to tailor their product configurations based on customer requirements, while also enhancing accuracy in pricing and generating quotes quickly and efficiently. The system automates the process, resulting in greater efficiency, which in turn leads to high customer satisfaction and accelerates the quote-to-order cycle. Furthermore, CPQ systems aim to reduce process time, increase process quality, integrate information from various enterprise systems, and leverage explicit and implicit knowledge from individuals. They also emphasize delivering competitive quotes in a timely manner, improving customer orientation, and ensuring a sufficient margin for the supplier. (Michelle Jordan 2020)

PLM (Product Lifecycle Management) is instead a strategic approach to managing the entire lifecycle of a product, from its inception through design, manufacturing, deployment, and eventual disposal. It provides a structure to store and quickly access standard items, to easily see the relationships between parts and assemblies, including and maintaining BOMs. This, in turn, makes it easier to customize and configure products to meet the customer's needs and reduces the time to market. The advantage it offers is more than just a structured library and incremental savings; it helps to gain control over the whole product lifecycle and lifecycle processes. It involves the integration of people, processes, and business systems to ensure that product-related data is effectively managed and utilized across all stages in the lifecycle. Operational PLM software solutions facilitate various areas including collaboration, version control, documentation tracking, traceability, and streamlining of business processes. It enable organizations to optimize product development processes, and enhance product quality and innovation. (Immonen 2008)

While CPQ deals with customer-specific configurations and pricing data, PLM manages a wider range of product-related information, including design specifications, manufacturing processes, and performance analytics. In essence, CPQ is sales-oriented and pre-sales-focused, aiming to boost revenue and customer satisfaction, whereas PLM is product-centric, spanning the entire lifecycle to drive innovation, efficiency, and quality.

2.7.2 Suppliers

Tacton is known for its configurator solutions and offers a sophisticated platform designed to streamline the process of product configuration. Starting with CPQ and moving closer to the PLM system, it uses advanced algorithms that enable the generation of customisable product designs that cater to the different needs and preferences of customers. Tacton's intuitive interface and robust functionality make it highly attractive for product configuration and customisation. (Tacton 2024)

ConfigIT is recognised for its expertise in configuration lifecycle management and provides comprehensive solutions tailored to complex product configuration management. Like Tacton, they also extend from CPQ and approach PLM systems. ConfigIT offers organisations effective management of complex product structures, optimising configurations and improving overall operational efficiency. ConfigIT's scalability and navigation within complex product configurations make it attractive to customers. (ConfigIT 2024)

Siemens is an established company with a rich history of innovation in digital technology and manufacturing. Unlike its predecessor, Siemens is instead starting from a PLM system and approaching CPQ. They have a range of software solutions aimed at optimising product development processes. Through their integrated approach to digitalisation, organisations can achieve higher productivity and innovation across the entire product lifecycle. (Siemens 2024)

Dassault is a leader in 3D design and digital transformation. They also build their system on a PLM system and approach CPQ like Siemens. Dassault's flagship product, CATIA, is slightly different from the previously mentioned suppliers' systems, in that it visualises the product design process through its advanced modelling and simulation capabilities. (Dassault 2024)

3

Method

This chapter introduces theoretical models that have been relevant to the project and demonstrates how they have been applied to facilitate the project's progress.

3.1 Method Theory

The project will apply a methodology called Design Researched Methodology (DRM). A structured approach to design research that involves four stages: Research Clarification, Descriptive Study I, Prescriptive Study, and Descriptive Study II. Each stage contributes with a specific purpose in the understanding of the design problem and to formulate solutions.

The method will help the project team to systematically navigate through the complexity of a problem definition to solution development. By following the stages, researchers can gather information, analyze data, and generate actionable insights that will set the direction of the design process and lead to more successful outcomes. (Blessing and Chakrabarti 2009)

3.1.1 Research Clarification

The first stage will focus on understanding the problem areas and to define the scope. This involves clarifying research objectives, identifying key stakeholders, and establishing research questions. Gather information of the background, review literature in relevant areas and conduct interviews and observations to gain insights into the problem. The goal is to define the research goals and set the direction for following stages.

3.1.2 Descriptive Study I

This stage involves gathering data to describe the current working processes and methods related to the design problem. To conduct the data and information, methods such as interviews, surveys, observations, and analyzing data to collect both qualitative and quantitative information will be used. The idea is to get an understanding of the user behaviors, needs, preferences, and challenges within the context of the problem.

3.1.3 Prescriptive Study

In this stage, researchers analyze the data collected in the previous stages to identify patterns, trends, and to get more insight. The goal is to make decisions and address the design problem as good biased as possible. The project team may also explore alternative solutions and evaluate their feasibility and effectiveness. The outcome of this stage is a set of actionable recommendations or design principles that will guide the development of the system.

3.1.4 Descriptive Study II

The final stage involves validating and refining the recommendations and decisions or design principles derived from the previous stage. Researchers may conduct additional research and testing to further explore specific aspects of problems or suggested solutions. This could be an iterative process with usability testing, prototyping, or design cycles to refine and validate design concepts. The goal is to ensure that the system is practical, effective, and aligned with the customer's needs.

3.2 Applied Methodology

The research was divided into 4 stages according to the 4 different stages of the DRM. The following sections describe the events within each stage.

3.2.1 Research Clarification

During this stage, the objective was to gather as much information and knowledge about the current product configuration process as possible. This was achieved through qualitative data collection methods and a market analysis.

3.2.1.1 Qualitative data collection methods

Within the initial stage of the DRM methodology, Research Clarification, the objective was to enhance the current understanding of the research topic and establish the complete aim of the research. To achieve this, various methods, such as informal interviews, semi-structured interviews, observations, and workshops, were used. While the primary focus of these methods remained on explaining the existing understanding, interviews aimed to dig deeper into the evolution and flow of information, whereas observations and workshops sought to get insights into the usage and transformation of data throughout the process. All of these methods were used on all levels of the process in order to gain as much knowledge about how the data evolves and was used throughout the process. A total of 27 semi-structured interviews and 2 workshops were conducted during the Research Clarification stage and the ratio of interviews and workshops between the departments is presented in table 3.1.

The interviews began with a comprehensive approach, ensuring that each department involved in the configuration process was interviewed at least once. Following

Table 3.1: *Number of interviews and workshops***Interviews**

Nr of interviews	Department
6	Product Managers
2	Specification Managers
4	Digital (Decision makers)
5	Digital (Programmers)
3	R&D Sweden
2	R&D United Kingdom
2	Technical Communicators
3	Head of Product Management and Specification

Workshops

Nr of workshops	Attending department
1	Product Managers, Specification Managers, Technical Communicators
1	Product Managers

this, the selection of parties prioritized for additional interviews was determined by areas requiring further clarification to advance the project and where deeper insights were necessary for subsequent analysis of the data flow throughout the process. The semi-structured interviews and workshops were organized with designated meeting times for each activity. In contrast, informal interviews were conducted promptly whenever uncertainties emerged or when there was an opportunity to delve deeper into particular issues or obtain quick responses. Observations were made during both types of interviews, primarily to illustrate how employees operated within their respective parts of the current process. This facilitated a deeper understanding of the interconnections between sub-processes and how the work of different parties was executed.

Notes were taken during each semi-structured interview and workshop to provide input and material that would guide and serve as a foundation for the subsequent analysis and development of the new process.

3.2.1.2 Market analysis

A configuration process can consist of multiple sub-processes, each associated with its own IT system. Alternatively, a configuration process can utilize a single IT system that covers all the tasks of the sub-processes, thereby functioning as a super system. Polestar does not employ a super system; instead, they utilize multiple IT systems for each stage of the process. A market analysis was conducted to assess the existing options available on the market. The information for the market analysis was sourced from the internet and from employees of both Polestar and R&D partners.

The programs included in this analysis is presented in Table 3.2.

Table 3.2: Market Comparison

	Excel	Tacton	ConfigIt	Siemens	Dassault	Web-App
Number of User	One at a time	Many	Many	Many	Many	Many
Flexible in Use	Extremely	Good	Good	Intermediate	Intermediate	Very Good
Cost	Very Cheep	Expensive	Expensive	Expensive	Expensive	Cheep
Versatility	Very High	High	High	Very High	Very High	Intermediate
Complexity of Implement	Very Low	High	High	Very High	Very High	Low
Total	Good	Intermediate	Intermediate	Intermediate	Intermediate	Very Good

Excel

Excel application emerges as a versatile tool for all types tasks. It's offering a comprehensive platform for data organization, analysis, management, and much more. The application have a user-friendly interface, and it is a common used tool in the business environment. Excel have flexible functionalities which make it an ideal choice for businesses seeking to be more efficient and to streamline their workflows.

Within the product configuration context, Excel could facilitates the creation of customized templates tailored to specific product categories and configurations. These templates enable the user to input and manipulate configuration data, allowing for adaption and accurate testing of product offerings.

Excel's built-in formulas and functions empower users to calculate total prices and volumes more accurately, based on selected features and pricing rules. It allows the users to be more flexible and free in terms of, changing and add parameters, creating charts, graphs, and their own processes. These outputs provide stakeholders with a clear and intuitive overview of the configured product, aiding decision-making processes and improving communication between customers and sales representatives. The application serves as a valuable asset in product configuration processes, offering businesses the flexibility, accuracy, and visualization capabilities needed to create personalized product offerings and enhance customer satisfaction.

Tacton

Tacton specializes in CPQ solutions for industries such as automotive, industrial equipment and high-tech electronics with a strong foothold in the market. Their unique strength lies in handling a wide range of complex product configurations through advanced algorithms and 3D visualization, and leveraging AI to stay at the forefront of technology. They also prioritize support and training programs, giving them a competitive advantage in a growing market. Tacton has a solution that could probably be modified to be applied within Polestar's processes including configuration and data management. Additionally, Tacton can provide a service that calculate prizing and quotes in combination whit the configuration. The solution fulfills many of Polestar's requirements and have the same way of thinking in terms of being innovative and adoptable to the costumer. Costumer as ABB and MAN which are two big company in the industry segment, which gives a reliability to the company.

ConfigIt

They have a powerful platform that can operate in many different areas and industries. ConfigIt's vision is to streamline and optimize complex configuration processes, which has led them to become one of the leading providers of configuration software solutions. The system should empower organizations to become more efficient in managing product configurations, reducing time-to-market, and being more flexible to meet customers' needs.

One of the areas where ConfigIt's system solution operates is in electrical vehicles. The configuration system plays a pivotal role in driving innovation forward and providing automakers with a competitive edge. Market preferences are changing faster than ever, and in combination with new innovative solutions being developed all the time, companies need to be able to constantly develop their products. ConfigIt's solution helps manufacturers keep track of the implementation of new technologies and optimize the product.

Siemens

In comparison to the previous two configuration systems, Siemens provides a system solution that has its roots in the PLM system. The system integrates with other Teamcenter offerings in the company and eases product configuration management. Companies can achieve a multitude of objectives with the system, including complex configuration and internal operational effectiveness, while still enhancing customer satisfaction.

In contrast to the system that operates from the CPQ, this system is more integrated with other systems, making it less agile and flexible for development in the product configurator. In a market where changes are not constant and for a company with heavily established processes, this system could be more beneficial. Therefore, the solution Siemens is providing may not be optimal for Polestar, which is a relatively young company and operates in a world where development and changes are constant.

Dassault

Dassault's configuration solution stands out as a robust system built on PLM principles, similar to Siemens'. The Dassault solution offers the advantage of seamlessly integrating with other offerings and facilitating streamlined product configuration management.

Organizations adopting Dassault's solution can achieve various objectives, such as managing complex configurations and enhancing internal operational efficiency, all while improving customer satisfaction. However, like Siemens' systems, Dassault's approach prioritizes deeper integration with existing systems, which could potentially restrict agility and flexibility in product configurator development compared to CPQ-driven systems.

Web application

By addressing a variety of configuration challenges, the conceptualization of a bespoke web application emerges as a central solution that aims to encapsulate the brand's design character while streamlining its multifaceted processes. Leveraging

the sophistication of modern web development frameworks such as React.js, Angular, or Vue.js, combined with robust backend architectures such as Node.js or Django, the solution could provide a dynamic and intuitive interface for the product configuration landscape.

Within its virtual domain lies the promise of unified data management, facilitating real-time collaboration between business stakeholders and seamless integration with existing IT infrastructure. With cloud-based hosting as a foundation, scalability and reliability transition from desirable aspirations to tangible realities, providing the high level of flexibility required to navigate highly intensive market developments.

The customization possibilities within the web application remain extensive. The solution could leverage existing designs and applications within Polestar to create a consistent design and integrated product within the organization. Since the system begins almost from scratch, it can be customized to Polestar's own requirements to a significant extent. However, its development will be time-consuming and resource-intensive, requiring extensive interaction with the solution's users. Nevertheless, it is anticipated that the system will be easier to implement within the organization compared to standardized systems.

For further development of the web application, the possibilities are almost endless. Its modular architecture can facilitate integrations with Enterprise Resource Planning (ERP) systems or machine learning initiatives, providing decision-makers with predictive insights. The main limitations lie in time and resources—what can be achieved with a web application as a solution and which processes could be linked and automated.

Market Comparison

The study has been conducted on the factors: Number of Users, Flexibility in Use, Cost, Versatility, and Complexity of Implementation. The first factor, 'Number of users,' indicates the capability of each solution to accommodate multiple users simultaneously, ranging from only one user at a time to supporting many users concurrently. All of the solutions, except excel, could support a large number of users simultaneously and could be implemented on an enterprise-level. Excel on the other hand, limits usage to just one at the time.

The 'Flexibility in Use' factor assesses how customizable each solution is from a user perspective, including how many parameters, values, and additions the user can adjust and make themselves. The solutions range from extremely flexible to those that offer more limited flexibility. A solution in Excel is extremely flexible in use for the user, and the interface is often familiar. The user can change almost everything and create new processes by themselves if needed, as Excel is a tool that the user uses nearly every day. The other solutions have some more limitations, depending on how they are built. The user cannot add functions and can only change parameters that are specified in advance. The solution provided by an external company will be a modified standard system, where restrictions could arise. A new web application could be specified as the company wants, with no restrictions at the beginning as the others have. Still, it is not as flexible as Excel for the user, since parameters need to be specified beforehand as well.

The 'Cost' of the solution takes into consideration how significant an investment it

would be to integrate the solution into the organization, as well as to maintain the service afterwards. The solution provided by an external company would require a significant investment. For Excel, it would only be the monthly fee the company is already paying for the application. To develop an in-house web application, the costs could vary. In this case, it would be developed in-house, which reduces the costs, but it would still require resources and maintenance. In the long-term perspective, when more functions and processes could be desirable to add on, it is harder to compare the in-house developed application with the external solution regarding costs.

In the area of 'Versatility,' the solutions are compared based on the breadth of functionalities and capabilities offered. This factor evaluates how much freedom and control the user would have and assesses the solution's ability to adapt to diverse use cases and user needs, encompassing aspects such as customization options and functions that could be beneficial to add for the feature. All of the solutions performed well, more or less, in this area.

The factor 'Complexity of Implementation' measures the difficulty and resources needed to implement each solution, including how much would have to be changed and affected by the solution. It ranges from solutions with very low implementation complexity, requiring minimal work, to those with high implementation complexity, where many processes would have to be changed and many divisions could be affected. Siemens and Dassault placed at the top of the scale; both would require a lot of processes to be changed in the organization. Tacton and ConfigIt are not far behind. The Web-application needs to be implemented and up running in the system but will not require integration with other systems. To implement a solution based on Excel would require minimal effort, after the development is more or less just uploading it.

3.2.2 Descriptive Study I

In the second phase, Descriptive Study I, the collected knowledge related to the research topic was explored, and gaps were identified. This was achieved through analyzing the data collected in the first step via process modeling and information modeling. These analyses clarified the flow of information and the timing of certain actions in the product configuration process of the cars. The models were presented and discussed with the collaborating company Polestar. The project deliverables were discussed, and boundaries were set to ensure timely delivery. The objective of this phase was to clarify if challenges of implementing changes to a product configuration process can be overcome by analyzing the flow of data. To test the results of analyzing the flow of data, the configuration process at Polestar was analyzed. In the following part of the section, the methods used for analyzing the flow of data are described.

Mapping of the data flow

The flow of data was mapped out with help of the qualitative data collection methods explained in section 3.2.1.1. The mapping started in the beginning of the configuration process and when the handover of the data was identified a new interview was booked with the responsible for the next step in the sub process. This method was repeated until the end of the process was reached. When the whole process had been walked through for the first time, a simple map of the data flow was made in order to visualize the whole product configuration process (see Figure 3.1 or Appendix A.1).

The initial map illustrated the process by which the product manager established the contents of the vehicle binder, which listed the features of the car. Notably, the vehicle binder comprised general functional features rather than specific parts. For instance, it included items such as a panoramic glass roof, with the specific components to be determined during later stages of the configuration process.

Following the establishment of the vehicle binder, both the revenue team and the product manager collaborated to define the package structure. This structure outlined which features were available within each package tier. For instance, the selection of sport rims was contingent upon opting for the sport package. These associations were delineated at the feature level during this phase.

Subsequently, this structured framework served as the foundation for the creation of the Offer-file, tailored to specific markets and detailing the requisite offerings for each car. For instance, certain regions necessitated the inclusion of a fire extinguisher, while it was deemed unnecessary in others. The Offer-file was subsequently transmitted to the Research and Development (R&D) department for further refinement.

The R&D department undertook the task of dissecting the features into individual parts and ensuring the accurate configuration of cars based on market specifications and the established package structure. As depicted in Figure 3.1, this process involved coordination with three distinct R&D entities: an internal R&D team at Polestar responsible for internally developed components, as well as two external R&D divisions within R&D partners.

The features outlined in the vehicle binder and the potential configurations specified in the Offer-file were integrated into the systems of the respective companies. These systems meticulously defined the composition of cars at a component level, serving as comprehensive inventories detailing all parts of market-specific or variant-specific vehicles.



Figure 3.1: Simple map of the data flow within the configuration process.

This map was presented to all the responsible employees of each sub process. This enabled corrections to be made and an even clearer image of the process emerged. With the revised data flow a second map was conducted in order to describe the flow of data and in a more accurate way (see Figure 3.2, or Appendix A.2).

The differences between the first and second maps lie in the relationship between the Vehicle binder and the Offer-file, as well as in the operational methods of the R&D departments. The second map illustrates that the Vehicle binder served as the foundation for establishing the package structure, which subsequently informed the creation of the Offer-file. However, it's noteworthy that the Vehicle binder remained unchanged during this phase of the process.

Both the Offer-file and the Vehicle binder were transmitted to the relevant R&D departments for the specific projects. These files were integrated into the systems of external parties, while internally, the R&D department at Polestar created an exact replica of the car in Polestar's system called Team center.

Flow of specifications

A diagram that describes the development of the specifications of the car. From VB to Team Centre

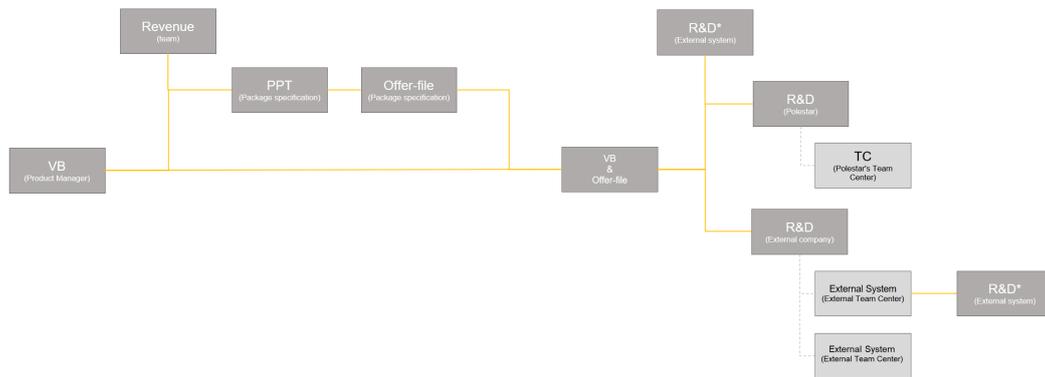


Figure 3.2: The second map of the data flow within the configuration process.

Process model

The second map was the basis for the process model created. In the process model the involved parties and the happenings between each state of the process were added. The process model is shown in Figure 3.3 and in Appendix A.3.

Process model

A diagram that describes the development of the specifications of the car. From VB to Team Centre

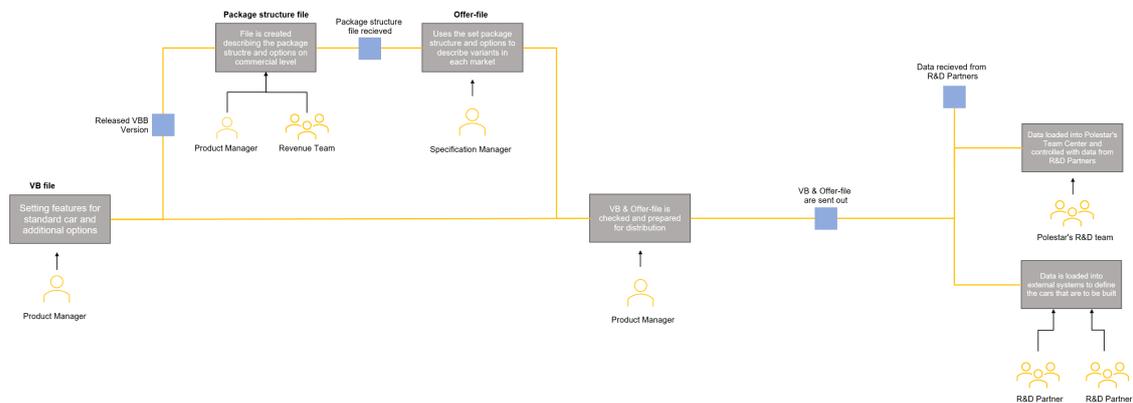


Figure 3.3: Process model of the configuration process.

Information model

To analyze the data further, an information model was conducted. The objective with the information model was to examine the type of data within each step of the configuration process and assess the correlation and connections between the data in different steps. The information model was based on the same mapping structure as the process model, specifically the second map. Below, in Figure 3.4 and in Appendix A.4, the information model is presented.

Information model

A diagram that describes the development of the specifications of the car. From VB to Team Centre

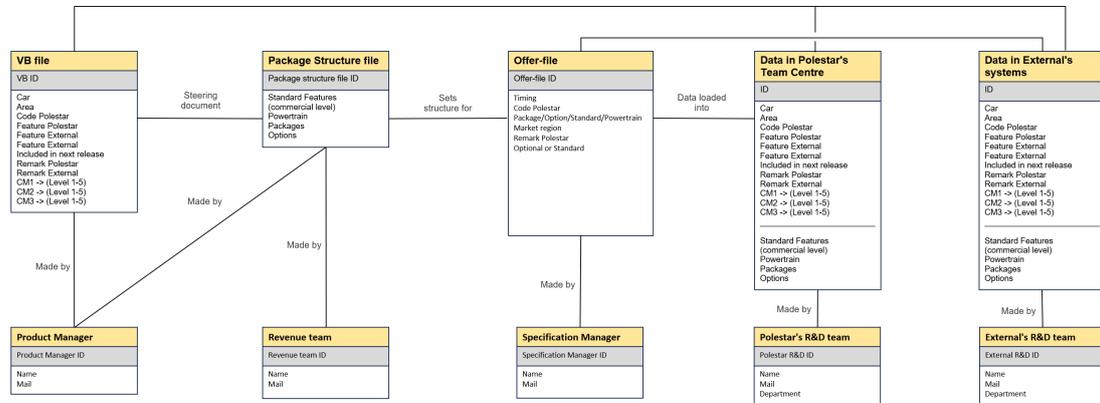


Figure 3.4: *Information model of the configuration process.*

When conducting the information model, the understanding of how the data changed throughout the configuration process was clarified. The data was very unmatched, indicating that data wasn't simply added or changed from the data created in the first step (VB file). Instead, additional datasets were added, specifying other areas of the configuration. In the second phase of the process, the Package Structure file, similar data was present, but all the features were grouped in different packages. For the third step in the process, the Offer-file, the data did not contain all the features, but rather additional features for each market, resulting in a new type of dataset. Therefore, it was easier to jointly combine and create the data in steps one and two than with all the first three steps.

With the process and information model, the project deliverables were established with Polestar. The focus was on the beginning of the configuration process to ensure completion before the end of the designated time frame. This included the IT system for specifying the Vehicle binder. If this was completed with time to further continue the development of the IT system, the package structure was to be included.

KJ analysis

With the notes gathered from interviews conducted during the research clarification phase, as well as insights from the information model and process model, a KJ analysis was conducted. The notes were written on Post-it notes and grouped based on their content. The information and process models provided valuable context, allowing for a better understanding of the broader configuration process.

By incorporating the models, it became clearer to identify which areas of difficulty each note corresponded to within the configuration process. The result of the KJ analysis is depicted in Figure 3.5, where all the notes are divided into five distinct areas, providing a comprehensive overview of the key insights and challenges identified during the analysis.

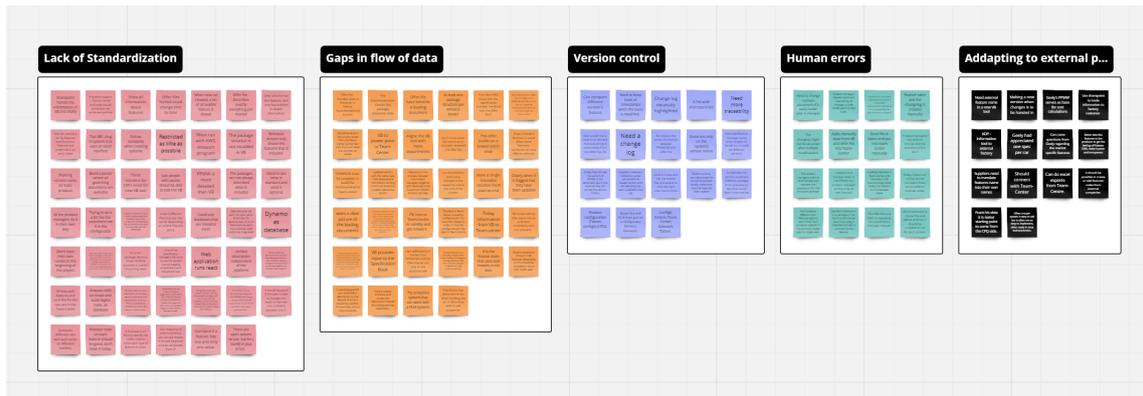


Figure 3.5: *The notes divided into five areas of the KJ analysis.*

The five areas were the following:

- Lack of Standardization
- Gaps in the flow of data
- Version control
- Human errors
- Adaption to systems and external parties

In the first area, Lack of standardization, there appeared to be a notable absence of uniformity across various documents and sub-processes such as the VB, and the Offer file. The format of these files could vary significantly, particularly across different car models, leading to confusion and inefficiencies as different teams worked with diverse formats and structures.

Concerning the second area, Gaps in the flow of data, there was a lack of clear structure regarding which parties were dependent on which files. There existed no definitive pathway throughout the process whereby all involved parties knew the exact sequence of parties involved before and after them. This resulted in information gaps, as some parties did not receive the correct or latest files, as the file deliverer did not specifically send the file to those parties.

In addressing the third area, Version control, the challenge centered around identifying the latest released version and understanding the changes between two releases. Regarding the fourth area, Human errors, many sub-processes within the configuration process were manually conducted, leading to instances of overlooked tasks or incorrect data entry.

Lastly, in the fifth and final area, Adaption to systems and external parties, complications arose in consistently adapting to external programs. Some systems were not able to change, such as those used by external parties, while others posed challenges due to specific input format requirements. This occasionally resulted in additional loops within the configuration process, as exemplified by Polestar needing to transmit information to external parties and then reconcile the data in their systems. They were unable to build on the input file for external parties due to potential errors in data loading, necessitating reconciliation in Polestar's system.

3.2.3 Prescriptive Study

For the third step, Prescriptive Study, solutions were proposed. An MVP (Minimum Viable Product) was developed based on the analysis of the data retrieved in earlier stages to test the functionality of a new system. This was analyzed with Polestar, and a general direction for continued development was established. Several alternative designs were considered to determine which design best fulfilled the purpose of the system. Through ongoing feedback and check-ups with the intended users, a final system was developed based on earlier prototypes. If the intended purpose of the IT system was not well fulfilled at the current stage of the development process, a discussion with the end user took place, and decisions regarding how the continuation of the project should look like were made in consultation with them.

The first MVP was based on the same system they used when the project began, which was excel, but with all of the cars in one document instead of different documents. This action was taken to get a better overview of the documents and not loose versions or preventing someone sitting with on old version when there was a newer version available. The problem with version handling was mentioned during the research clarification phase of the project and was one of the most frequently mentioned problems. The front page of the MVP was therefore built up by cards with the different cars available in the system (see Figure 3.6).

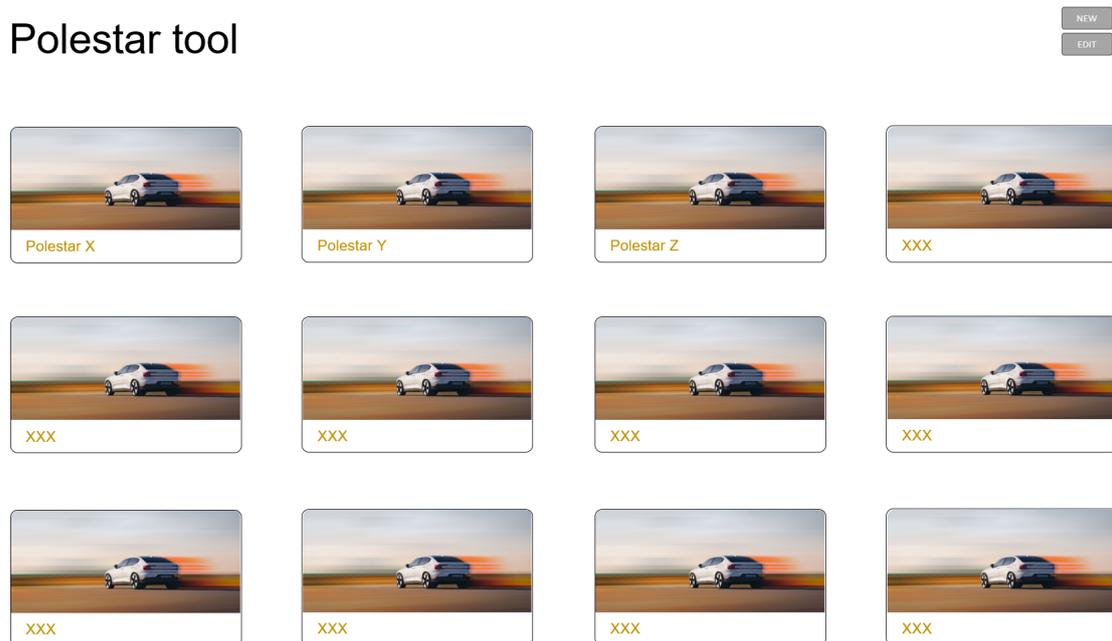


Figure 3.6: *The front page of the MVP.*

On the front page, it was only possible to modify, create, or enter a vehicle that was supposed to be configured. When a car was entered, the user was directed to the configurator page for the specific car (see Figure 3.7). There, the user could view all the features and their additional areas, one feature per row in the table.

It was possible to add, change, or remove features. The MVP Excel file consisted of one large table with all the features for all the different cars and versions. Upon entering a specific car, the data was queried from the table, and only the relevant information for the entered car was presented.

The screenshot shows a web-based configurator interface for Polestar X. The main area is a large table with columns labeled 'Areas' and 'Features'. The 'Areas' column is highlighted in green, and the 'Features' column is highlighted in blue. The table contains multiple rows of data, likely representing different car configurations. At the top right, there are buttons for 'Define groups', 'Reset', and 'Save'.

Figure 3.7: The configurator page of the MVP.

Additionally to the Vehicle binder, the MVP also included the package structure. There was one for each car, so when creating a new model year of a car, a package structure template was also created (see Figure 3.8). The product manager could therefore specify the groupings of the features simultaneously as it created the Vehicle binder.

The screenshot shows the 'Polestar X Offer structure' page. The header includes 'Polestar X Offer structure', 'MARKET NAME', and 'MY23 (23W12)'. The main content is divided into four sections: 'Standard', 'Powertrain', 'Packages', and 'Options'. The 'Standard' section lists multiple 'Standard' items. The 'Powertrain' section is divided into three sub-sections: 'SRSM' (grey), 'LRSM' (yellow), and 'LRDM' (dark yellow), each containing a list of 'Feature 1' through 'Feature 5'. The 'Packages' section is divided into three sub-sections: 'Plus' (grey), 'Pilot' (light grey), and 'Climate' (light grey), each containing a list of 'Feature 1' through 'Feature 5'. The 'Options' section contains a vertical list of 'Option' buttons.

Figure 3.8: The package structure page of the MVP.

With the MVP, discussions were held regarding the continuation of the project, focusing on the benefits and challenges. One of the main benefits of the MVP was its high flexibility due to being created with Excel. New columns could be added if additional car models were to be made, and it was possible to integrate a database so that all interactions were made in Excel, while the data was saved in a database. The market analysis conducted during the research phase helped in assessing the benefits and challenges of different solutions.

However, with the flexibility that came with using Excel, there was a risk of users accidentally modifying data that they were not supposed to change. Another significant challenge was that only one user could enter the program at a time, which was impractical as product managers typically operated the Vehicle binder simultaneously but with different cars. As a result, it became necessary to change the program used for creating the Vehicle binder. This decision was made in consultation with the Head of Product Management and Specification and an IT developer within Polestar.

Considering factors such as cost, multiple users, and the time frame, a web application in JavaScript with an additional database was chosen as the new IT system. Other options mentioned in the market analysis such as ConfigIt and Tacton etc. were deemed too expensive and too complex to implement and were therefore excluded.

The MVP was presented to the users, who found the layout to be a good foundation for building the future program. Consequently, a JavaScript web application was developed as the first prototype, following a similar format to the MVP. The style of the web application had to align with Polestar's internal packages. The initial prototype was created without a database, using fictional data, to rapidly test functionality and provide a reference for further development discussions. In Figure 3.9, the front page of the first JavaScript prototype is presented. The format is based on the same layout as the MVP, featuring cards that could be clicked to enter the car.

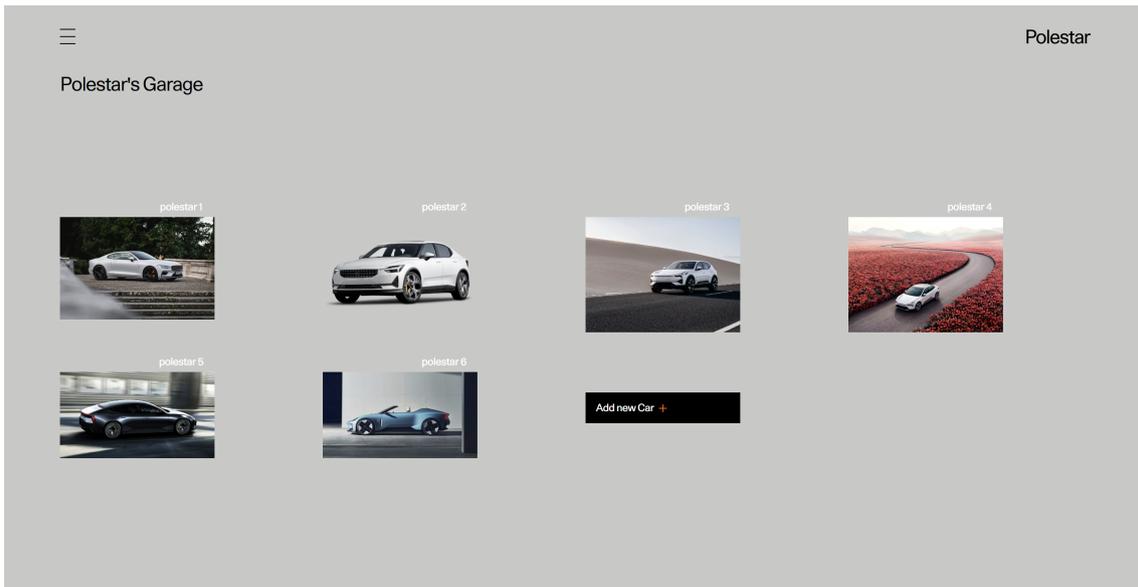


Figure 3.9: *The front page of the first web application.*

The Configurator page (Figure 3.10) in the first web application still featured a table with three buttons that facilitated various actions. These actions included "Add new feature," "Save," and "Print to Excel." The "Print to Excel" function allowed the table to be exported to an Excel file. Additionally, there were two options available: one format for each R&D partners. This was implemented to ensure continuity for external parties, in line with the criteria established from the outset.

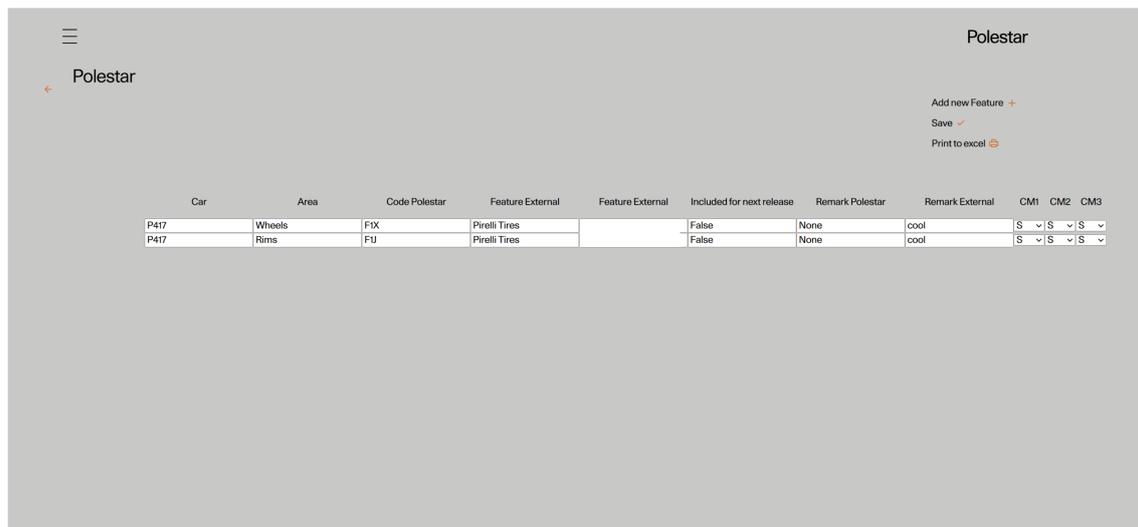


Figure 3.10: *The configurator page of the first web application.*

With the first web application prototype in place, a workshop was conducted with the product managers to specify their requirements for the application, including design and functionalities. During the workshop, each participant had access to papers, Post-it notes, scissors, and pens (see Figure 3.11). This setup allowed users to

visualize their ideas rapidly and clearly. Simultaneously, the web application served as a foundation for further development and provided inspiration. It also acted as a guide, dividing the workshop into different areas that corresponded to the different pages of the application. This structure facilitated focused discussions and enabled feedback across all areas of the application.



Figure 3.11: *The output of the workshop.*

From the workshop, the need for a change log and minimizing the number of clicks emerged. Participants expressed a preference for a side navigation on the front page instead of using cards (see Figure 3.12). The side navigation was favored as it was perceived as cleaner and more structured than the version with cards. Additionally, participants emphasized the importance of making buttons more visible and improving navigation within the table, especially considering that there could be over 1000 rows of features.



Figure 3.12: *The refined prototype with a side navigator instead of cards.*

One participant suggested dividing the features within the table into their respective areas to enhance navigation during feature editing. The change log was deemed necessary to show differences between the active version and the previous version, facilitating quick identification of changes made between versions and their impact on subsequent steps in the configuration process. Previously, this process was manual and involved adding every change since the beginning of the configuration, which could become overwhelming.

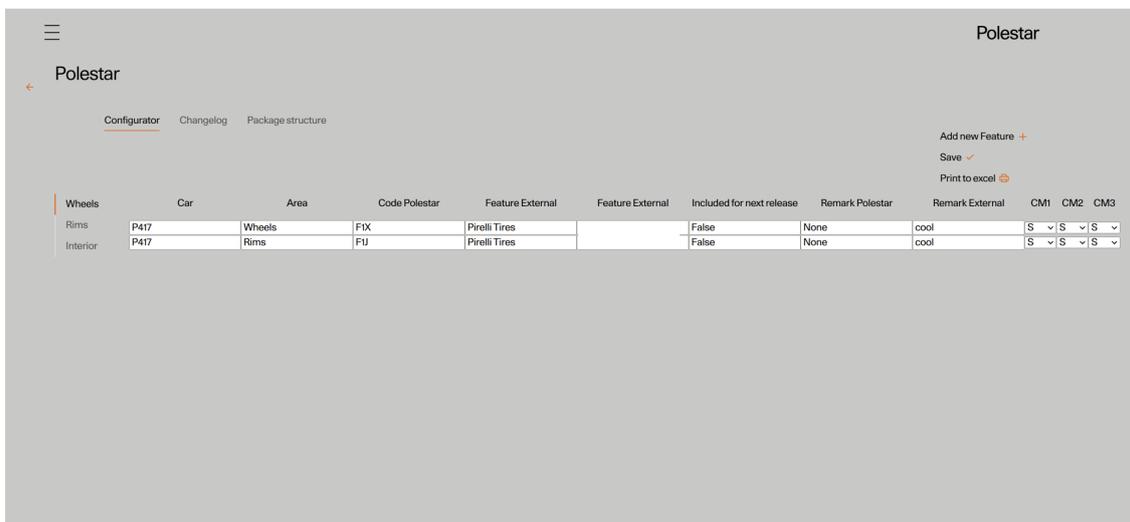


Figure 3.13: *The revised prototype with the area navigator to the left and a top navigator to the change log.*

After refining the prototype, informal interviews were conducted with the product managers to gather input for further development. Minor adjustments to the pages were made based on these informal interviews, while larger decisions were addressed in more formal meetings. One significant meeting was held to establish the exact columns that should be included on the configurator page. As the program was

intended to replace one Vehicle binder for each R&D partners, all columns from these programs needed to be incorporated into the new program.

During the refinement process, users expressed a need to see the differences between model years of the same car. This feature would allow product managers to view only the rows that differ between models, rather than displaying all features, as many rows were identical across models. Additionally, users expressed a need for a standardized way to distribute released versions of a car.

All of these needs were addressed and included in the final concept, which is presented in Section 4.1.2.

3.2.4 Descriptive Study II

In the fourth and final step, Descriptive Study II, the final solutions from the previous phase were evaluated and analyzed. The collaborating company for this project, Polestar, tested the system and analyzed its functionality. The input retrieved from this testing phase formed the basis for further improvements. Feedback from Polestar's end users was obtained through observations, workshops, and interviews after the program had been used for a period of time.

Throughout the development of the program, testing and analysis of the pages was a continuous process, ensuring that any issues or areas for improvement were identified and addressed promptly. However, during the final month of the project, dedicated efforts were made to focus solely on testing and analyzing the functionality of the program.

This involved loading the new IT system with real car features and providing product managers with the opportunity to extensively test the program in the context of their daily work. By simulating real-world usage scenarios, any potential challenges or shortcomings in the program's functionality could be thoroughly evaluated and addressed before final deployment.

4

Results

In the following chapter the findings regarding the research questions will be presented.

4.1 Key aspects of a new configuration process

One of the research questions was "What are the key aspects of implementing a successful new product configuration process?" The following section delves into the findings of this question and explores both the theoretical results found in this project and the practical results implemented with the collaborative company Polestar.

4.1.1 Theoretical key aspects

During the Descriptive Study I, multiple analyses were conducted, including the KJ analysis, Information model, and Process model. From the KJ analysis, five main areas of difficulties were established. These areas were the primary problems expressed by the employees within Polestar's configuration process. The key aspects to prevent those problems from occurring, and therefore creating a more successful configuration process, would therefore be the following five steps:

Standardization of Formats and Processes:

- Establish a standardized format for all documents and sub-processes involved in a configuration process.
- Define clear templates and guidelines for data entry and presentation to ensure consistency across different models and variations.
- Conduct regular training sessions to educate stakeholders on the standardized formats and processes.

Streamlining Data Flow:

- Develop a clear workflow outlining the sequence of parties involved and their dependencies on specific files throughout the process.
- Implement automated notifications or triggers to ensure timely delivery of files to all relevant parties.
- Integrate systems to enable seamless data transfer between different stages of the process, reducing gaps and delays in the flow of information.

Enhanced Version Control:

- Implement a robust version control system that clearly indicates the latest released version of each document.
- Provide detailed change logs or revision histories to track changes between different versions, aiding in understanding updates and revisions.

Minimizing Human Errors:

- Automate repetitive tasks and data entry processes to reduce the likelihood of human errors.
- Implement validation checks and error alerts to flag potential mistakes before they impact the process.
- Establish clear accountability and review mechanisms to catch and rectify errors in a timely manner.

Adapting to Systems and External Parties:

- Collaborate closely with external parties to understand their system requirements and ensure compatibility with Polestar’s systems.
- Develop standardized data exchange protocols or APIs to facilitate seamless integration with external systems.
- Provide support and guidance to internal teams on how to adapt to external systems, including training and documentation.

By implementing these measures, the configuration process would become more efficient, error-resistant, and collaborative, aligning with both internal standards and external requirements. This would ultimately lead to smoother operations, reduced lead times, and improved overall quality of deliverables.

4.1.2 Implemented key aspects

In the following section, the created web application for the first sub-process within Polestar’s configuration process, the Vehicle binder, will be presented, along with its correlation to the key aspects of a successful configuration process.

Standardization of Formats and Processes:

With the notes gathered from interviews and supported by the information and process models, the lack of standardization emerged as a critical challenge in implementing a successful new product configuration process. Initially, it was essential for all product managers to adhere to the same work process. The system needed to support users in recognizing their tasks and enable them to navigate the system regardless of the car model they were working on. The application starts with a front-end interface (see Figure 4.1), allowing users to select the car and model year from the side-navigation menu (see Figure 4.2). The design and process aimed to adopt a similar design language to Polestar’s public web page, where customers select cars for customization. As most product managers had utilized this web page to design their own cars, this process was familiar to users within the industry.

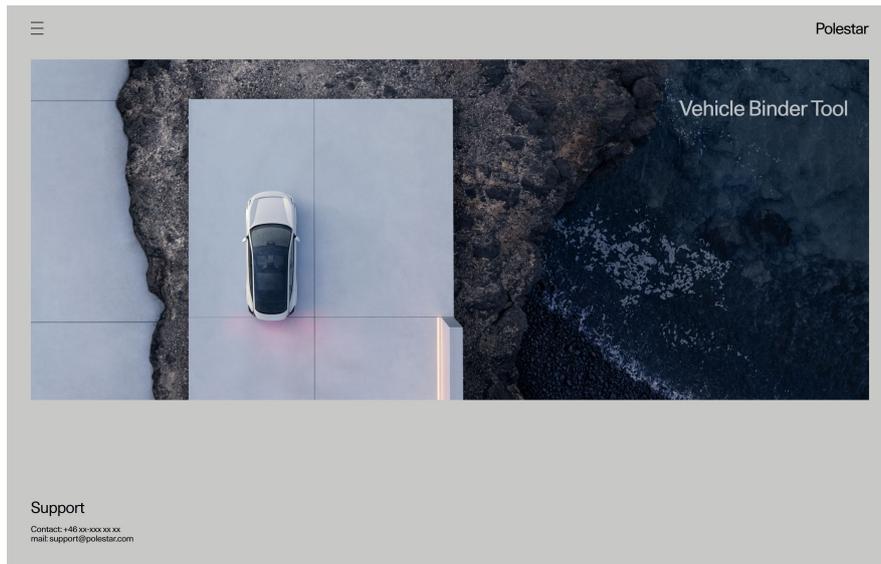


Figure 4.1: Home page of the Web application.

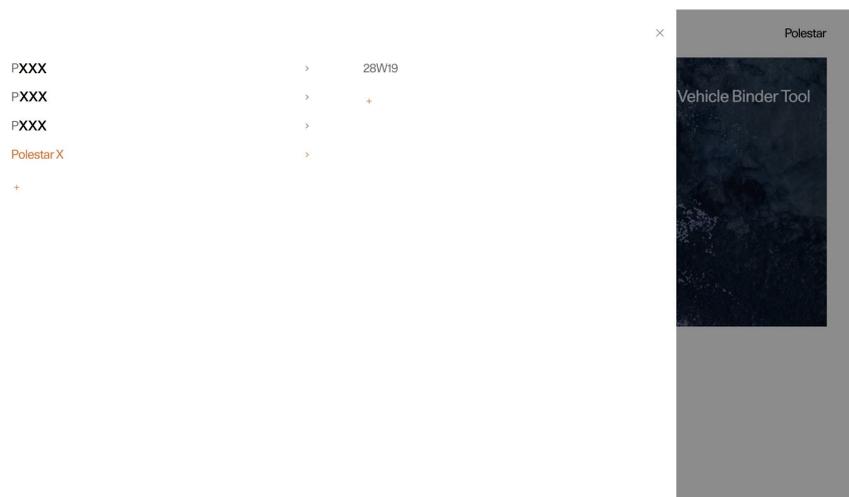


Figure 4.2: Menu in the home page to select car and model year.

Once within the configurator, the interface remained consistent regardless of the car or model year (see Figure 4.3 and 4.4). The list format accommodated both the work procedures of product managers towards R&D partners as external customers. Rather than employing different methodologies, the project opted to consolidate them into one. The list featured a few additional columns for users to fill in, or they could choose to leave them blank if unnecessary. The list offered greater flexibility compared to the existing Vehicle-Binder tool and was similar to an Excel spreadsheet. Users could modify values, add or remove rows or areas, but not add or remove columns.

The screenshot shows the Polestar configurator interface. On the left, there are navigation buttons: 'Add Area +', 'Save', 'Print to excel', and 'Release'. Below these are category filters: Brake functions, Exterior, Interior, Steering, and Wheel. The main area displays a table with columns: Area, Feature Polestar, Code Polestar, Feature External, Feature External, Included for next release, Remark-Polestar, and Remark. The table lists various features such as Brake functions (Stability control, Brake control, Electric parking, Brake high speed), Exterior (Spoiler, Reverse light, Exterior light, Camera, Color, Mirror), Interior (Light, Panorama roof, Warning Triangle, First Aid Kit, Frunk, TV), Steering (Buttons, Sport steering, All wheels steering), and Wheel (Sport, Rims 20, Rims 22 sport, Rims 21, Wiper, All around, Reserve).

Figure 4.3: Configurator page with the feature list.

This screenshot shows the same feature list table as Figure 4.3, but with additional columns for status indicators: CM1, CM2, CM3, M1, M2, and M3. Each of these columns contains a grid of status indicators (S, O, N/A) for each feature. For example, 'Testing quality' has 'S' in CM1, CM2, CM3, M1, M2, and M3. 'Need testing' has 'O' in CM1, CM2, CM3, M1, M2, and M3. 'Blue, red, green, with an' has 'O' in CM1, CM2, CM3, M1, M2, and M3. 'Glass' has 'O' in CM1, CM2, CM3, M1, M2, and M3. 'In the back' has 'S' in CM1, CM2, CM3, M1, M2, and M3. 'Space in front' has 'S' in CM1, CM2, CM3, M1, M2, and M3. 'Back seat' has 'O' in CM1, CM2, CM3, M1, M2, and M3. 'Need to specify' has 'S' in CM1, CM2, CM3, M1, M2, and M3. 'Good' has 'O' in CM1, CM2, CM3, M1, M2, and M3. 'Align software' has 'O' in CM1, CM2, CM3, M1, M2, and M3. 'Specify type' has 'S' in CM1, CM2, CM3, M1, M2, and M3. 'Choose which one' has 'O' in CM1, CM2, CM3, M1, M2, and M3. 'Same on the car or another' has 'O' in CM1, CM2, CM3, M1, M2, and M3.

Figure 4.4: Configurator page with the feature list all the way to the right.

When the list was ready for release or printing for review by individuals without system access, users selected the customer to which it should be released (printed) (see Figure 4.8), and the list would be formatted accordingly for the chosen customer. The released or printed version was always placed in a shared SharePoint for relevant personnel. The SharePoint system organized the lists into a standard

format, categorizing them and adding dates to each file. This facilitated easy access and ensured that stakeholders could identify the newest version to follow.

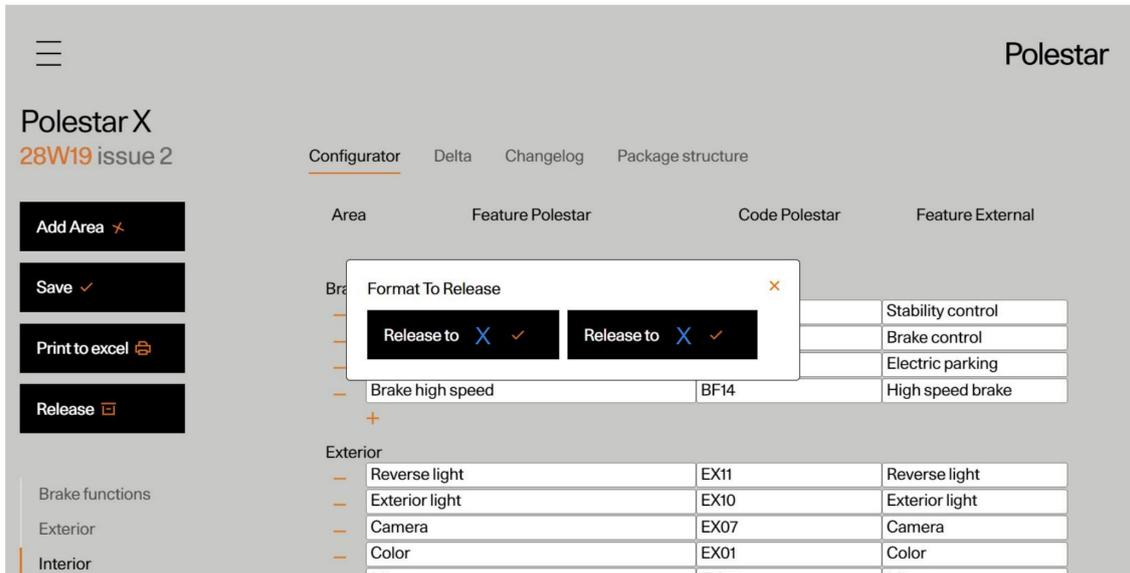


Figure 4.5: Release issue of model year and choose format.

Despite project managers typically working exclusively with their own cars, standardized work methods remained advantageous. Standardization enabled project managers to support each other when necessary and simplified the on-boarding process for new colleagues. It also ensured greater consistency and ease of integration within the system.

Streamlining Data Flow:

The analysis revealed significant gaps in the flow of data within the configuration process. Despite the presence of information and process models, there was a lack of clear structure regarding the dependencies between parties and the sequence of file transmission. Consequently, information gaps and delays occurred, as some parties did not receive the correct or latest files.

To ensure the efficient handling of the right information, the focus shifted towards creating a central repository for information. This led to the development of a web application for product managers, where all work could be conducted in a standardized manner. Once the configuration was ready for release, it was placed in SharePoint in a structured format for all stakeholders to access. This approach provided clarity on where to work and allowed stakeholders to easily identify the most recent updates, irrespective of the car model chosen for data collection.

One of the most significant risks identified was the gap between the feature list and the structure package, which could lead to miscommunication or disruptions in the data flow. Specification managers or communicators sometimes struggled to locate or ascertain the currency of data within the structure package. To streamline the flow of information, an additional column was added to the feature list on the configurator page (see Figure 4.6). This column enabled product managers

to specify the location within the package structure to which a feature would be assigned directly upon addition.

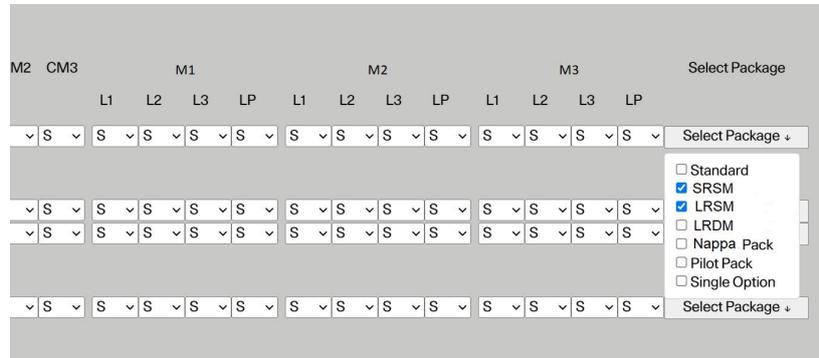


Figure 4.6: *Package Structure dropdown list to assign feature to package.*

Consequently, the feature would automatically appear in the package structure page (see Figure 4.7), ensuring it remained up-to-date and easily accessible to stakeholders with access, without necessitating manual dissemination by the product manager. For those without access, the structure package would be uploaded onto SharePoint in the same manner as the feature list.

Another benefit stemming from this approach is the enhanced control mechanism ensuring that everything is appropriately assigned. Product managers can directly visualize where features are assigned, and stakeholders can independently make changes if discrepancies are identified.

Polestar X
Offer Structure
MARKET NAME
28w19 issue 1

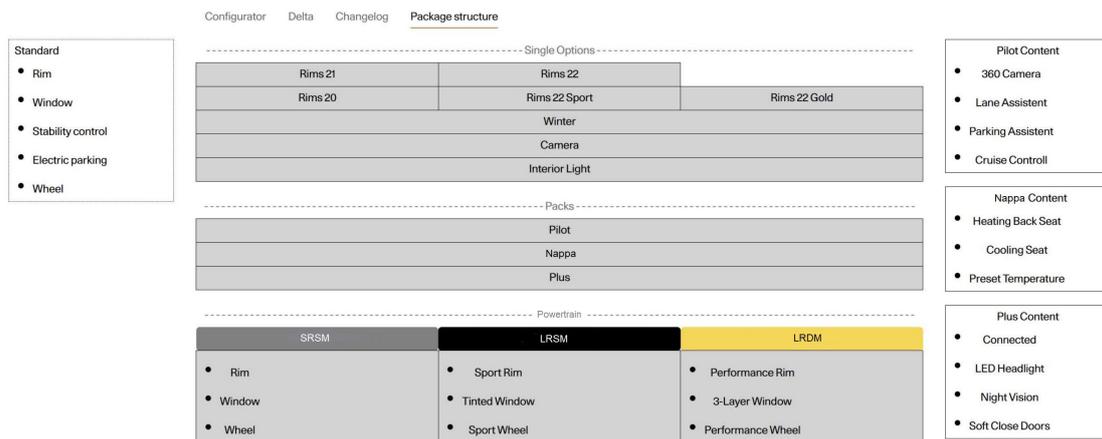


Figure 4.7: *Package Structure page.*

Furthermore, this streamlined process offers an added layer of oversight, facilitating efficient quality control checks to ensure that each element is correctly placed within the structure. Product managers gain immediate visibility into the assignment of features, empowering them to promptly address any inconsistencies or errors. Similarly, stakeholders are granted autonomy to rectify inaccuracies, fostering

a collaborative environment conducive to swift problem resolution. This not only accelerates decision-making processes but also fosters a culture of accountability and transparency throughout the configuration workflow.

Bringing together the management of features and structure into one system, the risk of discrepancies or misalignment's between the two components is significantly reduced. This integrated approach minimizes the potential for miscommunication or data inconsistencies, making the configuration process more reliable. As a result, stakeholders can confidently rely on the accuracy and completeness of the information presented, streamlining decision-making and driving efficiency across the entire product configuration life-cycle.

Enhanced Version Control:

Version control emerged as a critical area of concern in ensuring the accuracy and integrity of data within the configuration process. The challenge centered around identifying the latest released version of documents and understanding the changes between different releases.

The industry is accumulating more data and processes than ever before, making it increasingly important for companies to demonstrate to authorities that they have a structured approach to data storage. Polestar, which advocates transparency and aims to be a leader in sustainability and society, therefore needs to be particularly diligent in its documentation.

Therefore the system automatically builds the version structure. It initially organizes all data related to car configurations in one central location. Subsequently, it structures and stores all versions of issues. When a feature list is completed and ready for release, the user selects the customer to whom it should be released (see Figure 4.8) and receives a printed list of all features and changelog in the appropriate format (see Figure 4.9). Simultaneously, a new issue is created and displayed for the user. The previously released issue is now locked and cannot be edited.

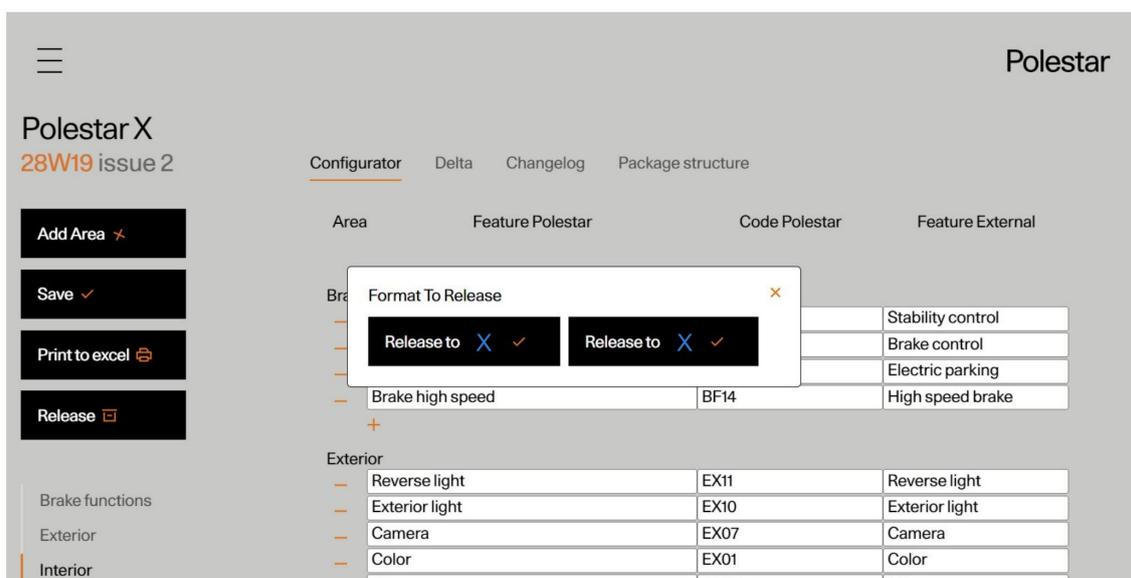


Figure 4.8: Choose format to release.

Area	code	Poles	featurePo	featureExt	featureExt included	remarkPol	remarkExt	cm1	cm2	cm3
Brake functions										
	BF10	Stability cc	Stability cc		True	Testing qu	Need supp	S	S	S
	BF01	Brake con	Brake con		True	Check test	Testing qu	S	S	S
	BF02	Electric pa	Electric pa		True	Code		S	S	S
	BF06	Brake high	High speed		True			S	S	S
Exterior										
	EX02	Spoiler	Spoiler		True	Need testi	Design?	O	O	O
	EX11	Reverse lig	Reverse lig		True		Which ont	S	S	S
	EX10	Exterior lig	Exterior lig		True		Which ont	S	S	S
	EX07	Camera	Camera		True			O	O	N/A
	EX01	Color	Color		True	Specify co		S	S	S
	EX05	Mirror	Mirror		True			S	S	S
Interior										
	IN10	Light	Light Inter		True	Blue, red, Specify		O	O	O
	IN23	Panorama	Panorama		True	Glas		O	O	O
	SF02	Warning T	Warning T		True	In the bac		S	S	S
	SF01	First Aid K	First Aid K		True		Placement	S	S	S
	IN05	Funk	Funk		True	Space in fr	Space in fr	S	S	S
	IN26	TV	TV		True	Back seat		O	O	O
Steering										
	WB02	Buttons	Steering b		True	Need to sf		S	S	S
	WB01	Sport stee	Sport stee		True	Good	Connectec	O	O	S
	WB12	All wheels 4	Wheel si		True	Align softv	Check fact	O	O	S
Wheel										
	WL03	Sport	Low profil		True			O	O	O
	WL06	Rims 20	Rims 20		True			S	S	S
	WL04	Rims 22 sf	Rims 22 sf		True			O	O	O
	WL05	Rims 21	Rims 21		True			O	O	O
	WL01	Winter	Winter		True		Specify tyf	S	N/A	O
	WL02	All around	All around		True	Choose wl		O	N/A	O
	WL07	Reserve	Reserve		True		Same on t	O	S	S

Figure 4.9: The released list in format to R&D partner.

Minimizing Human Errors:

The reliance on manual processes within the configuration process contributed to instances of human errors, ranging from overlooked tasks to incorrect data entry.

To tackle this challenge, the new system have a approach to addressing human errors, by implementation of an automatically updated changelog. Unlike the previous manual method where the product manager had to manually track and update changes across multiple places, the new system seamlessly records every change that have been made to the feature list. This ensures that the changelog remains accurate and up-to-date, providing stakeholders with complete transparency and accountability regarding any modifications made (see Figure 4.10).



Area	Feature Polestar	New Feature Polestar	Code Polestar	Action
Interior	Light	Interior Light	IN10	Changed
Exterior	Spoiler		EX02	Deleted
Brake functions	Brake high speed	Brake high speed	BF14	Changed
Steering		Assistent	WB21	Added

Figure 4.10: *The Changelog for Polestar X issue 2 compare to issue 1.*

This automated changelog significantly reduces the likelihood of human error. By handling all change-tracking processes into a single, user-friendly interface, the system minimizes the potential for discrepancies that often arise with manual work. Product managers can instead focus on strategic decision-making and problem-solving, rather than getting overwhelmed by administrative tasks.

In addition to addressing human errors in change management, the system also offers a robust solution for minimizing errors in package structuring. By standardizing the format and layout of package structures, the system eliminates the need for manual creation and ensures consistency across all configurations. This simplifies the process for product managers and enhances accuracy by making it easier to identify any missing or misaligned elements.

Adapting to Systems and External Parties:

As the company embraced internal changes and recognized the necessity for a new system, the external parties posed challenges. Despite internal flexibility, external parties were resistant to modifying existing document formats. While internal processes and procedures could be adjusted to meet evolving needs, the output had to align closely with previous formats to accommodate external stakeholders.

Recognizing the importance of seamless integration with Polestar's operations and the need for user-friendly functionality, the new system was meticulously crafted from the ground up in collaboration with users. This collaborative approach ensured that the system met the specific requirements and preferences of those who would rely on it daily.

Once the system met the rigorous standards and demands of internal users, attention shifted towards bridging the gap between the internal system and external parties. This critical bridge was facilitated through the implementation of a print or release button within the system interface. When users needed to transmit data, they could seamlessly choose between printing the list for review or releasing it once the configuration process was complete.

Both the Print to Excel and Release buttons provided users with the flexibility

to select the desired format tailored to the needs of Polestar’s manufacturing customers. This adaptability ensured that the system remained responsive to evolving requirements, with the potential for updates to accommodate future changes. By prioritizing collaboration, user feedback, and adaptability, the project successfully navigated the complexities of integrating a new system while ensuring alignment with external stakeholders. This approach not only facilitated a smoother transition but also laid the foundation for continued innovation and efficiency in the configuration process.

4.2 Clarity of the configuration process

In addressing the research question regarding overcoming challenges in implementing a new configuration process, the comprehensive analyses conducted yielded insightful results. The initial phase involved mapping out the entirety of the configuration process, providing a valuable visual aid. This mapping exercise visualized the sequential flow of data from the start of the configuration process to its end, serving as a foundational step and offering stakeholders an initial visualization of the steps involved.

Building upon this foundation, the creation of a process model provided a more nuanced understanding of the configuration process dynamics. This model not only defined the sequence of events but also explained the roles and responsibilities of various stakeholders at each stage. Consequently, it facilitated a dual perspective, aiding both developers in refining the process and employees in understanding their roles within it. By clearly defining sequential and procedural aspects, the process model emerged as a vital tool for enhancing organizational clarity and efficiency.

Simultaneously, the information model delved deeper into the data dynamics within the configuration process. By analyzing the types of data present at each stage and their interconnections, the information model uncovered crucial insights. It revealed that while certain sub-processes seamlessly integrated data, others revealed differences, necessitating further alignment efforts. This rough understanding of data dynamics enabled stakeholders to pinpoint areas of inefficiency and prioritize improvement initiatives accordingly.

Collectively, the implementation of these analyses resulted in a significantly clearer image of the configuration process. Stakeholders gained valuable insights into process dynamics, data flows, and potential areas for optimization. Moreover, the analyses facilitated collaborative discussions with Polestar, enabling the establishment of concrete project deliverables.

Furthermore, the process model emerged as a catalyst for continuous improvement, empowering employees to iteratively refine the configuration process. Since the stakeholders had a comprehensive understanding of process dynamics, they were better equipped to identify bottlenecks and streamline operations. Thus, the analyses not only clarified the current state of affairs but also laid the groundwork for

ongoing enhancements, ensuring the sustained efficacy of the configuration process.

In essence, the results of the analyses were visualization, offering stakeholders actionable insights and fostering a culture of continuous improvement within the organization. By leveraging these insights, stakeholders can navigate the complexities of the configuration process with greater clarity and efficiency, thereby driving organizational success.

4.3 Minimize the risk of information loss

By analyzing the created web application according to the five key factors for a successful configuration process, it was recognized that the factors "Minimizing Human Errors" and "Enhanced Version Control" had the biggest impact in minimizing information loss throughout the process. While "Standardization of Formats and Processes" and "Streamlining Data Flow" also played significant roles, their impacts were somewhat mitigated by the existing familiarity of employees with required documents and contact persons at each stage.

"Minimizing Human Errors" proved highly effective, primarily through the implementation of an automated change log. This change log automatically calculated differences between document versions (see Figure 4.10), lightening the burden on users to manually identify changes. Consequently, downstream stages of the configuration process could quickly determine if any modifications affected them, enhancing overall efficiency and accuracy.

Similarly, "Enhanced Version Control" significantly contributed to reducing information loss. By establishing dedicated SharePoint folders for each car model (see Figure 4.11), the latest versions of documents were readily accessible and clearly marked with version numbers. This simplified the process of identifying and accessing the most recent versions, ensuring that all stakeholders worked with up-to-date information. Additionally, the application was able to print draft Excel files containing the Vehicle binder and an additional change log which displayed updates to relevant stages, further enhancing collaboration and minimizing the risk of information discrepancies.

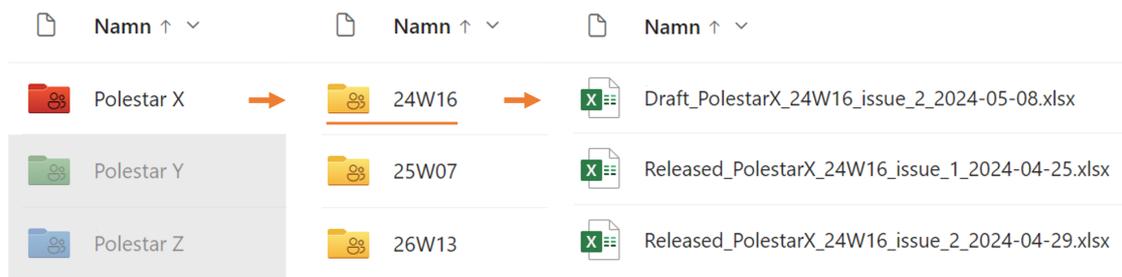


Figure 4.11: *The SharePoint file structure.*

Moreover, strong version control systems don't just reduce the chances of errors; they also help organizations comply with regulations and maintain clear audit trails. This fosters accountability and transparency throughout the configuration process, building trust among stakeholders. Being able to track revisions and maintain an audit trail allows organizations to show compliance with industry standards and regulations. This not only improves internal governance but also boosts confidence among customers and regulatory bodies.

In summary, these measures not only reduce the likelihood of errors but also make it easier to access and share information, leading to a smoother and more collaborative configuration process. Continuously monitoring and refining these aspects are crucial for maintaining high performance and adapting to evolving needs and challenges.

By prioritizing factors like minimizing human errors and improving version control, organizations can reduce the risk of information loss and enhance the efficiency and effectiveness of the configuration process. Through ongoing evaluation and improvement, organizations can stay agile and competitive in the dynamic automotive industry landscape.

5

Analysis

The findings from the investigation into key aspects of implementing a successful new product configuration process, along with the practical implementation within the collaborative company Polestar, revealed several critical insights into process optimization, stakeholder engagement, and system design. In section 4.1.1 a framework was described, which emerged from analysing the patterns of the collected data in the project. The framework is built up by five key aspects for among other things improving efficiency, reducing errors, and enhancing collaboration within the configuration process. In the following part of this section each key aspect will be described, analyzed, and compared to other findings within the same subject.

5.1 Standardization of Formats and Processes

One of the most prominent patterns observed was the emphasis on standardization across formats and processes. Theoretical research and practical implementation both underscored the importance of establishing clear templates, guidelines, and standardized formats for data entry and presentation. This standardization not only promotes consistency across different models and variations but also facilitates ease of use. By implementing standardized processes, organizations can streamline operations, reduce confusion, and minimize errors, ultimately leading to improved overall quality of deliverables.

Multiple studies have explored the effects of standardizing processes, consistently finding that it brings clarity and predictability, ensuring consistent outcomes and easier planning. Standardization also aids knowledge retention by documenting procedures, facilitating onboarding, and preventing the loss of critical information. Additionally, it promotes flexibility in team building and product replacement, while maintaining consistent quality and regulatory compliance. Furthermore, it reduces waste by identifying and resolving inefficiencies. However, to avoid pitfalls such as limited product variety, decreased agility, and product stagnation, flexible approaches and periodic reevaluation are necessary (Echtelt 2024).

Given these findings in other researches, the implementation of standardized processes is desired in the configuration process at the collaborative company Polestar. This underscores the importance and accuracy of standardization as one of the five key aspects identified in this study.

5.2 Streamlining Data Flow

Another key pattern that emerged was the focus on streamlining data flow throughout the configuration process. Both theoretical research and practical implementation highlighted the importance of developing clear workflows, implementing automated notifications, and integrating systems to ensure seamless data transfer between different stages of the process. This emphasis on streamlining data flow aims to minimize delays, gaps, and errors in information exchange, thereby enhancing efficiency and productivity. Moreover, by centralizing data within a single platform, such as the web application developed for Polestar, organizations can improve visibility, accessibility, and accountability, enabling stakeholders to make informed decisions based on accurate and up-to-date information.

Streamlining processes offers numerous benefits that enhance organizational efficiency and effectiveness. It increases cost efficiency by utilizing streamlined software and reducing manual tasks, saving money on resources by removing ineffective documentation. This allows funds to be allocated elsewhere within the organization. Additionally, it improves productivity by providing employees with a clearer understanding of their tasks, enabling them to focus on quality rather than unnecessary activities. Streamlined processes facilitate enhanced communication between departments, reducing the time spent on coordination and ensuring tasks are completed promptly. Better time management is achieved as fewer tedious tasks allow both employees and management to prioritize important activities and allocate time more effectively. Streamlining processes offers risk minimization by providing greater transparency, making it easier to track progress, identify mistakes, and meet regulatory requirements or deadlines, ultimately reducing business risks (Indeed 2023). The streamlining aspect of the framework also addresses the desired changes for the configuration process. With streamlined processes, positive effects occur which affect other key aspects in the framework like reducing manual work, impacting "Minimizing Human Errors," and increasing progress tracking, affecting "Enhanced Version Control."

5.3 Enhanced Version Control

Enhanced version control also emerged as another critical aspect of the configuration process. Theoretical research emphasized the importance of implementing robust version control systems and providing detailed change logs to track updates and revisions. Practical implementation confirmed this finding, demonstrating the value of establishing dedicated repositories for storing and managing document versions. By maintaining clear version histories and facilitating collaboration through shared platforms like SharePoint, organizations can minimize the risk of information loss, ensure compliance with regulations, and build trust among stakeholders.

Version control, is a system for managing changes to records, files, datasets, or documents. It provides a detailed audit trail of revisions and changes, facilitating track-

ing of a document's evolution through various stages and identifying contributors. Access to historical data aids in understanding changes' purposes, identifying contributors, and improving overall functionality. Ensuring distinguishability between different document versions aids clarity in software development and management. It provides management with a comprehensive perspective of project development, including authorship, change purpose, progress timeline, and impact assessment. It fosters transparency, consistency, and open communication among colleagues and teams, simplifying workflow coordination and enhancing productivity. Additionally, detailed tracking of changes ensures compliance readiness by preserving an audit trail of document alterations and specifying team member access (Reqtest 2020).

From the data of the process retrieved in the beginning of this research, there were difficulties regarding tracking which version was active and what the changes were. According to Reqtest 2020 the benefits of implementing Version Control, would address the mentioned difficulties, improving the process.

5.4 Minimizing Human Errors

Minimizing human errors was a recurring theme throughout both the theoretical and practical aspects of the investigation. Theoretical research suggested automating repetitive tasks, implementing validation checks, and establishing clear accountability and review mechanisms to catch and rectify errors in a timely manner. Practical implementation aligned with these recommendations, demonstrating the effectiveness of automated change logs and error alerts in reducing the likelihood of human errors. By leveraging technology to automate manual processes and provide real-time feedback, organizations can improve accuracy, efficiency, and overall process reliability.

According to cflow 2023, automation offers numerous benefits for businesses, such as reducing operating costs, improving worker safety, enhancing ROI (return on investment), and creating competitive opportunities. It also increases production output, aids in better planning and organizing, reduces the need for outsourcing, boosts employee satisfaction, enables easy integration, and enhances productivity and efficiency.

However, cflow 2023 also mentions that automation presents challenges, including the significant capital expenditure required for implementation, concerns about job displacement, the possibility of redundancy in automated processes, and the ongoing need for human interaction despite automation. Understanding both the benefits and challenges of automation is essential for businesses to effectively implement and maximize its potential.

In the implemented system conducted in this research, the benefits exceed the challenges. The automation in the new system involves the change log and the creation of the package structure. These functions were not expensive or extremely time-consuming to implement, which mitigates the need for a significant investment. Additionally, the automations implemented in the study only streamline the process and do not eliminate job positions, addressing that negative aspect.

5.5 Adapting to Systems and External Parties

Lastly, adapting to systems and external parties has emerged as a critical consideration for successful configuration processes. Theoretical research underscores the importance of close collaboration with both internal and external stakeholders, comprehending each party's system requirements, and providing support and guidance to the teams involved in the configuration process to navigate diverse systems effectively. Practical implementation further underscores these findings, emphasizing the necessity of standardized data and aligned inputs and outputs between internal and external systems.

This aspect of the framework can be compared to modularization, where each module is interconnected through a standardized interface (Johansson n.d.). In the context of the research conducted, ensuring that sub-process inputs, outputs, and the final output to external parties follow predefined formats is essential. This approach enables modifications and enhancements of sub-processes without impacting the main process, as the inputs and outputs remain consistent and predefined.

5.6 Resemblance to the Lean methodology

The 5 key aspects identified in this research share significant similarities with Lean principles. Just as Lean emphasizes iteratively enhancing processes, products, and personnel to eliminate waste and improve efficiency, the identified framework aims to remove unnecessary tasks and streamline processes. While Lean methodology is a continuous process, the framework in this research was identified while focusing on a specific process change (ATLASSIAN n.d.).

Both methodologies underscore the importance of understanding customer needs and delivering value. While Lean emphasizes identifying value by engaging directly with customers to understand their pain points and how products address them, this research's framework similarly prioritizes framing work around customer needs, where the customer is the employees of Polestar. This alignment suggests a shared commitment to customer-centricity and underscores the importance of delivering value to end-users (ATLASSIAN n.d.).

The methodologies emphasize visualizing workflows and optimizing processes. Lean methodology employs value stream mapping to visualize project processes and identify improvement opportunities, while this research's framework uses process and information models to understand process dynamics. By visualizing workflows, both methodologies aim to streamline operations, minimize waste, and enhance efficiency (ATLASSIAN n.d.).

In essence, while both methodologies have unique nuances and terminology, they share a fundamental commitment to continuous improvement, customer-centricity, visualization of workflows, and collaboration. The resemblance of the methodologies

could strengthen the identified framework in this research, as Lean methodology has been tested and established for decades and is applicable across industries (Terry n.d.).

5.7 Conclusion of analysis

In conclusion, the analysis of key aspects of implementing a successful new product configuration process revealed several critical insights into process optimization, stakeholder engagement, and system design. By emphasizing standardization, streamlining data flow, enhancing version control, minimizing human errors, and adapting to systems and external parties, organizations can improve efficiency, reduce errors, and enhance collaboration within the configuration process. The analysis of the data collected provide valuable guidance for organizations seeking to optimize their configuration processes, but with the data collection and the analysis conducted throughout the project the root cause of a problem, and clarity in a complex system and process can be achieved.

6

Discussion

The implementation of the application for configuring cars at Polestar has provided significant insights into streamlining processes within the automotive industry. This discussion aims to explore the transferability of this process to other companies, the potential for broader applications within Polestar itself, the considerations involved in developing a new system versus integrating existing solutions, insight in the framework, and finally some recommendations for further development.

6.1 Integration of the system

The methodologies and principles utilized in the development of the car configuration application draw significant parallels to Lean methodologies, emphasizing efficiency, standardization, and error reduction. This alignment suggests a robust potential for the broader adaptation of this process beyond Polestar, extending its benefits to other automotive companies and industries alike. Through the systematic standardization of formats and processes, optimization of data flow, enhancement of version control mechanisms, minimization of human errors, and seamless integration with external systems, organizations can replicate and build upon the success realized at Polestar.

Traditional car manufacturers struggle with many of the challenges stemming from large amounts of data, complex configurations, and fragmented data management systems. The implementation of a similar application holds the promise of overcoming these challenges, thereby enhancing productivity, reducing errors, and ultimately fostering greater satisfaction among customers. This transformative impact is not limited to the automotive sector, but also extends to other industries facing similar operational barriers. In particular, companies looking to adopt or already using Lean methodologies can greatly benefit from the application's adaptability and efficiency-driven approach.

The application's capabilities extend beyond industry boundaries, offering a scalable solution for organisations looking to streamline operations and increase operational flexibility. By applying lean principles, companies can effectively navigate complex situations, promote operational excellence and maintain an edge over competitors in the ever-changing environment. The application therefore not only represents a tailor-made solution adapted to Polestar's requirements, but also demonstrates how

organisations from different sectors are working on process optimisation and innovation.

However, it's essential to underscore the necessity for thorough testing to validate the application's efficacy across different companies and industries. While initial indications are promising, empirical evidence is required to confirm its positive impact in diverse contexts. This underscores the importance of evidence-based decision-making and ensures that organizations can confidently adopt solutions that align with their unique needs and challenges.

6.2 Internal development vs Super-system

When considering developing a new application or integrating existing solutions, several factors need to be taken into account. Firstly, the organisation should specify its needs and challenges that underpin the scope and functions of the system. A thorough requirements analysis and communication with stakeholders can ensure that the end product is in line with the organisation's objectives.

Secondly, the feasibility and scalability of the chosen approach must be carefully evaluated. While building a new application from scratch offers the possibility of customisation and control, it also involves significant investments in time and resources. On the other hand, integrating existing solutions can speed up the implementation process, but may present compatibility issues and integration challenges, as well as a large upfront investment cost.

In exploring potential systems for integration into Polestar's processes, the market analysis reveals several viable options, notably Tacton and ConfigIt. These systems, developed with a focus on configuration and user perspectives, hold promise for enhancing Polestar's operational efficiency.

The advantages of integrating such solutions are several. Foremost among them is the establishment of an integrated system wherein all configurations, versions, and documentation are centralized and streamlined across the organization. This would increase efficiency, reduce operating costs, improve decision-making and increase competitiveness in the market. By streamlining processes, minimizing errors and facilitating interdepartmental collaboration, this consolidation facilitates collaborative efforts among divisions, reducing the likelihood of discrepancies arising from disparate versions or incomplete solutions. All of these benefits will not come in the beginning, mostly like just a few of them. The real value of a comprehensive super-system lies further ahead in the future. When the system has been fully integrated and the organisation has learned all the processes.

However, the path to integration is not without challenges. As articulated by a R&D partner representative, while solutions like these may appear attractive, the reality of integration often diverges from expectations. Integration processes inher-

ently require time and resources, and the implementation of a system of this scale is bound to encounter hurdles.

The financial implications of integrating a comprehensive super system into Polestar's operations are critical considerations. The potential long-term benefits may outweigh the initial investment, striking a balance between pursuing financial viability while maintaining strong, adaptable, and innovative processes becomes a crucial factor.

The initial investment required to implement a comprehensive super-system can be significant and includes expenses such as software license fees, hardware infrastructure, implementation costs, and employee training. It is important to understand the integration process and the risks and challenges that come with it. The integration of a system is almost never the same and often encounters unforeseen obstacles, such as compatibility issues, complex data migrations and stakeholder resistance. These costs can be unexpected and difficult to predict, potentially impacting the profitability of a company like Polestar.

The solution needed to not have a significant negative impact on the financial situation while aligning with Polestar's core values and commitment to innovation. Systems implemented, therefore, need to be in line with the company's strategic objectives and support its overall mission. Due to the financial implications of integrating a comprehensive super-system into Polestar's operations, the decision was made to proceed with an in-house developed application.

Even if the system promises cost savings in maintenance over time and efficiency gains through centralized processes, implementing a super-system of this magnitude entails additional challenges beyond the initial financial outlay. Educating employees about the new system and processes is essential, and this expense should not be underestimated. It is not only the cost of the system that needs to be taken into account, but also the resources required for training and adaptation.

It is possible to argue back and forth about which way is best, but based on the timeline of the project and Polestar's financial situation, the factors show that in-house development was more advantageous and the potential long-term benefits of a super-system did not outweigh the investment and time for the moment.

6.3 Synergistic outcome from framework

In the results chapter, we established a framework comprising five key areas. Each of these areas was explored individually, highlighting their significance in the development of a system for car configuration at Polestar. However, upon further examination, it became evident that these areas were interconnected, often yielding similar outcomes.

One notable example of this connection is the relationship between minimizing human errors and standardizing processes. By implementing measures to minimize human errors, such as incorporating validation checks and intuitive user interfaces, we inherently establish a standardized process. When errors are reduced or eliminated, it implies that processes are consistently followed, leading to greater uniformity and predictability in outcomes. Thus, the pursuit of minimizing human errors naturally aligns with the objective of standardizing formats and processes within the configuration system.

Similarly, the efforts directed towards streamlining data flow contribute to both enhanced version control and minimizing human errors. A seamless flow of data ensures that information is accurately transmitted between various stages of the configuration process, reducing the likelihood of discrepancies or inconsistencies. Consequently, this streamlined data flow facilitates effective version control by ensuring that all stakeholders are working with the most up-to-date information. Moreover, by minimizing the manual intervention required for data transmission, the potential for human errors is further diminished.

The adaptation to systems and external parties is closely intertwined with all other areas of the framework. As the configuration system interfaces with external systems and involves collaboration with external parties, adherence to standardized processes becomes crucial. Consistency in formats and procedures ensures compatibility and interoperability with external systems, thereby facilitating seamless integration. Moreover, by minimizing human errors and streamlining data flow, the system becomes more robust and reliable, enhancing its ability to interact effectively with external entities.

While the framework delineates distinct areas of focus, it is important to realise that they are interconnected. The pursuit of excellence in one area often yields benefits that extend across multiple dimensions, leading to synergistic outcomes. Therefore, in the design and implementation of the car configuration system at Polestar, it is imperative to consider these inter-dependencies and leverage them to maximize the system's effectiveness and efficiency.

The current application tailored to Polestar's car configuration process presents opportunities for expanding its scope within the organization. Developing a comprehensive system that integrates data from various departments could further enhance operational efficiency and collaboration. For example, by linking the configuration application to a centralized team center, Polestar could facilitate seamless communication and data sharing across different teams. This integration would not only streamline processes but also provide valuable insights into the entire product life cycle, from conception to delivery. Leveraging technologies such as artificial intelligence and machine learning could automate decision-making processes and anticipate customer preferences, thereby bolstering Polestar's competitive edge.

In summary, the successful implementation of the car configuration application at

Polestar underscores the potential for streamlining processes and embracing technological innovations. Similar methodologies hold promise for optimizing operations, increasing competitiveness, and delivering greater value to customers across industries. Whether through incremental improvements or holistic system development, the pursuit of operational excellence remains paramount in today's transformative industries.

6.4 Recommendations

This section presents recommendations for further developing the programs created within this project. These recommendations are based from the findings outlined in this report and are tailored for the case company, Polestar.

- Log dates in the Changelog when changes are made. This could increase the control and visibility of the changes.
- Linking masters and children. During discussions with product managers and other departments, the idea and need to link features emerged. If features are added or removed, messages indicating that other changes may be needed will be provided. For example, if hardware is added that requires software to function, users will get a heads-up that more features need to be added.
- Costs & Volumes. To be seen in the information flow further down in the process, the program could generate costs and volumes from the features, in combination with factors for either costs or volumes. This would make it easier to follow the data and minimize the risk of miscalculations based on incorrect information.
- Look over a implementation of a super system. In the long-term perspective, it could be beneficial to look over the idea if an implementation of a bigger-system. The more the company grows and set their own processes, the harder and more costly it will be to implement a bigger system.
- Automate the uploading of the feature list, changelog, and package structure to SharePoint. Currently, the product manager needs to manually perform this task. Additionally, sending out notifications to all stakeholders when a new update is placed on SharePoint would be beneficial. This would further minimize human errors by eliminating one more manual process.

7

Conclusion

In this research project, the aim was to investigate the implementation of a new product configuration process and identify the successful factors and challenges associated with it. Three main results were discovered in the study, which are presented in the sections below.

Key aspects of a new successful product configuration process

By analyzing the data collected in the project, five patterns were recognized as key factors that influence the success of a new configuration process. The five key aspects are as follows:

- Standardization of Formats and Processes
- Streamlining Data Flow
- Enhanced Version Control
- Minimizing Human Errors
- Adapting to Systems and External Parties

These factors were taken into consideration when implementing a new sub-process called Vehicle Binder within the product configuration process. The implemented system confirmed the findings and resulted in a more efficient and effective process with fewer possibilities of errors occurring.

Clarity of the configuration process

The analyses conducted in this project helped overcome challenges in implementing a new configuration process, as many of the challenges stemmed from stakeholders not having a comprehensive understanding of the data flow. Initially, visually mapping out the process provided an understanding of data flow. Building upon this, process and information models offered nuanced insights into process dynamics and data integration, enabling stakeholders to identify areas for improvement. These analyses clarified the current state and empowered stakeholders to participate in the streamlining operations conducted in the implemented system.

The empowerment of stakeholders was evident during the implementation of the new IT system with the collaboration company Polestar. With the different models and analyses, their understanding grew, and their inputs for further clarity of the process or possible streamlines increased.

Minimize the risk of information loss

The analysis of the web application, the new subsystem of the configuration process,

highlighted the significant impact of "Minimizing Human Errors" and "Enhanced Version Control" in reducing information loss. Automated change logs simplified the identification of modifications to the documents, while dedicated SharePoint folders ensured access to the latest document versions. These measures not only reduce errors but also enhance efficiency and compliance with regulations. Prioritizing factors like these led to a smoother configuration process, less information loss, and reduced responsibility over the data in the process for the users.

Further research and problems remaining to be solved

Further research could be conducted to confirm the validity of the findings in this study outside the collaborative company Polestar. Studies have shown that the key factors identified in the created framework affect the effectiveness and efficiency of a process, but the framework would be more valid if tested by more companies. This would confirm if the framework works in other industries and companies.

The IT system developed for this study could be further developed to have fewer bugs and include a larger part of the configuration process in order to enhance the system and increase the performance of the configuration process.

Additionally, one interesting study could explore whether a configuration process should consist of one supersystem or multiple subsystems, along with the benefits and challenges associated with each approach.

Bibliography

- Immonen, Antti Saaksvuori Anselmi (2008). *Product Lifecycle Management*. URL: <file:///C:/Users/MannerstraleVictor/Downloads/Immonnen%20-%20PLM%20annotated.pdf>.
- Blessing, L. T. and A. Chakrabarti (2009). *DRM: A Design Research Methodology*. Springer London, pp. 13–42.
- P.T Helo Q.L Xu, S.J. Kyllönen R.J Jiao (2010). *Integrated Vehicle Configuration System*. URL: https://lipas.uwasa.fi/~phelo/papers/Integrated-Vehicle-Configuration-System-Connecting-the-domains-of-mass-customization_2010_Computers-in-Industry.pdf.
- Callum, Ali Usman Kidd (2013). *Configurator Management Porcess Capabilities*. URL: <https://www.sciencedirect.com/science/article/pii/S2212827113005167>.
- Marlon Dumas Marcello La Rosa, Jan Mendling Hajo A. Reijers (2013). *Fundamentals of Business Process Management*. URL: https://eprints.ukh.ac.id/id/eprint/280/1/2013_Book_FundamentalsOfBusinessProcessM.pdf.
- Bligård, Lars-Ola (2015). *The development process from a human-machine perspective*. URL: <http://acd3.com/assets/files/ACD3%20-%20Utvecklingsprocessen%20ur%20ett%20manniska-maskinperspektiv%202.1.pdf>.
- Michelle Jordan Gunnar Auth, Oliver Jokisch Jens-Uwe Kühl (2020). *Knowledge-based systems for the Configure Price Quote (CPQ) process – A case study in the IT solution business*. URL: https://www.iiakm.org/ojakm/articles/2020/volume8_2/OJAKM_Volume8_2pp17-30.pdf.
- Reqttest (2020). *What Are The Benefits Of Version Control?* URL: <https://reqttest.com/en/knowledgebase/what-are-benefits-of-version-control/>.
- cflow (2023). *10 Benefits of Automation: Explore the Advantages and Disadvantages of Automation*. URL: <https://www.cflowapps.com/benefits-of-automation/>.
- Indeed (2023). *6 Ways To Streamline Business Processes and Workflows*. URL: <https://www.indeed.com/career-advice/career-development/streamline-processes-and-workflows>.
- ConfigIT (2024). *ConfigIT*. URL: <https://configit.com/about/about-us/>.
- Dassault (2024). *Dassault*. URL: <https://www.3ds.com/about/company>.
- Echtelt, Rick van (2024). *Benefits of standardization in the manufacturing industry*. URL: <https://www.ag5.com/benefits-of-standardization-in-manufacturing/>.
- Siemens (2024). *Siemens*. URL: <https://www.siemens.com/global/en/products/drives/selection-and-engineering-tools/siemens-product-configurator.html>.
- Tacton (2024). *Tacton*. URL: <https://www.tacton.com/about/>.

- ATLASSIAN (n.d.). *What is Lean methodology?* URL: <https://www.atlassian.com/agile/project-management/lean-methodology>.
- Johansson, Tobias (n.d.). *Methods for Modularization – Five Key Success Factors*. URL: <https://www.modularmanagement.com/blog/methods-for-modularization-five-key-success-factors>.
- Terry, Jon (n.d.). *What is Lean methodology?* URL: <https://www.planview.com/resources/guide/lean-principles-101/what-is-lean/>.

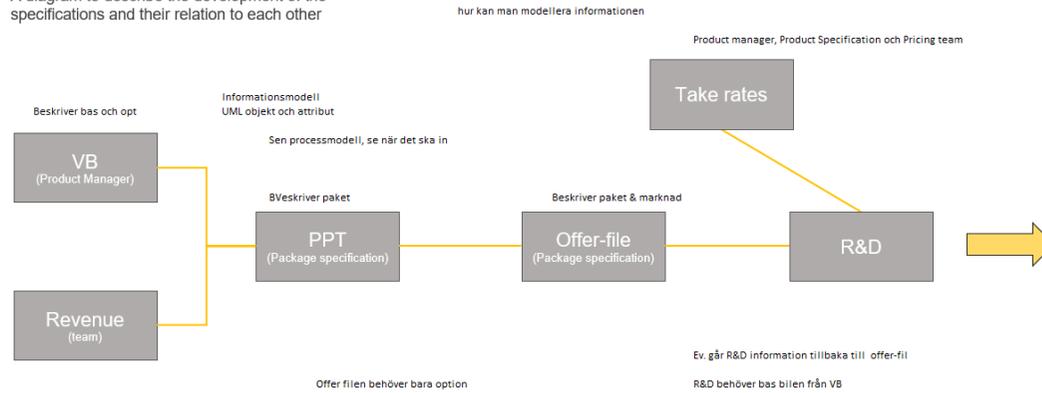
A

Appendices

A.1 First map of the data flow

Flow of specifications

A diagram to describe the development of the specifications and their relation to each other



Flow within R&D

This diagram is a continuation on the earlier diagram. For the moment Polestar mirrors External's systems to their own, to have the old models in their TC when Polestar starts to use their TC as a basis for the car production.

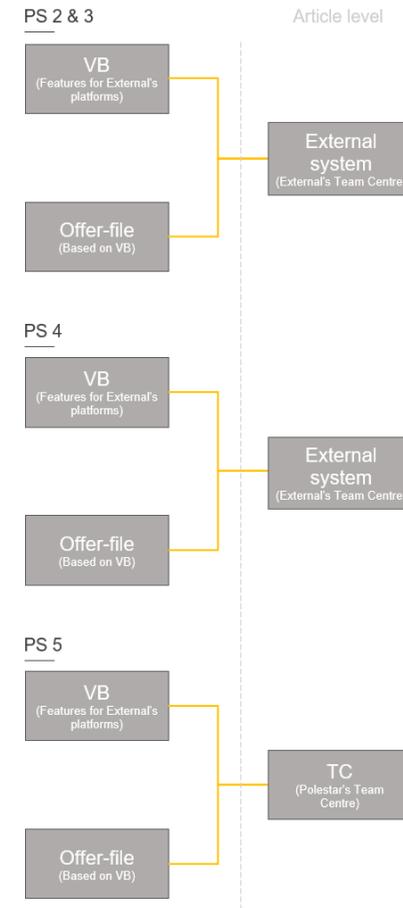


Figure A.1: First map of the data flow in the configuration process.

A.2 Second map of the data flow

Flow of specifications

A diagram that describes the development of the specifications of the car. From VB to Team Centre

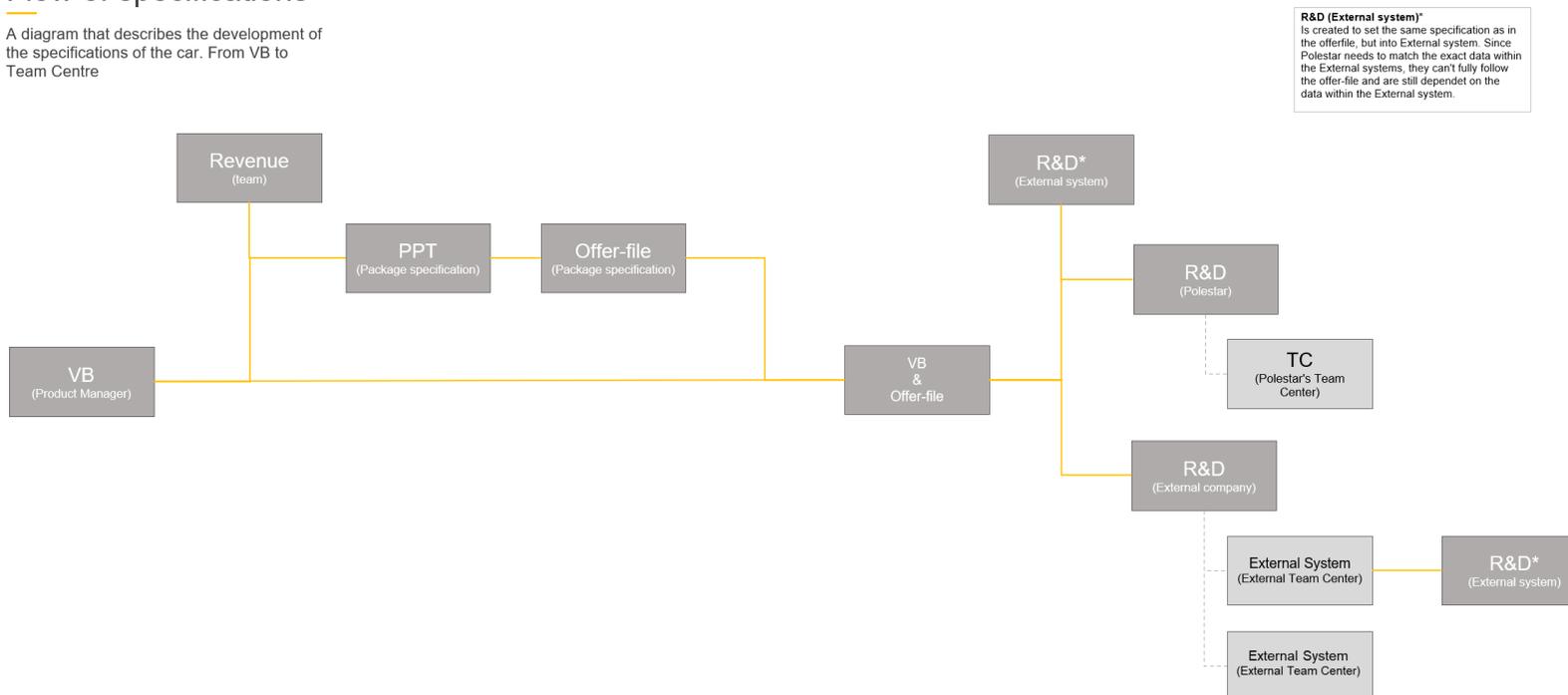


Figure A.2: The second map of the data flow in the configuration process.

A.3 Process Model

Process model

A diagram that describes the development of the specifications of the car. From VB to Team Centre

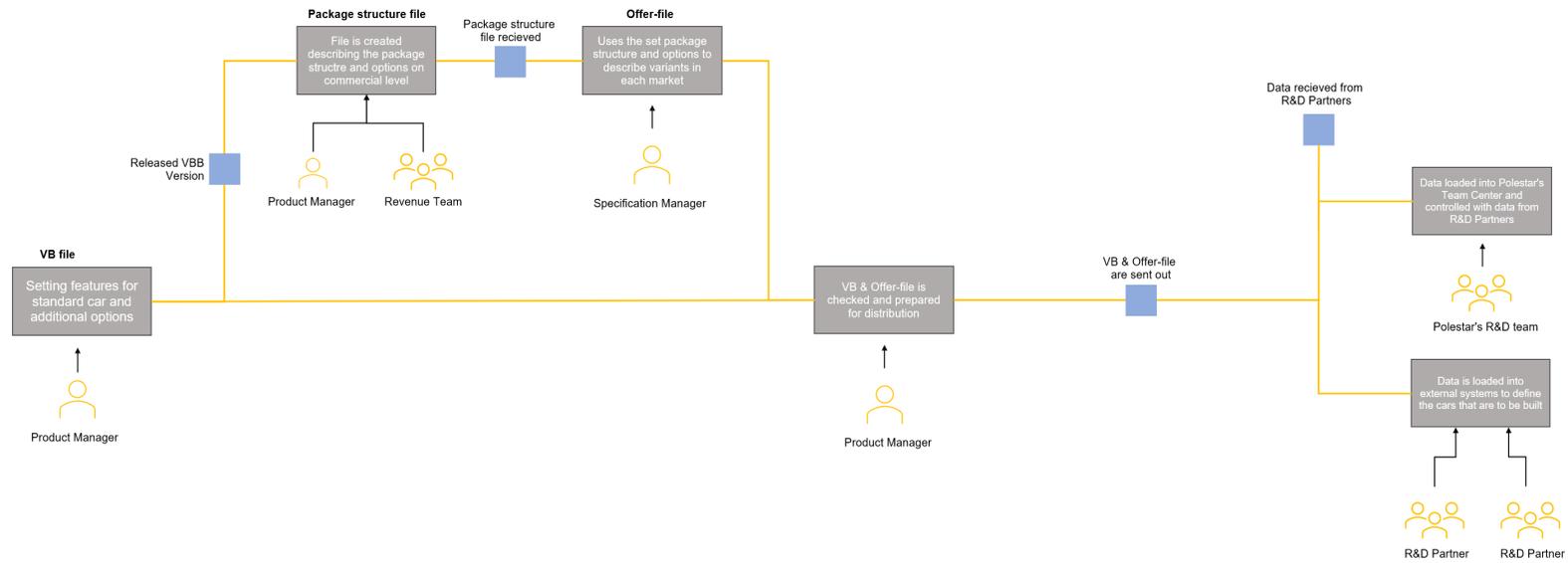


Figure A.3: Process model visualizing the data flow and the responsible parties.

A.4 Information Model

Information model

A diagram that describes the development of the specifications of the car. From VB to Team Centre

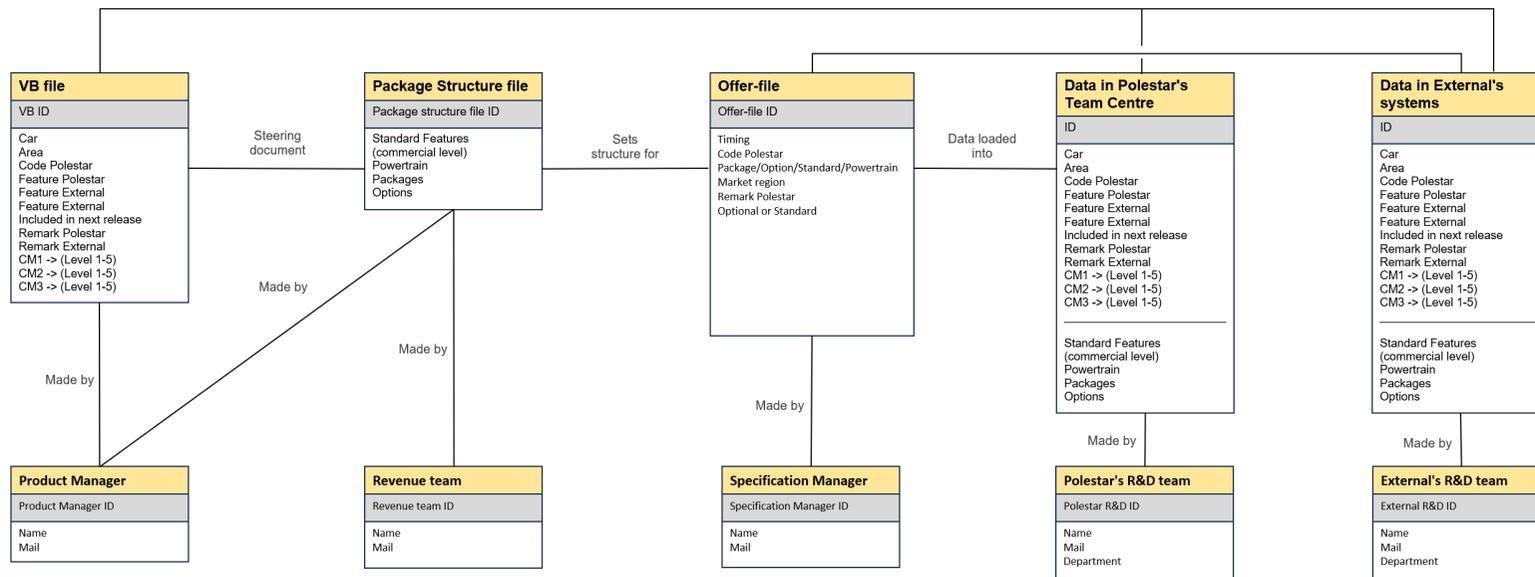


Figure A.4: Information model visualizing the data content throughout the process.

A.5 Gantt chart

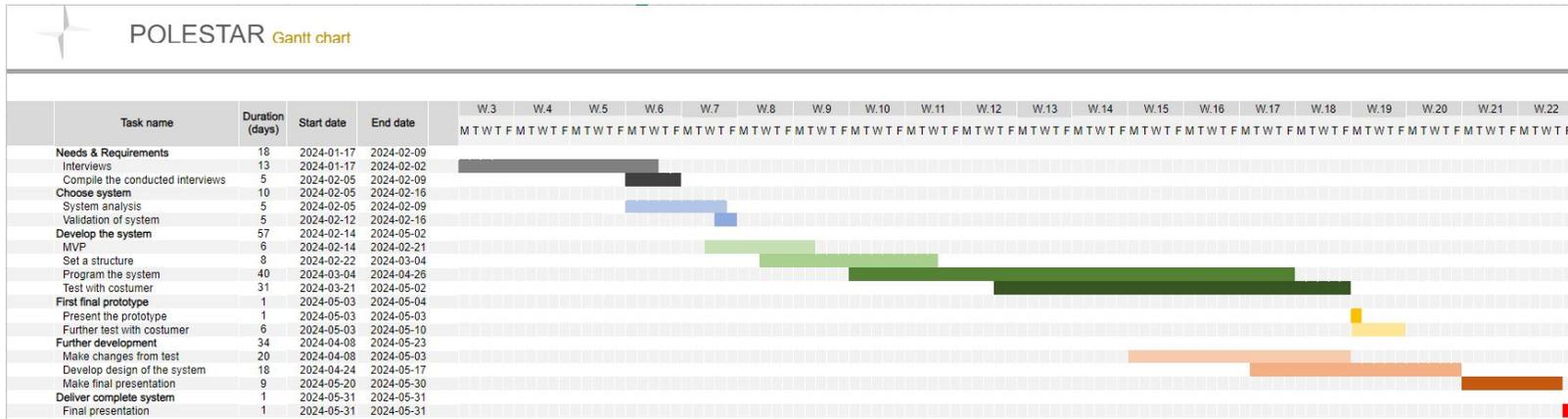


Figure A.5: The thesis's Gantt chart.

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