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Transitioning Spare Part Management: from Legacy System to Teamcenter PLM

A study for Electrolux Group

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Abstract

This thesis project examines the transition of Electrolux's legacy spare part management system to Siemens *Teamcenter*, addressing challenges of scalability, integration, and data consistency. The study evaluates how *Teamcenter's Service Lifecycle Management* (*SLM*) capabilities can modernize spare parts and service documentation processes while aligning with Electrolux's broader PLM ecosystem.

The work draws on literature review, case studies, and stakeholder interviews to define requirements and develop a customized framework for SBOM (Service Bill of Materials) management, technical documentation control, and change management. *RapidAuthor*-based authoring tools are integrated within *Teamcenter* to establish a single source of truth and enable a structured migration from the legacy system.

The results demonstrate that a PLM-based approach to spare part management not only streamlines operations and improves cross-functional collaboration but also enhances service readiness, reduces data duplication, and strengthens traceability between engineering and service domains. By enabling consistent, connected, and scalable spare parts data, the proposed solution lays the groundwork for future integration with downstream systems, supports faster response to market changes, and provides a foundation for advanced analytics and continuous improvement in aftermarket services.

Keywords

Product Lifecycle Management (PLM), Spare Parts Management, Teamcenter, Service Lifecycle Management (SLM), SBOM, Data Migration

Sammanfattning

Denna avhandling undersöker övergången från Electrolux äldre system för hantering av reservdelar till Siemens *Teamcenter*, med fokus på att lösa utmaningar kring skalbarhet, integration och datakonsistens. Studien utvärderar hur *Teamcenters Service Lifecycle Management* (*SLM*)-funktioner kan modernisera processer för reservdelar och servicedokumentation, samtidigt som de anpassas till Electrolux bredare PLM-ekosystem.

Arbetet bygger på litteraturstudier, fallstudier och intervjuer med intressenter för att definiera krav och utveckla en skräddarsydd ram för hantering av SBOM (Service Bill of Materials), teknisk dokumentationskontroll och ändringshantering. *RapidAuthor*-baserade författarverktyg integreras i *Teamcenter* för att etablera en gemensam sanningskälla och möjliggöra en strukturerad migrering från det äldre systemet.

Resultaten visar att ett PLM-baserat tillvägagångssätt för hantering av reservdelar inte bara effektiviserar verksamheten och förbättrar tvärfunktionellt samarbete, utan även stärker serviceberedskapen, minskar dataduplicering och förbättrar spårbarheten mellan konstruktions- och servicedomänerna. Genom att möjliggöra konsekvent, sammankopplad och skalbar reservdelsdata lägger den föreslagna lösningen grunden för framtida integration med nedströmsystem, snabbare respons på marknadsförändringar samt en bas för avancerad analys och kontinuerliga förbättringar inom eftermarknadsservice.

Nyckelord

Product Lifecycle Management (PLM), Reservdelshantering, Teamcenter, Service Lifecycle Management (SLM), SBOM, Datamigrering

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Omkar Janardhan Kharat & Paresh Sakala Vishwanath

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List of acronyms and abbreviations

Acronym	Full Form
3D	Three-Dimensional
API	Application Programming Interface
AWC	Active Workspace Client
BOM	Bill of Material
CAD	Computer Aided Design
DMU	Digital Mock-up
DPL	Digital Parts List
EBOM	Engineering Bill of Materials
ECM	Engineering Change Management
ERP	Enterprise Resource Planning
IPC	Interactive Product Catalog
ITK	Integrated Toolkit
KPI	Key Performance Indicators
MBOM	Manufacturing Bill of Materials
MES	Manufacturing Execution System
PDM	Product Data Management
PLM	Product Lifecycle Management
RBAC	Role-Based Access Control
ROI	Return on Investment
SBOM	Service Bill of Materials
SCM	Supply Chain Management
SDT	Spares Documentation Team
SLM	Service Lifecycle Management
SOA	Service-Oriented Architecture
TC	Teamcenter
TcRA	Teamcenter Reporting and Analytics
TDS	Technical Documentation System
UI	User Interface
XML	eXtensible Markup Language

1 Introduction

Electrolux Group (referred to as Electrolux hereafter), a global leader in home appliances, has been at the forefront of innovation and quality for over a century. With a current focus on three main product lines: Taste, Care, and Wellbeing, in which Electrolux continuously reinvents experiences for millions of people worldwide.

- **Taste**: This product line includes kitchen appliances such as hobs, ovens, microwaves, refrigerators, and freezers. Electrolux aims to enable consumers to prepare great-tasting food with the right taste and texture, minimize food waste, and create healthy and nutritious meals [1]
- **Care**: Electrolux's Care products focus on laundry and garment care, including washing machines and dryers. These products are designed to provide optimal care for clothes, ensuring they look and feel their best [2]
- **Wellbeing**: This line includes appliances that enhance the home environment, such as vacuum cleaners and air purifiers. Electrolux strives to reduce harmful allergens and pollutants, promoting a healthier living space [3]

Figure 1: Logo of Electrolux Group

Electrolux operates in approximately 120 markets across the globe, with regional business areas in Europe, APMEA (Asia-Pacific, Middle East and Africa), North America, and Latin America. The company employs around 41,000 people worldwide [4], driving its mission to *"shape living for the better"* through sustainable and innovative solutions. Electrolux has expanded its global presence through strategic acquisitions, such as the purchase of *Frigidaire* in North America and *Refripar* in Brazil [5]. These acquisitions have allowed Electrolux to strengthen its market position and diversify its product range, ensuring continued growth and innovation.

To remain a global leader, one key focus areas for companies like Electrolux is to gain high customer satisfaction, one of the many ways to achieve this is by maintaining high reliability and performance of its products. However, customer satisfaction is an ongoing process and cannot be achieved in a single step. While innovation, technology, and state-of-the-art manufacturing facilities can produce great products that make customers happy initially, maintaining this satisfaction over time requires continuous effort.

One crucial aspect of this ongoing effort is the aftermarket service that Electrolux provides. Ensuring that spare parts are readily available is essential for reducing downtime and enhancing customer satisfaction. Hence, effective management of spare parts data plays a vital role. By integrating efficient spare part management practices, Electrolux can continue to uphold its commitment to excellence and innovation, further solidifying its position as a leader in the home appliance industry.

Until today, the *Technical Document System (TDS)* has been a cornerstone in managing the spare parts and their documentation at Electrolux. However, as technology evolves, *TDS* has begun to show its age. Built on outdated infrastructure, it struggles to integrate with modern systems, limiting scalability and efficiency. The growing volume of data and the expanding needs of the organization have exposed *TDS's* inability to handle advanced features such as real-time tracking and analytics. To address these challenges, Electrolux is exploring the possibility of extending the use of Product Lifecycle Management (PLM) system – *Teamcenter* to include spare part management. *Teamcenter*, already implemented in other domains within the company, offers comprehensive capabilities for managing product data and processes throughout the entire lifecycle.

PLM refers to the strategic process of managing a product's journey from its initial conception through design, manufacturing, service, and disposal. It integrates people, processes, business systems, and information to create a comprehensive framework for managing product data and workflows. This approach ensures that all stakeholders have access to up-to-date information, facilitating collaboration and informed decision-making throughout the product's lifecycle [6, 7]

The benefits of PLM include:

- **Improved Collaboration:** By providing a single source of truth, PLM enhances communication and coordination among different departments and teams.
- **Reduced Time to Market:** Streamlined processes and efficient data management help accelerate product development and launch.
- **Enhanced Quality and Compliance:** PLM systems ensure that products meet quality standards and regulatory requirements by maintaining accurate and complete records
- **Cost Savings:** Efficient management of resources and processes leads to reduced operational costs and increased profitability [7, 8]

There are several players in the market who develop software for PLM. One such solution is *Teamcenter*.

Teamcenter, developed by Siemens, is a leading PLM software that helps organizations plan, develop, and deliver innovative products. It connects people and processes throughout the product lifecycle with a single source of data, enabling efficient collaboration and informed decision-making. *Teamcenter's* key features include digital twin technology, which creates virtual representations of physical products for simulation and optimization, and comprehensive data management that ensures a single source of truth and version control for all product-related information. The software facilitates cross-functional collaboration and supplier integration, allowing seamless communication and early involvement in the product development process. *Teamcenter* offers scalable deployment options, including on-premises, cloud, and SaaS solutions, and its modular architecture allows organizations to implement functionalities as needed and scale up over time. Additionally, *Teamcenter* automates workflows and business processes, reducing manual effort and increasing efficiency, while providing robust change management capabilities to track, evaluate, and implement changes systematically. Compliance with industry standards and quality assurance are integrated into the product lifecycle, ensuring products meet the highest standards of quality and regulatory requirements. These capabilities enhance productivity, improve decision-making, reduce operational costs, and accelerate time to market, making *Teamcenter* suitable for various industries such as aerospace, automotive, consumer goods, electronics, and industrial machinery [9].

By leveraging *Teamcenter* for spare part management. This extension is expected to streamline operations, improve data integrity following the philosophy of single source of truth and support the scalability required to meet future demands. This strategic exploration represents a move towards modernizing Electrolux's spare part management, ensuring continued excellence and reliability in its products and services.

1.1 Thesis Context & Stakeholder Dynamics

This thesis project was initiated in response to a request from the Spares Documentation Team (SDT) at Electrolux, who expressed the need to transition from their current legacy system, *TDS*, to a more robust and integrated solution using *Teamcenter*. The objective of the thesis project is to explore how spare parts and service documentation can be more effectively managed by leveraging the capabilities of *Teamcenter*, while ensuring alignment with Electrolux's broader PLM ecosystem.

The thesis project is conducted within the PLM team at Electrolux. This team is responsible for gathering stakeholder requirements across the company, developing solutions, and overseeing the integration, migration, and support of digital tools across the product lifecycle. Hence, within this context, the thesis project focuses on fulfilling the request from the SDT, by evaluating technical feasibility, and proposing a data model and solution architecture to support a potential future transition of spare part management from *TDS* to *Teamcenter*.

As the primary stakeholder, the SDT consists of service engineers, internally referred to as *developers*, who are responsible for creating and managing spare parts, parts lists, and technical documentation for new products manufactured across various product lines and global factories. The output from SDT is essential for field technicians (referred to as *customers* in system terms), who rely on this information to perform effective service and maintenance operations in the field.

1.2 Scope & Objectives

To facilitate tracking and measuring the accomplishment of this research, the thesis project is broken down into specific objectives as outlined below. By examining current trends, evaluating existing systems, and analyzing new technologies, this research seeks to provide comprehensive insights and actionable recommendations that will fulfill the stakeholder's request for transition.

1.2.1 Understanding the Current Trends in Spare Part Management

- Conduct a literature survey to understand the latest trends in spare part management.
- Analyze case studies of companies that have successfully implemented different spare part management strategies.
- Gather insights on best practices through interviews with industry experts.

1.2.2 Understanding the *TDS*

- Assess the limitations and challenges associated with the aging infrastructure of *TDS*.
- Identify the gaps in scalability, integration, and advanced features.

1.2.3 Analyzing *Teamcenter's* Capabilities

- Investigate the functionalities and benefits of *Teamcenter* in managing spare parts data and service processes throughout the entire lifecycle.
- Examine how *Teamcenter* can address the current challenges faced by *TDS* and improve spare part management.

1.2.4 Building the Solution

After documenting the functionalities of *TDS*, gathering requirements and understanding the expectations of the SDT, and identifying relevant capabilities within *Teamcenter*, while also incorporating insights from external experts, the next step is to develop the data model. This objective can be further divided into the following components, on the developer's viewpoint:

- Defining a solution for creating and managing Service Bill of Materials (SBOM).

- Defining a solution for managing technical documentation, which is integrated with the above.
- Defining a solution for managing the changes for the above two, within the service context.

While on the customer's viewpoint:

- Defining a solution for non-domain users to access the documentation developed and managed by developers, with the help of solutions defined above.

1.2.5 Migration and Replacement of Legacy Data

- Analyze the process of replacing *TDS* with *Teamcenter* and highlight the benefits and potential pitfalls of system replacement.
- Outline the steps involved in migrating legacy data from *TDS* to *Teamcenter*.
- Discuss the challenges associated with data migration, including data integrity, compatibility, and security.
- Provide best practices for ensuring a smooth and efficient data migration process.

1.2.6 Solution Evaluation

- Propose a framework for evaluating the impact and operational efficiency of the solution.

1.3 Research Questions

The purpose of this thesis project is to address a specific knowledge gap identified within Electrolux, this study focuses on developing a structured understanding of how spare part management can be enhanced through the capabilities of modern PLM systems and how engineering and service data can be effectively managed within such an environment. While Electrolux currently relies on a legacy system *TDS*, the planned transition to *Teamcenter* presents an opportunity to modernize spare part data management, improve information consistency, and increase operational efficiency. Accordingly, the research questions have been formulated not only to address this knowledge gap but also to ensure that each objective of the thesis project listed in section 1.2 is systematically answered.

- **RQ1:** *What role can modern PLM systems play in enhancing spare part management?*
- **RQ2:** *What is an effective approach for managing engineering and service data in a PLM environment?*
- **RQ3:** *How can these principles be applied to design a Teamcenter-based solution to replace the legacy spare part management system at Electrolux?*

1.4 Limitations and Exclusions

While the thesis project aims to provide comprehensive insights into spare part management within a PLM framework, it is subject to certain limitations and boundaries:

- **Scope of Application:** The findings are primarily based on Electrolux's internal systems and operations. While they may have broader implications, direct applicability to other organizations may require contextual adaptation.
- **Technology Focus:** The study centers on developing the solution within Siemens *Teamcenter*, and a comparative analysis with other PLM platforms falls outside the scope of

solution development. Nevertheless, the literature review examines trends in spare part management across other PLM systems.

- **Integrations:** A methodology for at least one downstream integration will also be provided.
- **Business Region of Focus:** The current spare parts management practices may differ across business regions within Electrolux. For this study, the proposed solution is tailored specifically to the spare parts management processes in Europe.
- **Replacement Focus:** Of the multiple components and extensions within the *TDS* ecosystem, this thesis project focuses on two primary components: *TDS Edit* and *TDS Web*.
- **Process:** Modifications are limited to data modeling within *Teamcenter*, not to overarching business processes.
- **Data Migration:** Only the methodology for the migration process will be outlined.
- **Implementation:** The project will not include full implementation or post-migration performance audit
- ***Teamcenter* Client:** The focus will be on Active Workspace version 2412 (Web client of *Teamcenter*)

2 Background

2.1 Technical Documentation System (TDS)

TDS is a group of tools and is an integral part of Electrolux Home Products and other associated factories. It serves as a standardized system for creating and distributing aftermarket technical documentation across all factories in Europe. This system ensures uniformity in the creation, processing, and distribution of technical documents, which include spare parts lists, service manuals, training instructions and many more.

2.1.1 Purpose and Objectives

The primary purpose of *TDS* is to streamline the documentation process, making it efficient and consistent across various product categories. The objectives of *TDS* include:

- **Serviceability:** Introducing new spare parts to the service logistics function.
- **Order Facilitation:** Enabling service personnel to order spare parts.
- **Assembly Information:** Providing detailed information on product assembly and electrical connections.
- **Comprehensive Documentation:** Offering complete information about essential parts within the product.

2.1.2 System Architecture

TDS operates as a local solution in Germany and Italy, with clients connecting via a Windows Terminal Server (WTS) application. The system is installed on a server, and clients use the Citrix ICA Client to establish connections, ensuring that only frames are transmitted between the server and the client. This setup allows for efficient data processing and real-time updates.

Of the multiple components and extensions within the *TDS* ecosystem, this thesis project focuses on two primary components: *TDS Edit* and *TDS Web*. *TDS Edit* is used by developers for creating and managing spare parts, parts lists, and technical documentation for new products manufactured across various product lines and global factories. *TDS Web* provides an interface for consumers such as technicians and service personnel, allowing them to access the information generated in *TDS Edit*.

In addition to these core components, the *TDS* system includes several other modules and custom tools that support specialized functions:

- ***TDS 1.2.3:*** Manages dictionaries and translations.
- ***TDS Tools:*** Custom functionalities for BOM requests, PR management, data analysis for PR resolution, content maintenance, user statistics, and quality checks.
- ***Wihajster:*** Provides OEM support and enables custom prime data import into the *TDS* database.
- ***Berta:*** Supports North American processes.
- ***UPSPartsUpdate:*** Facilitates upstream parts import into the *TDS* database.
- ***PRTool:*** Developed specifically for the spares planning team to assist with data analysis and PR reporting.

2.1.3 Key Features and Functionalities of *TDS Edit*

TDS Edit encompasses a wide range of functionalities to support the creation and management of technical documentation. These include:

- **Spare Parts Creation and Management:** Creating, assigning, and managing individual spare parts.
- **Section Creation and Management:** Sections are used to logically group spare parts within a part list. This includes organizing parts into sections and linking them to corresponding exploded views.
- **Spare Kits Creation and Management:** Grouping related spare parts into kits to streamline handling and improve service efficiency.
- **Part List Creation and Management:** Involves requesting the Manufacturing Bill of Materials (MBOM) from the manufacturing team or importing it, and creating, editing, and maintaining the Service Bill of Materials (SBOM) for products from the received MBOM.
- **Technical Document Management:** Attaching various technical documents and diagrams for service personnel, such as parts lists with exploded views, service manuals, service bulletins, wiring diagrams, fitting instructions, user manuals and many more [10]

2.1.4 Key Features and Functionalities of *TDS Web*

As previously mentioned, the primary function of *TDS Web* is to provide access to the information created and managed in *TDS Edit*. This core functionality includes the following key features as described and illustrated below:

- Multi-language user interface support
- Document download capability
- User profile management
- Platform for reporting problems
- Quick access to help resources and fault diagnostics
- Advanced Search Query

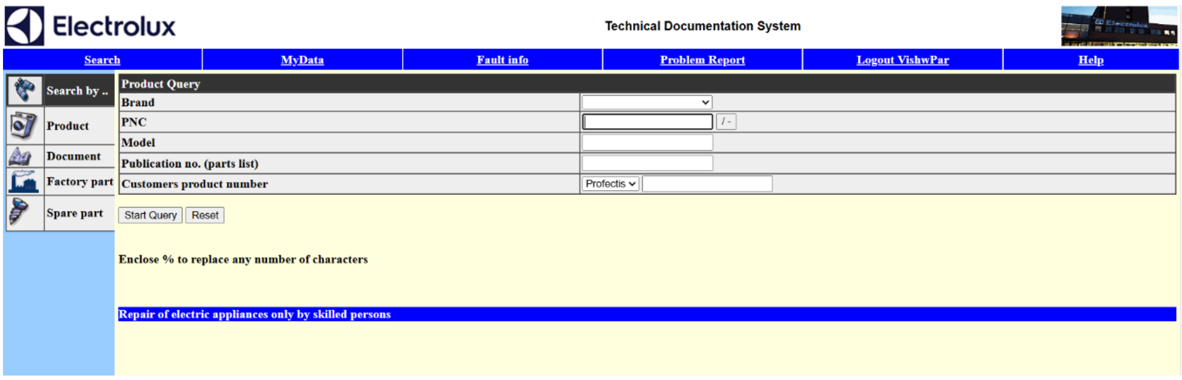

Figure 2: Snapshot of the landing page on TDS Web

2.1.5 Integrations of TDS

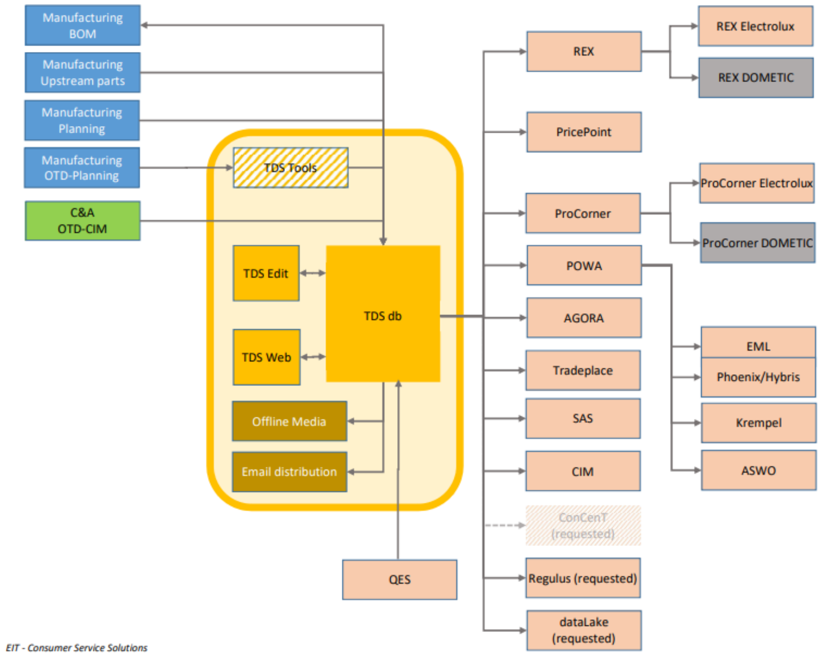

Figure 3: Integration of TDS [11]

Effective spare parts management in a PLM environment relies on seamless integration with both upstream and downstream systems. Upstream integrations connect *TDS* to the manufacturing facilities of the business regions that use *TDS* for managing spares. Downstream integrations link *TDS* to service, procurement, and logistics systems, enabling smooth transfer of spare part information for ordering, inventory management, and field service operations. Together, these integrations create a continuous flow of data across the product lifecycle, reducing errors, improving service readiness, and ensuring that the right parts are available when needed.

Studying integrations is a critical step in any PLM implementation project because it defines how information flows between the PLM system and its connected enterprise applications. Understanding what data is shared between systems, the direction of the data flow, and the frequency or timing of these exchanges helps ensure that all stakeholders work with accurate and synchronized information. Beyond data accuracy, integration studies also reveal dependencies between business processes, highlight potential data bottlenecks, and identify where automation can replace manual handovers. This knowledge supports the design of robust interfaces, minimizes duplication of effort, and reduces the risk of data inconsistencies.

In the scope of this thesis project, only the upstream integrations and *REX* were studied in detail [11]

- **Upstream Integrations:** (sends information to *TDS* db)
  - **Manufacturing BOM:** Components used to assemble the appliance in the factory.
  - **Manufacturing Upstream parts:** Component details
  - **Manufacturing Planning:** (Not used by the spares team)
  - **Manufacturing OTD-Planning**: Production batches
  - **TDS Tools:** External tool to display the data received from Manufacturing OTD-Planning. Also monitors the Problem reports raised on *TDS* Web by technicians.

   - **C&A OTD-CIM:** Consumables and accessories information created in PIM system.
- **Downstream Integrations:** (information sent out from *TDS* db)
   - **REX:** Spares operation (purchasing, warehousing, logistics, selling of spare parts).

2.2 Teamcenter Architecture and Functional Overview

As outlined earlier, *Teamcenter* by Siemens is a leading PLM platform that offers modular, scalable, and cloud-compatible solutions to connect data, processes, and people across the product lifecycle. This section delves deeper into the technical architecture and functional layers that enable the capabilities previously discussed.

2.2.1 Multi-Tier Architecture

Teamcenter employs robust multi-tier architecture, enabling separation of concerns, scalability, and streamlined integration:

- **Client Tier (Presentation Layer):**

Users interact with *Teamcenter* via:

   - **Rich Client:** A full-featured desktop interface for advanced users.
   - **Active Workspace:** A modern, web-based interface offering responsive, intuitive access from anywhere.
   - **Thin Clients / Mobile Apps:** Lightweight interfaces for specific roles and mobile usage.

- **Application Tier (Business Logic Layer):**

Houses the *Teamcenter* Server Manager and Business Logic Server, which handle workflow execution, access control, and caching. This layer orchestrates business processes such as product approvals, release workflows, and data routing across departments.

- **Integration Tier:**

This middleware layer enables integration with CAD, ERP, and MES systems. *Teamcenter* provides standardized connectors and APIs to tools such as:

   - CAD (NX, CATIA, SolidWorks, Creo)
   - ERP (SAP, Oracle)
   - Office suites and email clients

- **Data Tier (Persistence Layer):**

Core product data is stored in enterprise-grade relational databases such *as Oracle or Microsoft SQL* Server. File content is managed by the *File Management System (FM*S), which enables distributed file handling across locations and supports hybrid cloud setups.

2.2.2 Functional Modules and Their Technical Implementation

- **Product Data Management (PDM):** Data integrity and a “single source of truth” are enforced through centralized metadata storage, file versioning, and role-based access control. The system automatically tracks revisions, ownership, and audit trails.

- **Bill of Materials (BOM) Management:** *Teamcenter* enables multi-view BOMs (engineering, manufacturing, service), and synchronizes with ERP systems in real time. BOM variants are managed using built-in rules engines and configuration options.
- **Workflow and Change Management:** As previously mentioned, *Teamcenter* automates business workflows. Technically, this is handled through process templates, change items (ECR/ECO), and status-based routing, all configurable by administrators.
- **Visualization and Digital Mockup (DMU):** The system supports JT files (lightweight 3D format), enabling stakeholders to review CAD models without native tools. Markups, measurements, and interference checks can be performed directly in the visualization module.
- **Integration and Interoperability:** *Teamcenter* supports deep integration with external systems through:
    - **ITK (Integration Toolkit):** C++ based APIs for low-level integration
    - **SOA (Service-Oriented Architecture**): XML-based services for structured data transactions
    - **RESTful APIs:** Modern web services for cloud applications and mobile solutions

2.2.3 Customization in Teamcenter Using BMIDE

Teamcenter offers robust customization capabilities to tailor the PLM system to specific business needs. A key tool for this is the Business Modeler Integrated Development Environment (*BMIDE*) an Eclipse-based configuration and development environment provided by Siemens. *BMIDE* enables administrators and developers to define and modify the *Teamcenter* data model and business logic without altering the core source code. Through *BMIDE*, organizations can customize the "business object model" of their *Teamcenter* deployment, aligning data structures, workflows, nomenclature, and presentation with their unique processes and industry standards.

Table 1: Capabilities of BMIDE

Capability	Description
Data Model Extension	Define or extend business objects, create new object types (e.g., "CustomPart"), add properties, and set default values or validation rules.
Naming Rules and Numbering	Implement logic for part numbering schemes, revision naming, or automatic ID generation
User Interface Configuration	Customize how forms, properties, and actions appear in the Rich Client and Active Workspace.
Property Policies	Control read/write access, mandatory fields, or visibility for object properties based on user roles or conditions.
Business Rules	Define rules and constraints using expressions or Java extensions for validation and conditional behavior.

Custom LOVs (List of Values)	Create dropdowns or enumerated fields for specific object attributes.
Client Customization Hooks	Use pre-conditions, post-actions, or trigger points to extend workflows or validation logic.

BMIDE generates XML-based configuration definitions that are compiled into a *BMIDE* Template. This template is deployed on the *Teamcenter* server to update the data schema and business logic across environments. Typical deployment steps include:

- Define/modify business objects in *BMIDE*.
- Build and export the *BMIDE* template.
- Deploy the template to the server using tc_deploy.

Synchronize clients (Rich Client or Active Workspace) to reflect changes.

3 Methodology

3.1 Research Design:

This thesis project adopts a 'qualitative, applied, and design-oriented' research design, tailored to the practical nature of the problem being addressed, transitioning to a new spare part management system through the replacement of the legacy *TDS* with a modern PLM solution.

- **Qualitative and Applied Nature**

The research is qualitative in nature, relying on in-depth exploration of current practices, expert insights, and system evaluation rather than numerical or statistical analysis. It is also applied, as it focuses on solving a real-world problem within a specific organizational setting. The aim is not only to understand the existing challenges in spare part management but also to deliver a functioning solution that addresses those challenges.

To gather insights and build the foundation for the solution, the following qualitative methods were used:

I. **Literature Review:** A survey of academic and industrial literature was conducted to identify recent trends, challenges, and best practices in spare part management and PLM implementation.

II. **Case Study Analysis:** Industry case studies were examined to benchmark how other organizations have successfully transitioned from legacy systems to integrated PLM-based spare part management.

III. **Semi-Structured Interviews:** To gain a comprehensive understanding of the existing challenges and potential solution pathways, semi-structured interviews were conducted with various stakeholder groups. This method allowed for guided yet flexible conversations, enabling the exploration of both predefined topics and emergent insights.

- **Design Science Research (DSR)**

The research also follows a Design Science Research (DSR) approach, which focuses on the development and demonstration of an artifact, in this case, a demonstration of working framework for spare part management on *Teamcenter*. DSR is particularly suitable when the research goal is to design and evaluate IT-based solutions to practical problems.

In line with DSR methodology, the research progressed through the following stages:

I. **Problem Identification:** As outlined before, through stakeholder interviews and system evaluation, the limitations of the aging *TDS* system were clearly identified.

II. **Objective Definition:** Based on literature and stakeholder expectations, the desired capabilities of the new system were outlined.

III. **Design and Development:** A data model was developed within *Teamcenter* based on the objectives.

IV. **Demonstration:** A working version of the solution was configured and is now operational for demonstration purposes within the organization.

V. **Evaluation:** Feedback from stakeholders was used iteratively during development to refine the solution and ensure it meets functional and business needs.

VI. **Communication of Results:** The outcomes, including the framework, design rationale, and implementation considerations, are documented in this thesis project and intended for organizational use and further development [12]

3.2 Literature Review

The literature review in this thesis project serves as the foundation for understanding both the theoretical and practical aspects to propose a solution for the transition. It begins by examining best practices for implementing PLM projects, recognizing that this project partly involves critical roles such as the business analyst - responsible for gathering requirements and developing conceptual workflows and the solution architect - tasked with implementing the solution and creating a functional demo. Understanding the methodologies and approaches for successful PLM implementation is therefore essential. Building on this, the literature review explores the role of PLM in enhancing spare part management, highlighting trends and capabilities that modern systems offer. Finally, through analysis of industry case studies, it identifies effective approaches for managing engineering and service data within a PLM environment, thereby providing answers to the first two research questions of this study.

3.2.1 Best Practices for Implementation of PLM Projects

- **Data Modeling Techniques**

PLM environments are inherently complex, involving numerous processes, systems, and stakeholders. To navigate this complexity, modeling is recognized as a best practice for simplifying, communicating, and understanding PLM systems. Models act as a common language, enabling stakeholders to align their understanding and collaboratively develop effective solutions.

Two complementary modeling approaches are often employed in PLM implementations:

I. **Top-Down Approach:** Starts with a high-level, business-oriented view of the PLM environment and progressively moves into detailed layers, such as operations, data structures, and system functionalities.

II. **Bottom-Up Approach:** Begins with existing operational data and processes and builds upwards to achieve integrated systems and business-level understanding.

This thesis project follows a top-down approach to designing a *Teamcenter*-based spare part management solution. Starting from high-level requirements gathered from internal stakeholders - SDT members, and industry experts, the solution was systematically developed step by step to meet these business needs. This approach ensures alignment with Electrolux's broader digitalization strategy, provides a clear path from conceptual goals to detailed system functionalities, and supports consistency across the organization. By translating business requirements into structured processes, data models, and solution features, the top-down methodology enables a future-ready, scalable PLM implementation that addresses both current challenges and long-term objectives.

Once the approach is selected, modeling is further broken down into three parts:

I. **Process Mapping (As-Is Analysis):** This stage involves documenting existing processes to gain a clear understanding of current operations and identify inefficiencies or areas for improvement. It is sometimes referred to as Business Process Mapping, Process Charting, or Process Flow Charting.

II. **Process Design (To-Be Modeling):** Based on insights from the As-Is and requirement analysis, future processes are designed and visualized to reflect optimized workflows. This stage ensures that identified improvements are incorporated, creating a blueprint for how processes should operate moving forward.

III. **Process Measurement:** To enable continuous evaluation and improvement, metrics are integrated into each process. Typical measures include the number of documents processed, steps involved, or process cycle times. Process measurement ensures that designed workflows are effective and helps identify bottlenecks or areas requiring further refinement.

However, just as inefficiencies can arise in physical activities, they can also emerge within processes throughout the product lifecycle. Identifying and eliminating such process-related waste is essential to achieving an efficient PLM implementation. The Table 2 below highlights common examples of process wastes encountered in product lifecycle management which one should be aware of while designing a solution [7]

Table 2: Types of Digital Process Wastes

Types of Process Wastes	Definition
Transportation	unnecessary movement of product, of product data
Inventory	unnecessary stores of product, of product data
Motion	unnecessary movement of people, unnecessary notifications
Waiting	waiting for information, waiting for processing
Overproduction	producing unneeded information, or information before it's needed
Over Processing	too precise definitions, too many tests, too many iterations, superfluous conversions, unnecessary reformatting
Defects	rework, wasting effort on unnecessary inspections to prevent defects, translation errors, ambiguous data

3.2.2 Spare Part Management in PLM

Spare parts management is a critical component of the product lifecycle, especially in industries like aerospace, automotive, and industrial machinery where products require decades of maintenance support. Effective spare parts management can significantly impact profitability, for long-lifecycle products, aftermarket spare parts and services often generate profit equal to or exceeding the original product sale [13]**.** PLM systems, which traditionally manage a product's design and development data, have expanded to encompass after-sales service information, including spare parts, to help companies capitalize on this opportunity. Integrating spare parts data into PLM ensures that engineering, manufacturing, and service teams work from a *"single source of truth"* throughout the product's life, improving reliability of service and customer satisfaction.

Within PLM, spare parts are typically managed via an SBOM, which complements the Engineering BOM (EBOM) and Manufacturing BOM (MBOM). The SBOM is derived from the EBOM but enriched with service-specific information, it may include maintenance instructions, consumables, replacement part numbers, pricing, and stock availability. In practice, the EBOM captures the as-designed product structure, the MBOM reflects how the product is built, and the SBOM captures how the product is maintained (e.g. recommended spare parts and service procedures). Crucially, the SBOM is not an exact copy of the EBOM; instead, it reuses relevant design data but augments it with after-sales data (service kits, compatible replacements, etc.) [14]. By preparing a proper SBOM early, ideally as part of the design process, companies can ensure that once a product is delivered to customers, all necessary spare parts and documentation are identified and structured in the PLM system.

Modern PLM platforms maintain a *digital thread* that connects product data from inception through operation. This means the spare parts and service information are linked back to the original design and production data. For example, an engineering change that updates a component can automatically flag an update needed in spare parts catalogs or service manuals. This traceability is vital; without it, spare parts lists can become outdated, leading to technicians ordering the wrong parts or using incorrect procedures. Best practices in PLM-based spare parts management include: classifying parts for easy retrieval, linking spare parts to the exact product configurations they fit, and capturing *as-maintained* configurations (the record of each delivered product's specific parts) so that correct spares are identified for each serial-numbered asset. In summary, PLM-managed spare parts data provides a closed-loop between design and service – feeding design changes to service teams and feeding field data (failure rates, replacement history) back to engineering for continuous improvement.

With the increasing shift of manufacturing companies towards service-oriented and lifecycle-driven business models, Product Lifecycle Management (PLM) systems are evolving beyond their traditional role of supporting product development and engineering. In the context of aftermarket and spare parts management, PLM is increasingly recognized as a central enabler for data continuity, service optimization, and value creation throughout the entire lifecycle of installed products. Several key trends highlight how PLM is being extended to support aftermarket strategies more effectively.

- **Support for Predictive Maintenance and Lifecycle Monitoring:** One of the most significant trends is the growing role of PLM in supporting predictive maintenance strategies. Traditionally, PLM systems have focused on managing virtual product definitions, such as CAD models, bills of materials (BOMs), and engineering changes. However, their scope is increasingly expanding to include the management of real, installed systems throughout their operational lifecycle. This evolution aligns with expert visions of future lifecycle management, where digital representations of products remain continuously connected to their physical counterparts.

  By integrating PLM with data sources such as IoT sensors, condition monitoring systems, and maintenance records, companies can create a more comprehensive view of product usage and performance. This enables predictive maintenance by identifying failure patterns, estimating remaining useful life, and triggering proactive spare part provisioning before breakdowns occur. As a result, spare parts availability can be optimized, unplanned downtime can be reduced, and maintenance costs can be minimized. From a PLM perspective, this trend emphasizes the transition from static product data management towards dynamic lifecycle intelligence, where feedback from the field continuously informs maintenance planning, spare part demand forecasting, and future product design improvements.

  An increasingly important trend is the extension of the digital thread from product development to the installed base. In complex products with multiple variants and long operational lifetimes, spare parts compatibility depends heavily on the exact configuration of the delivered product. PLM systems are therefore evolving to manage serial-number-specific configurations, effectivity rules, and as-maintained product structures. By maintaining a continuous digital thread that links the as-designed, as-built, as-delivered, and as-maintained states of a product, PLM enables accurate identification of applicable spare parts for each installed unit. This reduces ordering errors, avoids unnecessary returns, and improves service efficiency.

- **Integration of PLM with eCommerce Channels for Spare Parts:** Another emerging trend is the integration of PLM-based spare parts management with eCommerce channels. As customers increasingly expect fast, accurate, and user-friendly access to spare parts, manufacturers are required to provide digital sales platforms that can handle complex product configurations and part variants. PLM plays a crucial role in enabling this by acting as the authoritative source of product and spare part data.

  Integrating PLM with eCommerce systems allows spare part catalogs to be generated dynamically based on the latest product structures, revisions, and effectivity rules. This ensures that customers are presented with correct and up-to-date spare parts that are compatible with their specific product configuration or serial number. Furthermore, such integration improves data consistency across systems by synchronizing PLM with ERP, CRM, and order management systems. Advanced search and filtering capabilities, enabled by structured PLM data, further enhance customer experience and reduce ordering errors. Overall, this trend highlights PLM's role in bridging engineering data and commercial aftermarket operations, thereby improving efficiency, accuracy, and customer satisfaction.

- **Improved Supplier Collaboration and Supply Chain Transparency:** PLM is also increasingly being used as a collaboration platform to improve coordination with suppliers in the context of spare parts management. In traditional setups, supplier communication is often fragmented across emails, spreadsheets, and disconnected systems, leading to delays, inconsistencies, and limited visibility into part availability and changes. By extending PLM access to selected suppliers, manufacturers can create a shared environment for data exchange and collaboration.

  Through PLM, suppliers can gain controlled access to relevant product data, specifications, change notifications, and demand forecasts. This ensures that suppliers are aware of current requirements and engineering changes affecting spare parts, enabling them to respond more quickly and accurately. Improved collaboration reduces lead times, minimizes the risk of obsolete or incorrect parts being delivered, and enhances overall supply chain efficiency. In addition, tighter PLM-based collaboration supports better coordination during ramp-ups, product updates, and end-of-life transitions, which are critical phases in aftermarket spare parts planning.

- **Closing the Loop and Supporting Circular Economy Strategies:** A further important trend is the role of PLM in "closing the loop" across the product lifecycle, particularly in support of Circular Economy (CE) principles. In the aftermarket context, spare parts management plays a key role in extending product life through repair, refurbishment, reuse, and remanufacturing. PLM can provide the digital backbone needed to support these activities by enabling traceability, data reuse, and structured feedback loops.

  By capturing data from the use and end-of-life phases—such as failure modes, returned parts, refurbishment outcomes, and recycling information—PLM systems can support the establishment of reverse supply chains. This information can then be analyzed to improve spare part designs, material selection, and modularity in future product generations. Furthermore, PLM can support decision-making regarding repair-versus-replace strategies, end-of-life markers, and compliance with sustainability regulations. In this way, PLM evolves from a tool for managing linear product lifecycles into an enabler of closed-loop lifecycle management, aligning aftermarket operations with sustainability and long-term value creation objectives.

- **Knowledge Management and Service Feedback Integration:** PLM is increasingly being used as a repository for structured service knowledge and feedback from the field. Traditionally, valuable information such as technician notes, failure descriptions, and workaround solutions remains siloed in service systems or unstructured formats. Integrating this information into PLM allows organizations to systematically capture, classify, and reuse service-related knowledge.

  This trend supports continuous improvement in spare part design and service documentation. By linking service feedback directly to specific parts, assemblies, or product versions, engineering teams can identify recurring issues and address them in future design iterations. Over time, PLM becomes a knowledge backbone that connects engineering, service, and aftermarket operations, supporting evidence-based decision-making across the lifecycle.

- **Integration of PLM with Advanced Analytics and AI for Spare Parts Planning:** Another emerging trend is the integration of PLM with advanced analytics and AI-based tools to improve spare parts planning and decision-making. While ERP systems traditionally handle forecasting and inventory management, PLM provides the contextual product data required to make these predictions more accurate.

  By combining lifecycle data, historical service records, and design information, AI-driven analytics can identify demand patterns, predict obsolescence risks, and recommend optimal spare parts strategies. PLM thus acts as a high-quality data foundation for advanced decision support, enabling more proactive and data-driven aftermarket management.

- **Lifecycle Costing and Value-Based Aftermarket Strategies:** There is a growing shift from cost-focused spare parts management towards value-based lifecycle strategies. PLM systems are increasingly used to support lifecycle costing by linking spare parts, service activities, and operational data to total cost of ownership (TCO) metrics.

  This enables manufacturers to design products and spare parts with serviceability, durability, and long-term value in mind. From an aftermarket perspective, PLM-supported lifecycle costing allows companies to evaluate trade-offs between upfront design decisions and downstream service costs, strengthening the strategic role of PLM in business planning and customer value delivery.

- **Regulatory Compliance and Traceability in Aftermarket Operations:** Finally, regulatory compliance and traceability are becoming more prominent drivers for PLM adoption in spare parts management. Industries such as household appliances, automotive, and aerospace face increasing regulatory requirements related to safety, sustainability, and material compliance.

  PLM enables traceability of spare parts across the lifecycle, including material composition, revision history, and compliance documentation. This trend is particularly relevant for managing recalls, safety updates, and end-of-life obligations. By embedding compliance information into spare part data structures, PLM reduces risk and ensures alignment with evolving regulatory frameworks [15]

3.2.3 Industry Practices (Case Studies)

3.2.3.1 Product–Service Systems as a Trend in PLM for Aftermarket Management:

Product–Service Systems (PSS) represent a relatively recent paradigm in industrial innovation, based on a holistic understanding of products as integrated combinations of tangible artefacts and intangible services. Instead of focusing solely on physical products, this approach emphasizes value creation through the integration of services across the product lifecycle, opening up new business opportunities for manufacturing companies. However, transitioning from a traditional product-oriented model to a service-oriented or product–service-oriented model requires the identification, coordination, and integration of new assets, capabilities, and stakeholders. In practice, this transformation is challenging, as most existing Product Lifecycle Management (PLM) tools and processes remain strongly product-centric. As a result, while PSS is widely acknowledged as a promising concept, particularly in the manufacturing sector—its industrial implementation remains limited.

This case study presents a successful industrial application of product–service management within the manufacturing domain. It describes how a household appliances manufacturer evolved from a traditional product lifecycle approach towards an integrated product–service lifecycle in order to manage newly introduced services, particularly in the aftermarket phase. The case illustrates how PLM can be extended beyond product development and production to support service-related activities and long-term value delivery.

A Product–Service System can be defined as a strategic offering that combines physical products with intangible services, deliberately designed to optimize product usage and enhance customer value. Value creation in PSS is typically enabled through an extended business ecosystem involving multiple stakeholders, such as suppliers, service providers, technology partners, and customers. This concept builds upon the notion of the "extended product," where services are embedded around a core physical product to increase its overall value proposition. In this context, PSS encompasses not only the product and associated services, but also the enterprise network and the supporting infrastructures required to deliver and manage them. After-sales and aftermarket services are among the most common and relevant applications of PSS in manufacturing industries.

The research underlying this case study proposes a structured methodology, supported by dedicated tools and workflows, to assist manufacturing companies in designing, implementing, and managing product–service solutions. A key focus of the methodology is the analysis of the company ecosystem and the relationship between existing tangible and intangible assets and those required to support the new PSS. Furthermore, the methodology emphasizes the definition of a coherent and sustainable PSS-oriented business model.

The proposed approach begins with a comprehensive assessment of the company's current situation and aims to address the following research questions:

- Is the company ecosystem ready to create and manage a Product–Service System?
- How can suitable partners be identified and selected to realize a Product–Service Virtual Manufacturing Enterprise (VME)?
- How can the integrated product–service lifecycle be effectively managed?

To answer these questions, the methodology is structured into five main steps:

I. **Analysis of the AS-IS Processes and Assets:** This step involves two complementary analyses. First, the existing Product Lifecycle Management (PLM) processes are examined, covering all phases from product ideation and design to manufacturing, delivery, use, and disposal. Second, a systematic mapping of the company's assets and those of its ecosystem is performed. These assets include both tangible elements (such as machines, materials, devices, and sensors) and intangible elements (such as skills, competencies, knowledge, and relationships among components and stakeholders). Process modelling tools are used to represent activities, inputs and outputs, required resources, involved competencies, and responsible organizational units. Asset mapping is supported through interviews and structured questionnaires aligned with key business activities and resources.

II. **Analysis of Servitization Readiness**: This analysis evaluates whether the company ecosystem is capable of creating and managing a PSS, or which areas require further development. Readiness is assessed across four dimensions: lifecycle management capability, ecosystem creation capability, innovation level, and network management capability. Each dimension is evaluated using targeted questionnaires to identify strengths and gaps related to servitization.

III. **Mapping of Tangible and Intangible Assets**: In this phase, the assets required for the new PSS, covering products, services, infrastructure, and ecosystem elements, are correlated with the assets available within the company and its partners. The mapping highlights how competencies and resources are distributed across the ecosystem, identifying which actors possess specific knowledge, provide components, develop software applications, manufacture products, or deliver services. This step enables a clear understanding of interdependencies within the PSS network.

IV. **Business Model Definition**: Based on the insights from the previous steps, a service-oriented business model is defined using the Business Model Canvas. This includes the identification of key partners, resources, and activities, as well as the value proposition, customer segments, channels, revenue streams, cost structure, and customer relationships. In addition, a STEEP analysis is conducted to assess external and internal environmental, technological, economic, political, and social factors influencing the PSS.

V. **Definition of the TO-BE Integrated Product–Service Lifecycle and VME**: The final step defines the future-state (TO-BE) integrated product–service lifecycle, incorporating both product-related and service-related activities and clearly identifying the roles of all involved actors. Building on the AS-IS process models, the lifecycle is adapted based on the servitization readiness assessment, asset mapping, and business model definition. This enables the company to establish the necessary Virtual Manufacturing Enterprise and coordinate partner contributions to successfully develop and manage the desired Product–Service System [16]

3.2.3.2 Enabling Service-Oriented Spare Parts Management in PLM

The increasing integration of services with manufactured products has led to a paradigm shift in industrial practice, commonly referred to as servitization. Rather than offering standalone physical products, manufacturers increasingly deliver hybrid solutions that bundle tangible goods with product-related services such as maintenance, training, refurbishment, and spare parts provisioning. While the strategic relevance of servitization is well established, its systematic implementation within Product Lifecycle Management (PLM) systems remains a challenge. In this context, this case study propose a structured approach for modeling service lifecycles alongside product lifecycles within PLM environments.

This study identifies a fundamental gap in existing PLM/PDM systems, which are primarily designed to manage tangible product data such as bills of materials (BOMs), CAD models, and manufacturing information. Although services significantly influence multiple stages of a product's lifecycle, particularly during operation, maintenance, and end-of-life, these services are often poorly represented or entirely excluded from PLM systems. As a result, service-related knowledge is frequently managed through isolated tools, leading to fragmentation, limited traceability, and inefficiencies in cost estimation, quality control, and internal communication.

To address this gap, the authors introduce the Product-Service-Lifecycle (PSL) approach, which conceptually distinguishes between product lifecycles and service lifecycles while explicitly modeling their interdependencies. In this framework, products and services each follow their own lifecycle phases; however, services are linked to specific product lifecycle stages rather than being treated as independent or purely downstream activities. For example, maintenance services are defined and planned during early product lifecycle phases but executed during the operational phase of the product. This decoupled yet interconnected lifecycle perspective provides a more realistic representation of how services evolve in industrial contexts.

Building on this theoretical foundation, this study demonstrates a practical implementation of service modeling within a commercial PLM system (Aras Innovator). Services are modeled as modular entities composed of service components, analogous to product components in a traditional product structure. These service components can be hierarchically organized and linked to product components, lifecycle stages, documents, workflows, and organizational resources. This modular modeling approach enables services to be managed using standard PLM functionalities such as lifecycle states, versioning, workflow control, and document management.

The contribution of this work is particularly relevant to domains characterized by highly customized products, low production volumes, and intensive after-sales service activities, such as special machinery and industrial equipment. By integrating services directly into the PLM system, the authors demonstrate how service-related information can be managed consistently across the product lifecycle, supporting both internal coordination and customer-facing service delivery.

From the perspective of this thesis, which focuses on the migration of a legacy spare part and service management tool into a modern PLM platform, this study provides both conceptual and methodological grounding. Spare parts management can be understood as a product-related service that spans multiple lifecycle phases, particularly operation, maintenance, and end-of-life. The Product-Service-Lifecycle approach supports the explicit modeling of such services within PLM, enabling traceability between spare parts, product structures, service activities, and lifecycle stages. Moreover, the demonstrated integration of services into a PLM system aligns closely with the objectives of replacing fragmented legacy tools with a unified, lifecycle-oriented PLM solution.

In summary, this study contributes a structured framework and practical modeling approach that extends PLM systems beyond their traditional product-centric focus. Their work underlines the importance of treating services, such as spare parts provisioning, not as peripheral activities but as integral elements of the product lifecycle. This perspective directly supports the thesis objective of enabling service-oriented spare parts management within *Teamcenter* by leveraging lifecycle modeling, data integration, and PLM-native workflows [17]

3.2.3.3 Teamcenter-based Service Data Management in MRO

This is an industrial case study on PLM-based service data management in the context of Maintenance, Repair, and Overhaul (MRO) activities for steam turbines. The study highlights the challenges associated with managing service and engineering data over long product lifecycles, particularly in environments where product-related service data is distributed across multiple, disconnected PDM and ERP systems. Due to the long operational lifespan of steam turbines and the continuous generation of service data, the lack of a unified lifecycle-oriented data management approach leads to poor traceability of configurations, increased engineering effort, and inefficiencies in spare parts and maintenance processes.

To address these issues, the authors propose a PLM-supported service process based on the use of a single, centralized PDM system integrated with an ERP system. In the presented case, *Teamcenter* is used as the backbone for managing both product and service data, enabling consistent tracking of "as-designed," "as-installed," and "as-maintained" configurations throughout the lifecycle. The case study demonstrates how service-related data such as spare parts documentation, repair BOMs, and maintenance records can be systematically managed within the PLM system, thereby improving configuration transparency and supporting service execution.

The findings of this study are directly relevant to this thesis, which proposes the use of *Teamcenter Service Lifecycle Management* (*SLM*) to migrate legacy service and spare parts management tools into a unified PLM environment. Similar to the presented case, the proposed solution aims to centralize service-related information, ensure configuration traceability across lifecycle stages, and support spare parts management using PLM-native structures and workflows. The study therefore provides empirical evidence that PLM-based service data management is a viable and effective approach for supporting long-term service operations and reinforces the suitability of *Teamcenter SLM* as a foundation for the proposed solution [18]

3.2.4 Spare Part Management in Teamcenter - SLM

Siemens Teamcenter Service Lifecycle Management (*SLM*) is an integrated module of the *Teamcenter* PLM platform that extends product lifecycle management into the service and support phase. It provides a digital thread of service information connecting design, manufacturing, and service execution domains, enabling a comprehensive digital twin of fielded assets. With *Teamcenter SLM*, organizations can manage all service aspects of a product, including creating service plans, synchronizing engineering and service bill-of-materials (EBOM and sBOM), and coordinating between service planning and execution – using a single source of truth for product and service data. This connected approach improves service readiness and first-time fix rates, reduces asset downtime and maintenance costs, and drives new aftermarket revenue opportunities by turning service into a value-add business. Across industries, from aerospace and heavy machinery to high-tech equipment, *Teamcenter SLM* helps companies meet strict service, compliance, and performance requirements over long product lifecycles by leveraging up-to-date asset knowledge and feedback loops between the field and engineering.

Figure 4: Modules of SLM [19]

Teamcenter SLM brings in multiple roles and capabilities:

- **Service Engineer:** Provides SBOM authoring and management capabilities, enabling the creation and maintenance of SBOMs along with related logistics data, and allowing accountability checks against source BOMs.
- **Service Planner:** Provides service planning capabilities, allowing the creation and management of service requirements and work cards, as well as the identification of additional resources needed to support the service planning process.
- **As-built manager:** Offers As-Built Management functionality for targeted use cases, enabling the generation of As-Built structures and the documentation of installations, deviations, and discrepancies throughout the manufacturing process.
- **Service Manager:** Provides asset management capabilities, enabling the configuration of SBOMs, generation of physical structures, and recording of service events to accurately track and maintain asset details throughout its lifecycle.
- **Service Forecasting:** Offers maintenance forecasting capabilities, allowing analysis of assets against time- and usage-based service requirements to produce maintenance due lists for specified time periods.
- **Service Work Instructions:** Gives technicians access to comprehensive asset maintenance information, including all *SLM* data related to the asset and its maintenance tasks, such as Service Work Instructions, while also enabling the recording of part movements, usage, and discrepancies.
- **Maximo Integration:** Enables integration between *Teamcenter* and *IBM's Maximo*, allowing bi-directional exchange of asset service information to seamlessly support both service engineering and service work order processes.
- **Micro-services:** Supports customization and integration capabilities, enabling the creation of new APIs and delivering performance enhancements when interacting with *SLM* products [19]

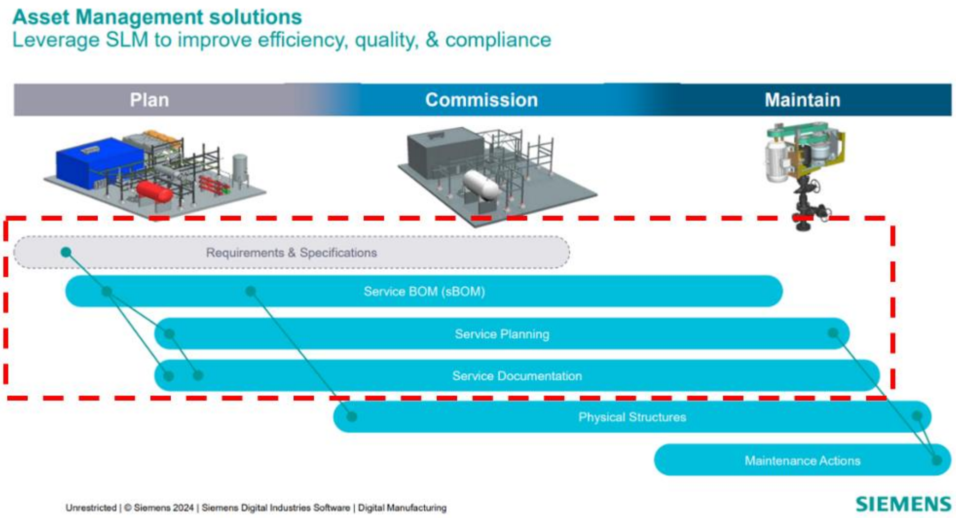

Figure 5: Asset Management of SLM and its relevance to Electrolux [19]

Asset management is the core fundamental area around which *Teamcenter SLM* is built for. With the growing customer requirements, aftermarket sales and maintenance have become important for product development and customer satisfaction. It helps in maximizing operational efficiency, ensuring quality and maintaining compliance throughout the asset lifecycle. Siemens' *SLM* solution supports this by integrating key service-related processes from the planning phase through commissioning and into the long-term maintenance of assets.

The figure illustrates how Siemens *SLM* provides a structured digital backbone to manage service data across three major phases: Plan, Commission, and Maintain. It begins with capturing requirements and specifications, which drive the creation of the SBOM. The SBOM represents a service-centric view of the product structure, tailored specifically for post-sales support and maintenance activities. Alongside SBOM, service planning is carried out to prepare for future maintenance tasks, spare parts logistics, and service workforce requirements. Detailed service documentation is also developed, ensuring that accurate, up-to-date information is available to technicians during operations. These elements are linked to physical structures, actual physical assets installed in the field creating a direct connection between digital data and real-world configurations.

Electrolux, as a consumer-focused white goods manufacturer, produces a large volume of product instances, i.e. individual units sold to customers globally. Given this scale, setting up and maintaining digital twins for every product instance presents significant challenges in terms of data management and associated costs. While real-time data from users could greatly enhance product development, the overhead of storing and updating detailed digital representations for each unit is impractical. Therefore, in the context of Electrolux, maintaining physical structures and recording maintenance actions at the individual product level was deemed inefficient. Instead, the proposed solution focuses on selectively leveraging the most relevant functionalities of the Siemens' *SLM* offering such as SBOMs, service planning, and documentation, without fully implementing digital twins for each product instance.

3.2.5 RapidAuthor for Teamcenter

RapidAuthor is a suite of applications tailored for integration with *Teamcenter,* is a modular technical documentation development suite by Cortona3D, designed to streamline the creation of interactive electronic technical publications, catalogs, training materials, and work instructions. It enables users to author rich 2D/3D content firmly tied to product data and BOMs in *Teamcenter*. Key components of this suite include:

- **RapidManual**: Creates interactive electronic maintenance and repair manuals with animated 3D sequences and synchronized text.
- **RapidCatalog**: Builds interactive parts catalogs that reduce ordering errors and improve user navigation.
- **RapidLearning / RapidIllustrator**: Develop training courses or high-quality graphics and exploded views based on CAD data.
- **RapidData Converter / Connector**: Provide CAD import and tight integration with *Teamcenter* interfaces like Active Workspace and *Service Planner* [20]

3.2.5.1 Features & Integration Highlights

- **PLM-native authoring and dynamic synchronization**: Authors work directly with *Teamcenter* items, BOMs, and CAD, ensuring publications always reflect the latest engineering data.
- **Standards support**: Fully compatible with DITA, S1000D, ATA2200, and SCORM standards, enabling multilingual and structured documentation publishing.
- **Change management, version and status control benefits:** Documents created in *RapidAuthor* are treated as *business objects* within *Teamcenter*, thereby inheriting all native

Teamcenter functionalities, including version control, status tracking, and structured change management.

3.2.5.2 Components available for Add-On

- **RapidDeveloper:** Enables customization of data import and export behavior via:
    - **RapidConfiguration**: Control how source CAD is loaded (units, geometry simplification, mapping to templates)
    - **RapidSpecification**: Define output formats, metadata binding, document layout per standard (e.g. DITA, S1000D)
- **Cortona 2D Editor Pro**: Provide advanced vector image editing (2D) capabilities, through user-friendly wizards, simplifying the transformation of engineering data into structured, graphic-rich documentation [20]

3.3 Data Collection:

3.3.1 Data Collection through Semi-structured interviews

Within Electrolux, a series of interviews and discussions were held with our stakeholder team SDT. These interactions offered valuable insights into the practical use of the current tools, *TDS Edit* and *TDS Web*. Through these sessions, we examined their core functionalities (as described in Sections 2.1.3 and 2.1.4) and gained a comprehensive understanding of the typical workflows followed by SDT in carrying out their tasks. In addition to understanding their operations, the discussions helped surface several limitations of the current system, along with the team's expectations and concerns regarding a possible transition to a PLM-based solution. The insights gathered through these engagements were synthesized to define the requirements for this thesis project. These are summarized in the table below.

Table 3: Formulated Requirements for Building a Solution

Viewpoint	Requirement Group	Requirement
Developer	SBOM Management	(a) Ability to create and manage spare part lists derived from a source BOM which is either requested or imported.
		(b) Structuring spare part lists into reusable sections to allow content sharing across different parts that follow similar configurations or structures.
		(c) Creation of spare parts with custom properties and assignment to source BOM items. Includes grouping into kits, managing part lifecycles (e.g., replacements, EOL, alternates), handling phantom and invisible parts, tracking by market, linking to external systems, assigning default section types, and supporting standardized, partially automated naming and numbering conventions.

	Technical Documentation Management	(d) Capability to attach diagrams such exploded views etc., to the Parts List of a Product.
		(e) Ability to link various types of technical documents, such as service manuals, service bulletins, fitting instructions, wiring diagrams and datasets like images, to the part list, section, and individual spare part levels.
	Change Management	(f) Capability to support status control, version control and post-release edits through a systematic change management process.
Customer	Field Technicians	(g) The system must support user profile management and tiered access levels for different user groups.
		(h) Customers should receive automated notifications when new spare part lists, service bulletins, or manuals are created or updated. These alerts must be filterable by brand, country, and product group
		(i) A robust search panel should allow filtering by product number, model name, spare part number, part number, document type, and document number. The interface must support multiple languages and scripts.
		(j) Spare part lists should be structured and revisioned, divided into clear sections. Each part must be linked to images and display quantity per use along with the display of exploded views.
		(k) Customers must be able to report issues and provide feedback through integrated forms.
		(l) A statistics panel should offer tailored data extracts for specific customers, helping them analyze usage and trends.

To incorporate external perspectives, interviews were conducted with industry experts from various companies and sectors (A sample questionnaire is provided in Appendix A). The goal was to explore best practices and alternative approaches adopted in spare parts and service documentation management. These conversations provided a number of actionable insights, which have been incorporated into the proposed solution. The key findings are organized thematically below:

- **Evolving Role of SLM:** A notable trend identified is the transformation of *SLM* from being traditionally viewed as a cost center to now being recognized as a potential profit center.
- **Designer Involvement in Spare Part Decisions:** Several companies involve design engineers early in the decision-making process to determine whether a component should be classified as a spare part. This practice contributes to smarter spare part strategies and reduces unnecessary inventory.

- **Connected BOM Philosophy (DBOM–MBOM–SBOM):** The importance of maintaining a connected structure between DBOM, MBOM, and SBOM was emphasized. This ensures data consistency across departments and improves traceability and product understanding throughout the lifecycle.
- **Modularization and Sectional BOMs:** A best practice observed was breaking down SBOMs into modular, reusable sections, which not only enhances modularity but also minimizes redundancy and data duplication, leading to more efficient documentation and configuration management.
- **Feedback Loop from Field to Design:** The integration of field feedback into product development was seen as essential. Establishing such a loop allows design teams to learn from recurring service issues and improve future product iterations.
- **Distinction and Connection Between ECM and SCM:** Experts stressed the need to clearly distinguish Engineering Change Management (ECM) from Service Change Management (SCM), while also ensuring that these processes remain interconnected within the PLM system to avoid misalignment.
- **Use of Cortona3D and RapidAuthor Suite:** Experts highlighted how Cortona3D's *RapidAuthor* Suite, when integrated with *Teamcenter SLM*, significantly improves the efficiency of managing service documentation by streamlining content creation and enabling seamless updates.
- **Tool Integration for Maximum Capability Utilization:** Lastly, the value of seamless integration between specialized tools (e.g., *Teamcenter SLM* for spares and SBOM management with authoring tools like *rapidAuthor* suite for *Teamcenter*) was highlighted as crucial. This approach allows organizations to leverage each tool's strengths, creating a more powerful and flexible end-to-end service management system.

Interviews and discussions with the solution vendor, Siemens Digital Industries, provided valuable insights into the technical capabilities and customization flexibility of *Teamcenter*, particularly in the context of *SLM*, as described in Section 3.2.4. These interactions deepened our understanding of how *Teamcenter* could be tailored to address the specific needs of Electrolux's SDT. Furthermore, complementary discussions with Cortona3D offered important perspectives on the benefits of integrating *Teamcenter SLM* with Cortona3D's *RapidAuthor Suite for Teamcenter*, as listed in section 3.2.5. This integration has the potential to significantly improve the efficiency and effectiveness of fulfilling stakeholder requirements, especially by streamlining content creation and management processes, and enhancing the overall documentation workflow.

Finally, internal consultations with Electrolux's PLM team provided valuable insights into how the proposed solution could be seamlessly integrated into the company's broader PLM ecosystem. These discussions addressed key considerations such as data migration strategies and system architecture alignment, ensuring a smoother and more sustainable implementation.

The following table provides an overview of the participants involved in the semi-structured interviews conducted during the study.

Table 4: List of participants in interviews/discussions

Group	Participants	Participant's Designation
Service Documentation Team (SDT)	Marcin Koczur	Sr Spares Doc Engineer & Automation Lead, Spares Documentation Team, Electrolux
Siemens	Håkan Eriksson	Presales Consultant, Siemens Digital Industries Software
PLM Team (Electrolux)	Pontus Carlsson	PLM & CAD Systems Lead, Electrolux
	Sachin Rao	Senior SME – PLM & CAD Systems, Electrolux
External Experts	Ashish P Killedar	Technical Project Manager, Hitachi Energy & PLM Business Consultant
	PLM Profesional	PLM Coach, Blogger & Lecturer and optimist
	Prasoon Deshpande	PLM Architect, *SLM*, Digital Product Leader at IKEA

3.4 Synthesis of Findings and Conceptual Framework Development for the Solution

This section brings together insights from the literature review, semi-structured interviews with internal and external stakeholders, and the analysis of industry case studies. These findings are synthesized into a unified conceptual framework that serves as the foundation for designing the spare parts management solution in *Teamcenter*. From a broader perspective, the developer's requirements for SBOM management are addressed through customization of the out-of-the-box (OOTB) *Teamcenter SLM* module. Technical documentation needs are met by integrating *Teamcenter SLM* with the *RapidAuthor Suite for Teamcenter*, while change management requirements are supported by *Teamcenter's* native change management capabilities, supplemented with targeted customizations to meet service-specific needs. The figure below (enlarged version can be found in Appendix B) presents the overall solution framework from the developer's viewpoint, showing activities grouped by requirement categories while maintaining their interconnections to provide a holistic view.

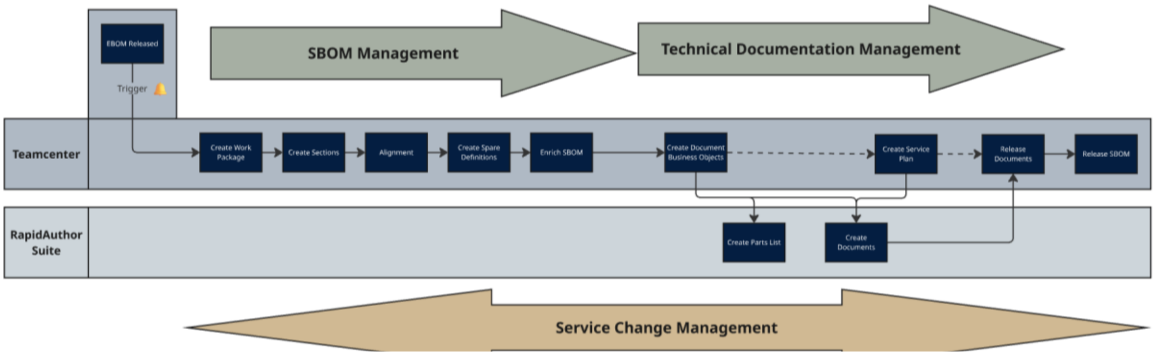

Figure 6: Conceptual Framework of the Proposed Solution

On the other hand, from the perspective of solution for customer viewpoint, the requirements are best addressed through Teamcenter's multi-site capabilities, which in this case is proposed to be *Teamcenter's SupplierConnect*.

4 Results

This section presents the detailed solution developed based on the requirements outlined in Section 3.3.1 and framework outlined in section 3.4. For each requirement, the current state on *TDS* (where applicable) is briefly described, followed by the proposed solution within *Teamcenter*, including any customizations applied and the identified next steps. The content is organized into two parts, reflecting the viewpoints of the two primary user groups: developers and customers.

4.1 Developer Viewpoint

This part of the results section outlines the proposed solution for developers, i.e. the service engineers who create and manage data in *TDS Edit* and distribute it downstream to systems integrated with *TDS*. To effectively address their requirements, the section is structured into two main areas: SBOM Management and Technical Documentation Management.

4.1.1 ER Models - TDS (as is) and Teamcenter (to be)

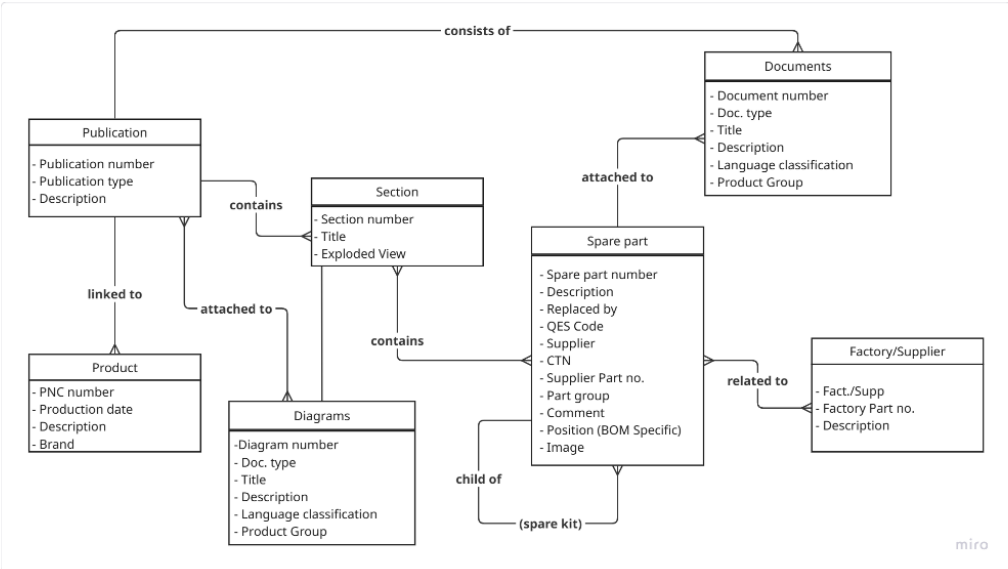

Figure 7: ER Model for the As-is Solution

- **Publication**: A unique identifier that exists as an independent entity and is linked to every other item published on *TDS*, such as diagrams, documents, spare parts lists, and more.
- **Section**: An entity that groups similar spare parts in a logical manner, providing structure to the spare parts list and making it more customer-friendly. For example, sections could include “Door,” “Electrical Housing,” or “Electrical Equipment.” Exploded views for easier understanding are attached at the section level.
- **Spare Part:** Contains spare part details along with multiple attributes (see Figure 7). Relation to itself enables the formation of spare part kits
- **Factory/Supplier:** Holds engineering part information. Each factory/supplier part is linked to its corresponding spare part to ensure traceability.
- **Documents:** Includes various types of documents such as service manuals, service bulletins, fitting instructions, and more.

- **Diagrams:** Stores different types of diagrams, including exploded views, elementary diagrams, wiring diagrams, and others.
- **Product**: Represents the product manufactured in the factory, with details such as production date, brand, and other relevant information.

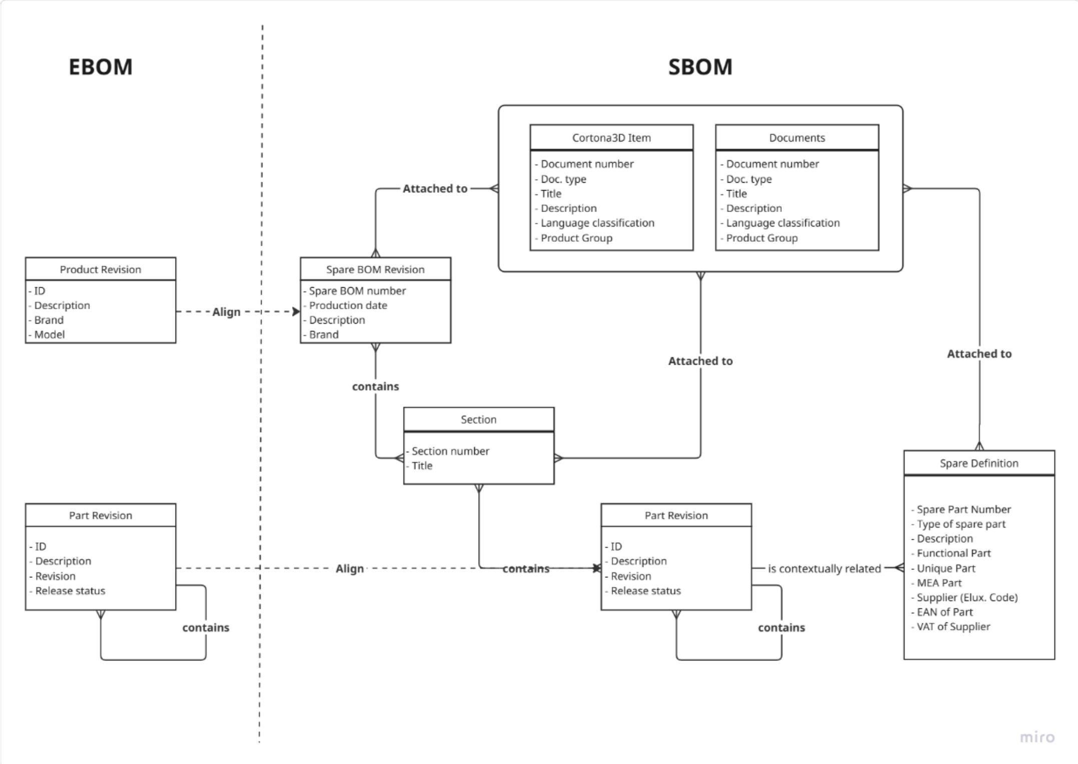

Figure 8: ER Model for the Proposed Solution

As seen here, the publication number as a separate entity has been removed, since every business object or entity in *Teamcenter* can have its own unique identifier, eliminating the need for unnecessary relationships. The product revision entity, often forming the top level of the EBOM, is aligned with the SBOM revision entity, which is also at the top level of the SBOM. Similarly, the part revision entity in the source BOM aligns with itself in the SBOM context. The spare definition is a separate entity, contextually linked to both the documents and part revision entities. Documents are categorized into two distinct entities: the Cortona3D item entity, which enables document creation and storage using *RapidAuthor* tools, and the generic documents entity, which serves to store documents that cannot be created using *RapidAuthor's* toolset or storage of legacy documents which can't be translated to Cortona3D item entity during the migration process.

4.1.2 SBOM management

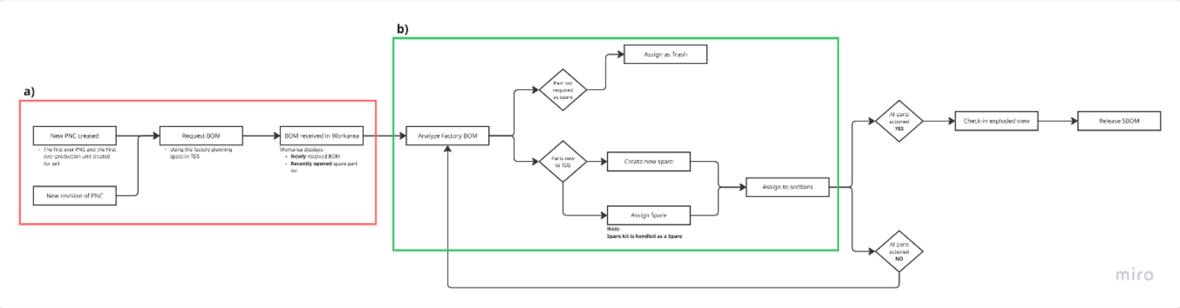

Figure 9: Current process of creation of spare parts list on TDS

a) Ability to create and manage spare part lists derived from a source BOM which is either requested or imported.

- **Current approach:**

In the current *TDS* system (refer to figure 9, enlarged version can be found in Appendix B), the activity of creating a spare parts list is initiated when a new product or a new revision of an existing product is manufactured for the first time. To begin this process, the developer must request MBOM from the production site, provided that upstream integrations are already established with that specific site. If such integrations are not yet in place, the developer can manually import the BOM material into *TDS Edit*.

As explained in Section 2.1.5 on *TDS* Integrations, the Manufacturing OTD Planning component generates a trigger within the *TDS* tools. This trigger enables the user to request the newly produced MBOM from the production site into the *TDS database (TDS DB)*, thereby making it available for the engineer to analyse and process.

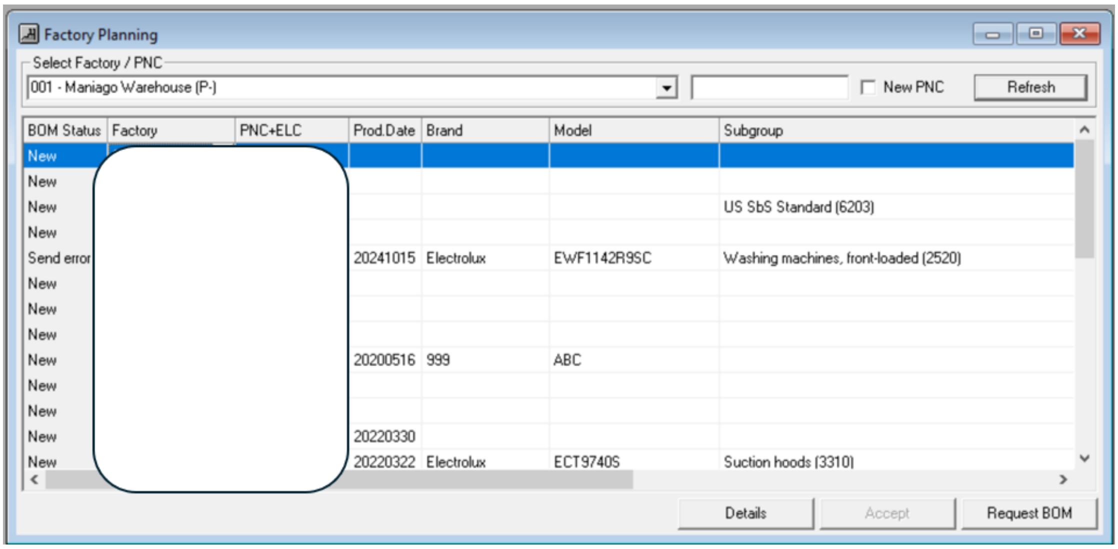

Figure 10: UI of Factory Planning [10]

Within the *factory planning interface* in *TDS*, the developer begins by selecting a factory, choosing a Product Number, or entering the required manufacturing data. Once the selection is made, the system generates a table, as shown in the image above, listing all Product Numbers created in the chosen factory. From this list, the developer selects the specific Product Numbers for which a spare parts list is to be created and then clicks the Request button. This action triggers the retrieval of the corresponding BOM.

- **Proposed Solution:**

For this thesis project, a *Teamcenter* OOTB test environment was set up using version 2412, without any Electrolux-specific templates installed. As a result, all available business objects were standard OOTB objects. A demonstration product, an oven was migrated into the environment to evaluate various *Teamcenter SLM* features and to apply data model customizations using *BMIDE*.

To enable the *SLM* module capabilities in the OOTB *Teamcenter* environment, the templates shown in the table below were deployed via *Teamcenter Deployment Center*. This deployment enabled the connected BOM philosophy - DBOM to EBOM to MBOM to SBOM - to be implemented.

Table 5: Teamcenter Templates Deployed

Template Name	Template File
MRO Core/Data Model	mrocore_template.xml
As-Built Management/Data Model	asbuilt_template.xml
As-Maintained Management/Data Model	asmaintained_template.xml
Service Planning/Data Model	serviceplanning_template.xml
MRO Core for Active Workspace/Data Model	smr1mrocorenaw_template.xml
Service Work Instructions for Active Workspace/Data Model	sw1slmserviceview_template.xml
As-Built and As-Maintained Alignment/Data Model	asbasmalignment_template.xml
Transaction Processing/Data Model	transactionprocessing_template.xml
As-Built for Active Workspace/Data Model	sab1asbuiltnaw_template.xml
As-Maintained for Active Workspace/Data Model	sam1asmaintainedaw_template.xml
Service Engineering, Active Workspace BOM Interface/Data Model	sen1serviceengineeringaw_template.xml
Service Planning for Active Workspace BOM Interface/Data Model	ssp1serviceplanningaw_template.xml
Service Processing/Data Model	serviceprocessing_template.xml
Transaction Processing for Active Workspace/Data Model	stp1transactionprocessingaw_template.xml
Service Event Management/Data Model	serviceeventmanagement_template.xml
Service Planning and Service Processing Alignment/Data Model	ssprsalignment_template.xml
Service Request Processing (Requires Change Management)/Data Model	servicerequest_template.xml
Service Scheduler/Data Model	servicescheduling_template.xml
Service Processing for Active Workspace/Data Model	spr1serviceprocessingaw_template.xml
Service Event for Active Workspace/Data Model	sem1serviceeventmgntaw_template.xml
Service Planning and Service Processing Alignment Active Workspace BOM Interface/Data Model	spi1sssprpalignmentaw_template.xml

However, in Electrolux's current processes, MBOMs are created in the ERP tool and are therefore not present in the production *Teamcenter* environments. Consequently, for the purpose of this thesis project, the EBOM was used as the source BOM for creating the product's SBOM. Within an on-going project in Electrolux, EBOMs would be available by next year in production environment. Hence, for the demo, use of EBOM was advised.

In the newer approach, SBOM creation begins with the creation of a work package. Before this step, it is essential to configure the correct session settings to ensure access to the necessary data and features available to the developer. *Teamcenter's* organizational settings establish data accountability and governance rules, ensuring that the right users have access to the appropriate and relevant data.

As shown in Figure 12, the session settings at bottom of the UI are configured as follows:

- **Group:** Engineering
- **Role:** Service Engineer

These settings ensure that the relevant tasks are displayed for the developer. These settings also

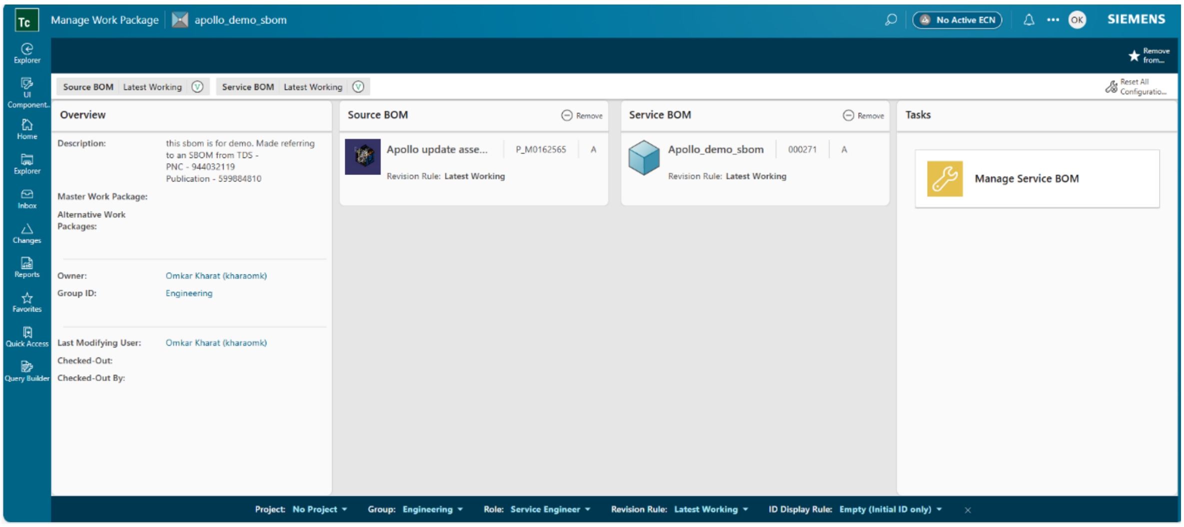

Figure 11: Creation of Work package

provide makes sure that the user has the access to the right set of data and rights to perform assigned activities.

A released EBOM was selected as the source BOM. When adding an SBOM, the developer is given the option to either create a new SBOM or reuse an existing one. During one of the interviews referenced in Section 3.3.1 with Siemens, it was conveyed that Siemens intends to provide companies with the flexibility to choose the source BOM in accordance with their business processes, rather than making it mandatory to use the MBOM when creating an SBOM. Selecting the *Manage Service BOM* option directs the developer to the alignment view, where the SBOM can be created from the chosen source BOM.

- **Next steps:**

In the current *TDS* process for creating a spare parts list, the developer initiates the process based on data received from the manufacturing site. Similarly, in the proposed solution, each time a new EBOM or a new revision of an existing EBOM is released for production, the developer should receive an automated notification. This customization would require implementing a subscription or event-trigger mechanism within *Teamcenter*, configured to monitor EBOM release status changes. Upon detection of a qualifying release event, the system would generate a task or message in the developer's workflow inbox, prompting them to initiate the creation of the corresponding SBOM and spare parts list.

Such a mechanism ensures that spare parts planning remains synchronized with the latest engineering changes, eliminates delays caused by manual follow-up, and aligns the spare parts management process more closely with the product lifecycle. Additionally, configuration of notification preferences, filtering based on product family, and linking the notification to the alignment view in *SLM* could further streamline the developer's workflow in the proposed solution.

b) Structuring spare part lists into reusable sections to allow content sharing across different parts that follow similar configurations or structures. Creation of spare parts with custom properties, assignment to source BOM items, Includes grouping into kits.

- **Current Approach:**

Once the requested BOM is available in the Workarea, the developer opens it in the *Edit BOM* window to perform a detailed analysis. Figure 12 illustrates how a typical MBOM appears in the *Edit BOM* interface, while Table 6 explains the meaning of the various markers displayed alongside the parts. For the BOM to be considered fully analyzed, each part must be explicitly flagged either as a *spare* or as *trash*. This classification ensures that every part has been reviewed and assigned an appropriate disposition within the spare parts management process.

Parts that are new to *TDS*, indicated by a green question mark, require special handling. These parts do not yet have a defined spare part status in the system and can be processed in several ways:

- **Assign Spare Part**: In this case, the system identifies the part number from the MBOM (also referred to as the *factory part*) and retrieves any existing spare parts linked to that same factory part. Along with the part number, the system also displays the associated descriptions, enabling the developer to reuse an existing spare part instead of creating a duplicate. This approach promotes data consistency and reduces redundant spare part records.
- **Assign Garbage**: This option sends the part to the *trash bin*, meaning it will not be considered a spare in the current context. Importantly, this action has no effect on how the same part is treated in other factories or product configurations. As a result, a part could be classified as a spare in one factory and as trash in another, making the designation occurrence-specific within the context of the current Service BOM. This flexibility is crucial for handling variations in product configurations across different manufacturing sites.
- **Create New Spare Part**: If no suitable existing spare part is found, the developer can create a completely new spare part record. This process allows the assignment of a unique position number, description, and section for the part, ensuring that it is accurately represented in the spare parts list.

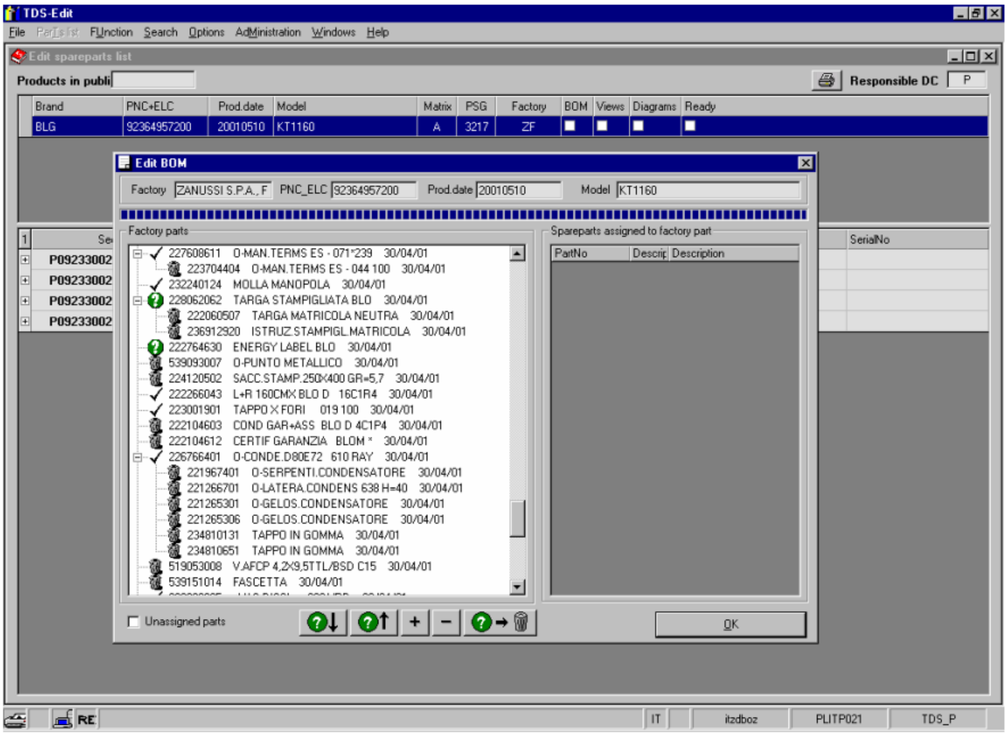

Figure 12: Appearance of imported MBOM in Edit BOM Interface on TDS Edit

Table 6: Meaning of the various markers displayed alongside the parts

	Parts are new to TDS. These are not present in TDS Database
	Already accepted as spares and are present in TDS database
	Assigned as trash. These are not required as spares but are present in the database

Creation of spare part: Sections are used to provide a logical structure to a product's spare parts list, allowing developers to group related parts together under specific categories, for example, *Door*, *Housing*, and other major assemblies. This grouping not only improves navigability for technical and aftersales teams but also aligns the spare parts list with the product's physical and functional breakdown.

The *TDS Edit* tool, being an in-house developed application, offered extensive flexibility for customization by the IT team in the past. Since it has been designed specifically to match the exact processes followed by the spares team, it accommodates their workflow requirements without the constraints often found in commercial off-the-shelf solutions. While creating a spare parts list in *TDS Edit*, a developer can either create a new section or search for and reuse an existing section, depending on the nature of the parts being added.

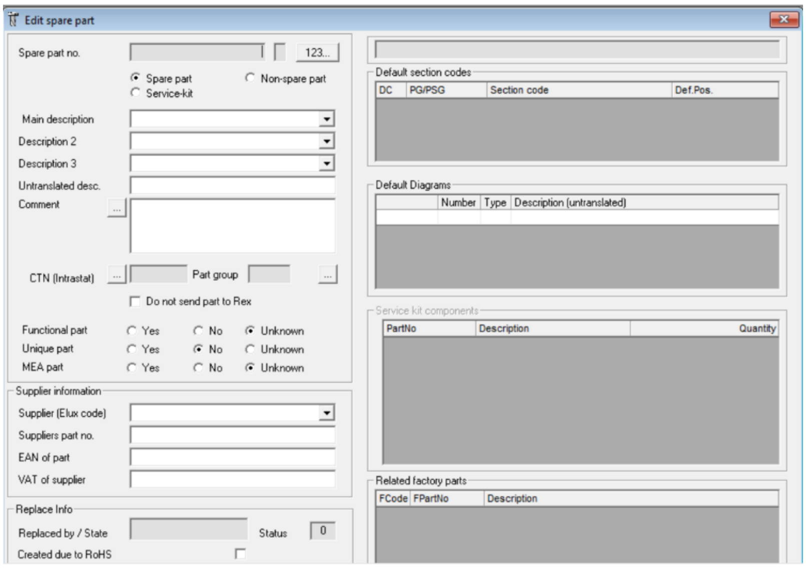

Figure 13: UI for creation of Spare Part

- **Creating a new section**: A new section is created when the number of spare parts, or the position of those parts on the exploded view (positions which serve as legends for locating parts in the diagram), differ from all existing sections within the same product group. This ensures that unique configurations or assemblies are represented accurately in the spare parts list.
- **Using an existing section**: When both the number of spares and their positions on the exploded view remain the same as those in a previously defined section, the developer can reuse that section instead of creating a new one. This promotes consistency across similar products and reduces redundant data creation.

In a spare parts list, all spares are assigned to a section, there are no spares that exist outside of a section. However, sections serve purely as a grouping mechanism; they cannot be ordered directly by a customer. Orders can only be placed for individual spare parts or pre-defined spare kits. This ensures that the sectioning logic remains an organizational tool, without affecting the ordering process.

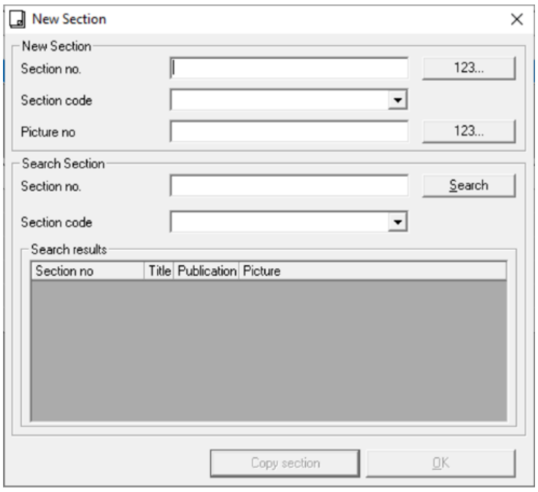

Figure 14: UI for creating a new section

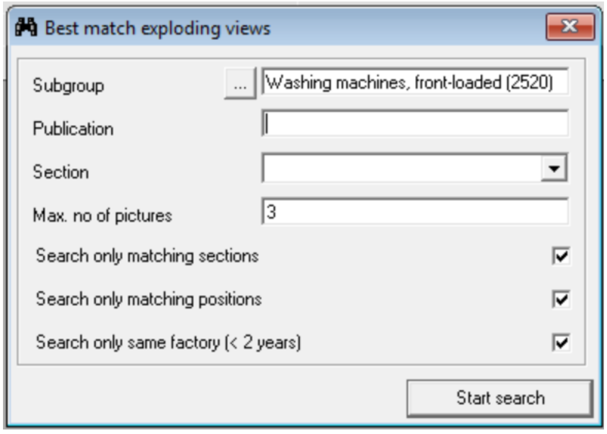

Figure 15: UI for attaching exploded views to the Section

Once a section is created and all relevant spares have been added, an exploded view is associated with that section. Every section has its own exploded view; for example, a *Door* section will have an exploded view of the door assembly. At this stage, the developer can either create a new exploded view and check it into the *TDS* database, or search for an existing exploded view already stored in the database.

When searching for an existing exploded view, the developer specifies the product sub-group, after which the system runs a search in the database and compares the results with the section currently in progress (WIP section). Once the search is complete, the system generates a list of matching sections and displays the corresponding spares. It also compares the spare part positions from the WIP section with those in the retrieved exploded view, enabling the developer to determine whether the existing view can be reused or if a new one needs to be created.

- **Proposed Solution:**

As described in earlier sections, the proposed solution utilizes EBOM as the source BOM for creating the SBOM, with the process initiated through the creation of work packages. In the context of *Teamcenter SLM*, aligning BOMs refers to establishing a direct relationship between equivalent business objects across different BOM structures. This alignment ensures that data such as part numbers, revisions, descriptions, and associated metadata remain linked and synchronized between the source and target BOMs. In the proposed solution, the alignment specifically involves associating a *Part Revision* business object from the EBOM with its corresponding *Part Revision* in the SBOM.

To replicate the current spare parts structuring methodology within *Teamcenter*, a custom business object *Section* was created using *BMIDE*. This object allows the SBOM to be organized in a similar way to the existing *TDS* process, where spare parts are grouped into logical sections such as *Door*, *Housing*, or *Electrical Components*. As shown in Figure 17, the BOM on the left represents the source BOM (EBOM), while the BOM on the right represents the SBOM.

In the current *TDS* process, the BOM is analyzed by flagging parts as either *spare* or *trash*. In the proposed *Teamcenter*-based solution, this activity is replaced by the alignment of parts from the EBOM to the SBOM. This alignment determines which parts will be included in the SBOM and, consequently, in the spare parts list. To simplify this process for the spares team, the engineering team can pre-flag parts as *spares* in the EBOM during its creation or update. As a result, only parts marked as spares in the EBOM are aligned into the SBOM. This approach reduces manual decision-making during SBOM creation, increases consistency across products, and ensures that spare parts planning is driven by engineering data at the earliest possible stage.

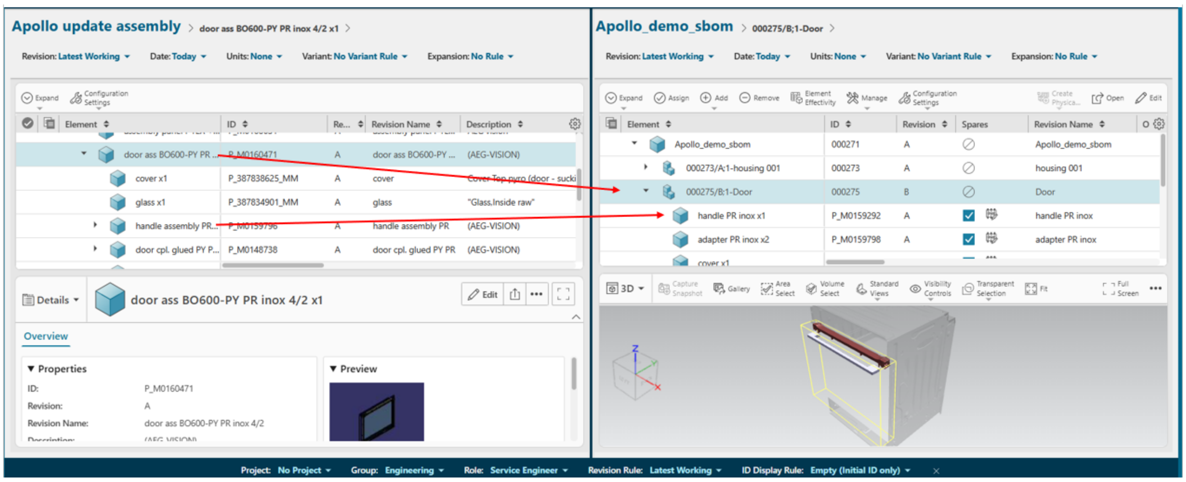

Figure 16: EBOM to SBOM Alignment view

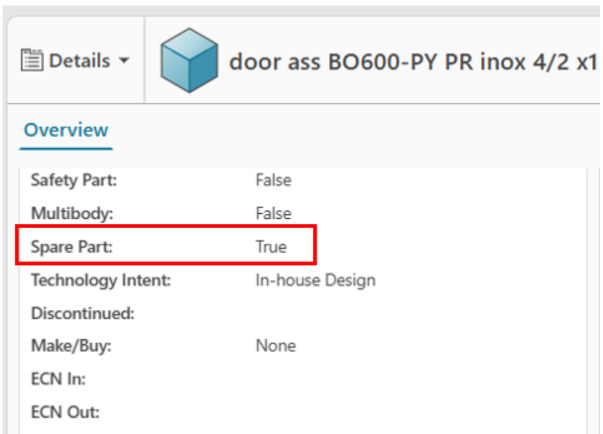

Figure 17: Property to flag as Spare Part

Once a part has been aligned from the EBOM to the SBOM, the next step is to define its spare-related attributes using the *Spare Definition* business object, which is available as part of the *Teamcenter SLM* module. The developer activates the spare definition feature to add the required spare properties. As illustrated in Figure 18, a spare definition has already been applied in the demonstration environment.

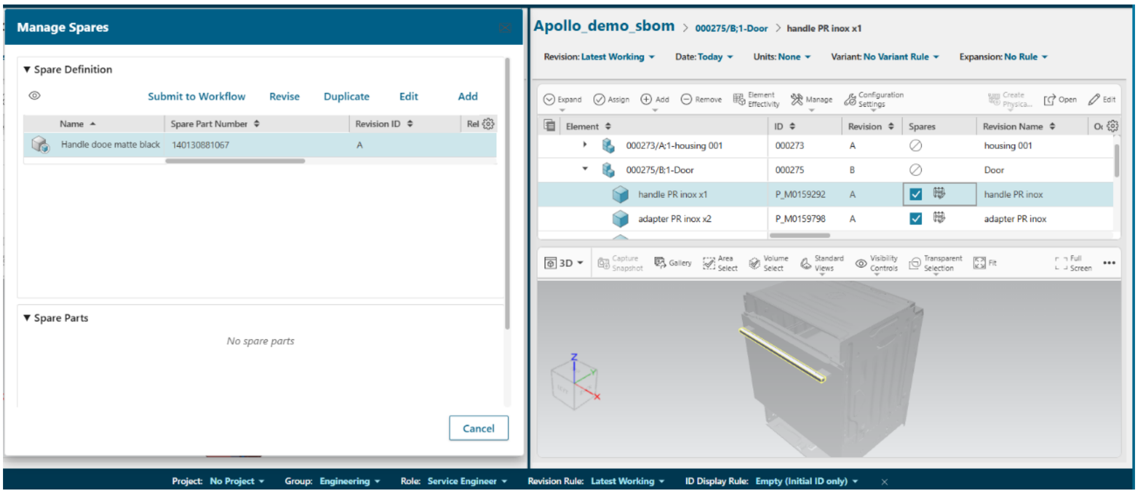

Figure 18: Selection of Spare Definition after the alignment

The *Spare Definition* object provides the ability to add multiple spare properties to a part, edit existing properties, and create revised versions of those properties as the product evolves. This revisioning capability enables version control, ensuring that spare definitions remain accurate and traceable over time. Furthermore, spare definitions can be associated with one or multiple workflows in *Teamcenter*, enabling formal approval, release, or change processes to be applied to spare-related data.

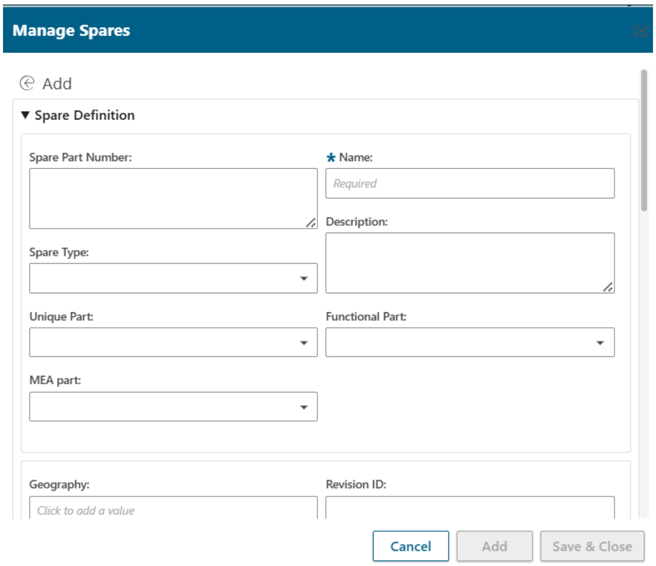

Figure 19: Detailed view of creation of Spare Definition

For the demonstration, several custom properties were added (as in figure 19) to the OOTB *Spare Definition* business object. Table 7 lists custom attributes, along with their descriptions and data types. These customizations were implemented to align the spare definition with Electrolux's specific business requirements.

Table 7: Custom attributes on Spare Definition Business Object

Sr no.	Property	Property display name	Data types
1	spare_part_no	Spare Part Number	String
2	spare_type	Type of spare part	List
3	description	Description	String
4	functional_part	Functional Part	List
5	unique_part	Unique Part	List
6	mea_part	MEA Part	List
7	supplier_elux code	Supplier (Elux. Code)	List
8	supplier_part_number	Supplier Part No.	String
9	ean_part	EAN of Part	String
10	vat_of_supplier	VAT of Suppier	String

What makes the concept of *Spare Definition* particularly valuable is its ability to maintain a consistent and structured flow of data throughout the BOM hierarchy. Parts move through the different BOMs (DBOM – EBOM - SBOM) via alignment, and the spare definition ensures that spare-specific attributes remain linked to the correct part revisions at each stage. This guarantees data integrity, reduces redundancy, and ensures that spare-related information is accessible and accurate regardless of where the part sits in the product lifecycle.

Additional benefits of using the *Spare Definition* business object include:

- o **Centralized spare data management**: All spare-related properties are stored and managed in one place, improving accessibility and maintainability.
- o **Improved change traceability**: Version control ensures that historical spare configurations can be reviewed, supporting warranty claims and service audits.
- o **Workflow integration**: The ability to link spare definitions to workflows ensures that spare data changes follow controlled approval and release processes.
- o **Data consistency across BOMs**: Spare properties remain consistent and up-to-date as parts progress through different BOM stages via alignment.

By embedding spare-related attributes directly within the *Teamcenter SLM* framework, the *Spare Definition* object ensures that service planning is tightly integrated with the engineering data model, creating a unified and reliable source of truth for spare parts management.

- **Next steps:**

While the proposed solution using *Teamcenter SLM* provides a structured and integrated approach to creating SBOMs and managing spare-related data, several customizations could significantly improve its efficiency and usability:

- o **Linking Spare-Related Documents to the Spare Definition** A useful enhancement would be the ability to attach documents directly to the *Spare Definition* business object. These could include service bulletins, fitting instructions or service manuals specific to a spare part. By linking these documents to the spare definition, the data package for a given spare part becomes more complete and accessible in a single location. Version control for these documents would ensure that only the latest approved versions are visible to end-users while maintaining a history of past versions. This would streamline both internal processes for the spares team and external servicing activities by technicians.

- **Automating BOM Alignment Based on Existing Properties** To reduce manual effort, the BOM alignment process could be automated by leveraging an existing property such as *Is Spare Part* (boolean: true/false). Parts with this property set to *true* in the EBOM could be aligned automatically to the SBOM without developer intervention. This automation would significantly speed up SBOM creation, especially for large and complex products, while reducing the risk of human error during manual alignment. The system could also generate an exception report for any parts that were not automatically aligned, allowing developers to review and handle special cases manually.
- **Enhancing the Alignment View with Spare Definition Properties** The alignment view could be enhanced to display key properties from the associated spare definitions, such as *Spare Part Number*, *Revision Status*, or *Lifecycle State*. Presenting this information directly within the alignment interface would allow developers to verify data accuracy without switching between multiple views or performing additional searches. This would improve the efficiency of the alignment process and help ensure that the correct spare parts are aligned to the SBOM, with accurate and up-to-date metadata.

By implementing these customizations, the proposed solution would not only replicate the functionality of the current *TDS* process but also introduce advanced capabilities that improve data accessibility, streamline workflows, and enhance accuracy in spare parts management.

c) Managing spare part lifecycles (e.g., replacements, EOL, alternates), handling phantom and invisible parts, tracking by market, supporting standardized, partially automated naming and numbering conventions.

- **Current Approach:**
  - **Managing Spare Part Lifecycles**: In the current *TDS* system, there is no capability to manage the lifecycle of spare parts. The system does not maintain version histories or status indicators to track the current state of a spare part throughout its life. As a result, there is no structured way to record when a spare part has been superseded by a replacement, when it reaches its end of life (EOL), or when alternate parts are available. These lifecycle attributes are critical for maintaining service continuity, avoiding obsolete stock in inventory, and guiding technicians towards valid and up-to-date replacements.
  - **Creating Phantom / Invisible Parts**: In certain scenarios, a spare part may need to exist in the database for logistics and stock management purposes but should not be directly available for ordering. Such parts are referred to as *phantom* or *invisible* parts.

For example, in the case of dishwasher basket wheels, the cost of individually packaging a single wheel is higher than the manufacturing cost of the wheel itself. To maintain economic efficiency, the spare is sold as part of a kit containing 10 wheels. Logistics must maintain stock of the single wheel, which requires it to have a valid spare part code. However, to prevent the sale of individual wheels to customers, the part must be made invisible in the customer-facing web portal.

  - **Standardized Part Numbering and Naming Rules**: The current *TDS* system already supports standardized part numbering and naming conventions, based upon business logics ensuring consistency in how spare parts are identified.

- **Proposed Solution:**
  - **Managing Spare Part Lifecycles:** In the proposed *Teamcenter SLM*-based solution, lifecycle management can be implemented using existing capabilities such as *Item*

Revision Status, *End Item Effectivity*, and *Alternate/Successor Relationships*. Spare parts can be assigned statuses like *In Production*, *Service Only*, *EOL*, or *Obsolete*, enabling clear communication of availability and serviceability. Replacement relationships can be established so that when a part is discontinued, the system automatically suggests its successor. This ensures traceability and improves planning accuracy for both service teams and procurement.

- **Creating Phantom / Invisible Parts**: In the proposed solution, phantom or invisible parts can be handled in *Teamcenter SLM* by using *Effectivity*, *Visibility*, and *Usage Constraints* properties. These properties would allow a part to be available for internal planning and stock control while restricting its ordering availability in integrated e-commerce or service ordering systems. Additionally, parts can be linked to kits or assemblies in the SBOM so that they are only offered as part of a predefined set of components.
- **Standardized Part Numbering and Naming Rules**: In the proposed solution, these conventions can be maintained and potentially extended within *Teamcenter* by implementing *Numbering Rules* and *Naming Templates*. *Teamcenter's* rule-based ID assignment can automate the creation of part numbers according to predefined business logic, while also preventing duplicate entries. Naming templates can enforce consistency in part descriptions, which is particularly important for multilingual environments and for ensuring clear communication with service teams and customers.

4.1.3 Technical Documentation Management

When *RapidAuthor for Teamcenter* is integrated with *Teamcenter*, it introduces specific business objects into the PLM environment to manage authored content in a structured and traceable way. One key object is *Cortona3D Item (aka Cortona3D Dita Topic)*.

Before any content authoring can take place, certain administrative objects must be created and configured within *Teamcenter*. These objects define how authoring tools interact with *Teamcenter* data and how outputs are managed after publishing.

- **Cortona3D Item Type Object:**

  Cortona3D Item Type is referenced by *Cortona3D Item object* (main object that serves as container for *RapidAuthor* project & publish data)

  The Item Type defines:

  - **Authoring tool selection:** Specifies which *RapidAuthor* application will be used (e.g., RapidManual for service manuals, *RapidCatalog* for illustrated parts catalogs etc.,).
  - **Import Profile:** A configuration file created in *RapidDeveloper* that controls item tree structure rules, measurement units, axis orientation, surface properties, representation handling, and metadata mapping.
  - **Specification reference:** Points to a specification component used within the chosen authoring tool.
  - **Optional Delivery Map reference:** Links to a *Cortona3D Delivery Map* object (required for non-DITA/S1000D workflows).
  - **Transfer Mode:** Defines how project data is exchanged between *Teamcenter* and *RapidAuthor*.

  - **Group restriction:** Limits Item Type availability to certain user groups in the *Teamcenter* UI.

- **Cortona3D Delivery Map Object:**

  The *Cortona3D Delivery Map* is referenced by *Cortona3D Item Type* object and defines how output from a *RapidAuthor* project is processed when saved back to *Teamcenter*. This includes special handling of files, metadata updates, and publishing automation.

  The Delivery Map specifies:

  - **Output rules:** Processing instructions such as extracting a PDF from a published archive, adding it to a PDF dataset in the Cortona3D Item Revision, or updating *Teamcenter* metadata based on project metadata.
  - **Customization for business processes:** Tailored delivery workflows to match organizational needs.

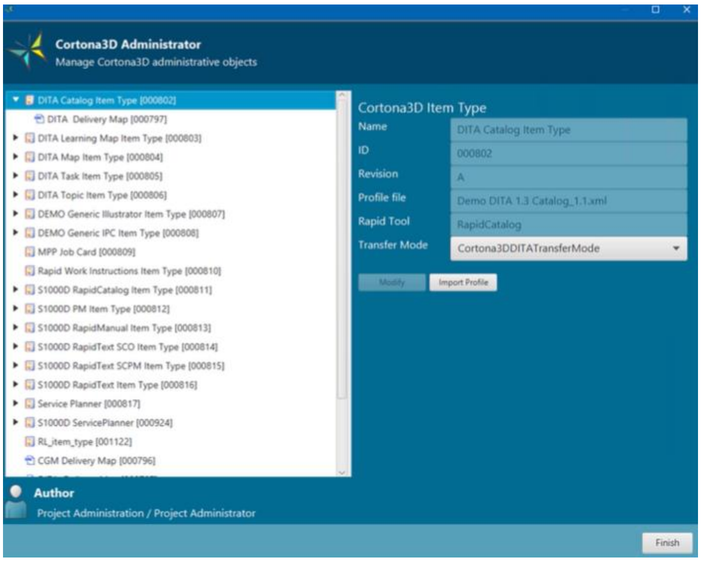

Figure 20: Snapshot of Cortona3D Administrator on AWC

The creation and maintenance of these administrative objects are handled through the Cortona3D Administrator application. This administrative interface allows configuration of the core objects that control how *RapidAuthor* projects interact with *Teamcenter*.

However, during the course of this thesis project, licenses for *RapidAuthor for Teamcenter* were not available; instead, licenses for the standalone mode of *RapidAuthor* were obtained. As a result, the findings do not explore the integration in depth but rather outline the proposed approach.

- **Cortona3D Item:** The OOTB business object does not provide attributes designed for the specific requirements of this thesis project and will therefore require customization to include these requirement-driven properties. To further align with the needs of SDT, each document or diagram should have specific properties that enhance classification and searchability, such as *Document Type*. These can be implemented through configuration in *BMIDE*, in the case of *Document Type*, it can be implemented as list-of-values (LOV) properties on the *Cortona3D Item* object.

- **Cortona3D Administrator:** Using the *Cortona3D Administrator*, it is recommended to create *Cortona3D Item Type* objects tailored to different documentation needs.

- **RapidConfiguration:** On the other hand, the OOTB *RapidAuthor* requires further customization to fully meet the detailed requirements. Specifically, *RapidConfiguration* must be employed to define and control the import behaviors when integrating with Electrolux's current template. This configuration dictates how data from the SBOM is imported into *RapidAuthor*, for example, which specific properties are extracted and displayed in the DPL table on *RapidCatalog*.

- **RapidSpecification:** Similarly, the solution also requires customization using *RapidSpecification* to tailor the output format and metadata to Electrolux's specific requirements. While the OOTB functionality supports standard document types and layouts, adjustments are necessary to configure the metadata fields, document structure, and formatting to align with the company's documentation standards. This includes customizing templates to incorporate specific properties from the SBOM and *Cortona 3D Item* objects, ensuring that generated publications, such as spare parts lists to reflect the required data accurately and are presented in a consistent, user-friendly format.

d) Structuring spare part lists into reusable sections to allow content sharing across different parts that follow similar configurations or structures. Creation of spare parts with custom properties, assignment to source BOM items, Includes grouping into kits.

- **Current Approach:**

  Currently, linking a diagram to a parts list is done in two steps:

  - **Step 1:** The diagram is checked in or out to the server using the *TDS edit* interface, where the appropriate diagram type and language are selected before uploading it to the server, as shown in the figure below.

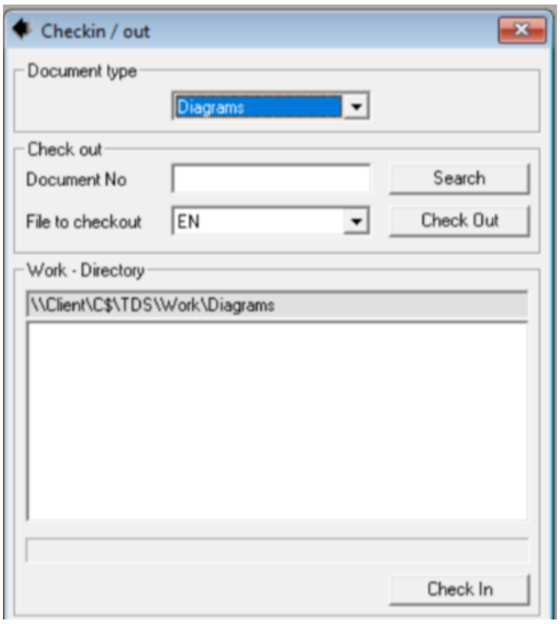

Figure 21: Checkin/out Diagrams to the Server

- **Step 2:** When creating or editing a parts list, the required diagram is available on the server, can be selected from the Diagrams section and linked to the parts list, as illustrated in the figure below.

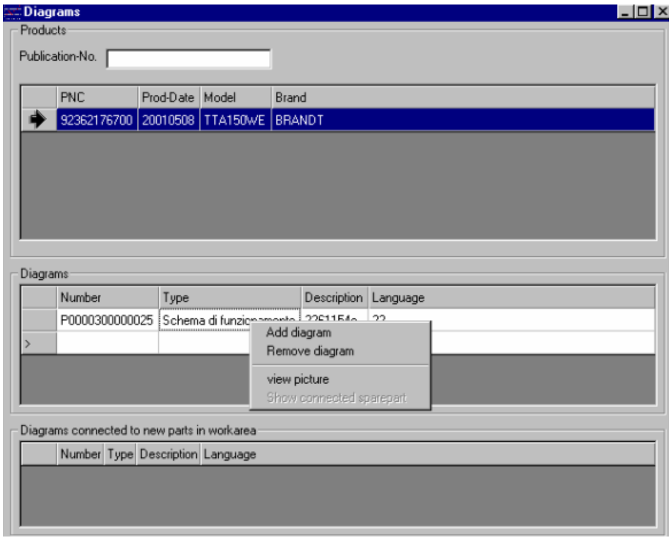

Figure 22: Attaching the Diagrams to the Part List

- **Proposed Solution:**

With an example creation of spare parts list with each section having exploded views, lets

- **Step 1:** Create a *Cortona3D DITA Topic* business object in *Teamcenter*

Instantiate a new *Cortona3D DITA Topic* and populate its attributes that define and categorize the document (e.g., Title, cortona3d item type = "Cortona3d-DITA-Catalog-ItemType", description etc.,). Upon customization of the Cortona3D Item object, further properties such as Document Type etc., can be made visible here. These attributes provide

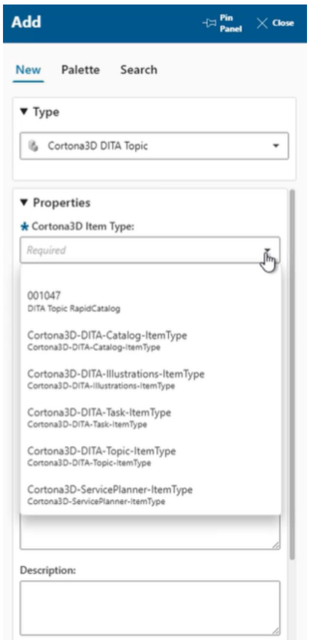

Figure 23: Creation of Cortona3D DITA Topic

the metadata needed for traceability, searchability, lifecycle control and downstream publication.

- **Step 2:** Open the sectioned SBOM

As described in the proposed solution for requirement (a), open the generated SBOM to which the Spare Part List should be linked.

- **Step 3:** Link the SBOM top-level into the Cortona3D DITA Topic

Copy the top-level SBOM node(s) and add them as child relationships under the new *Cortona3D DITA Topic instance* in *Teamcenter*. This creates an explicit, PLM-managed binding between the documentation object and the product structure it documents.

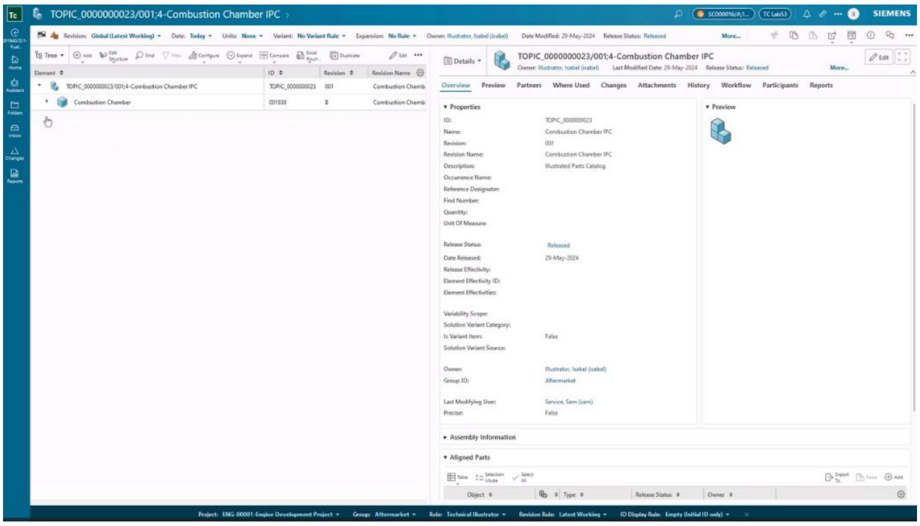

Figure 24: Link between SBOM top-level and the Cortona3D DITA Topic

- **Step 4:** Open the *Cortona3D DITA Topic* in *RapidAuthor*

Launch *RapidAuthor*. The SBOM children will be visible/imported into the *RapidCatalog* project context, ready for authoring.

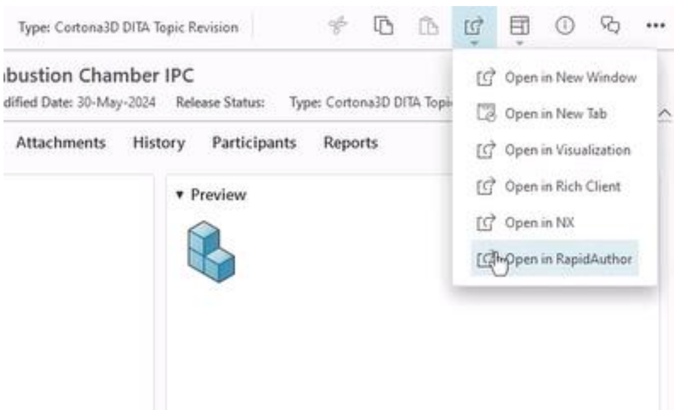

Figure 25: Launching RapidAuthor - 1

Figure 26: Launching RapidAuthor - 2

- **Step 5:** Authoring in *RapidCatalog* (beyond the scope of this thesis project and thus outlined only at a high level)
  - **Sorting the 3D data & tree cleanup:**

    Review the imported 3D geometry and SBOM tree. Remove redundant nodes, collapse irrelevant subassemblies, and filter out non-service items. Reorder and group nodes so the tree reflects logical service sections. Normalize names and ensure each catalog node maps to the intended part metadata. Confirm that each catalog node references the correct CAD dataset/version.

  - **Authoring: IPC Pages and SBOM → page mapping**

    An *IPC page* (Illustrated Parts Catalogue page) is a structured documentation unit within a parts catalogue that combines visual illustrations such as exploded views with detailed metadata for each part, including part number, description, quantity, relevant notes etc., As a part of the solution, it is proposed that *IPC pages* are created and mapped to corresponding SBOM sections, with one page typically representing a section of the SBOM depending on the required level of detail. Each *IPC page* can also have its children pages, which could even represent a different view of the same section if necessary. Verify that the Digital Parts List (DPL) table is updated accordingly.

  - **Add viewpoints and exploded views:**

    Set and store camera viewpoints for each *IPC page*, ensuring consistent visual perspectives. For every page, generate interactive exploded. Add callouts or annotations to these exploded views and link each callout to its corresponding part entry on the page, enabling bidirectional interaction, selecting a callout highlights the part in the list, and selecting a part highlights the corresponding callout. For more advanced exploded view editing, the integration with *Cortona2D Editor Pro* is recommended.

- **Publish the catalog content:**

  Choose the format for publishing output(s) such as interactive HTML5 catalog, 3D PDF, DITA XML export, etc.,

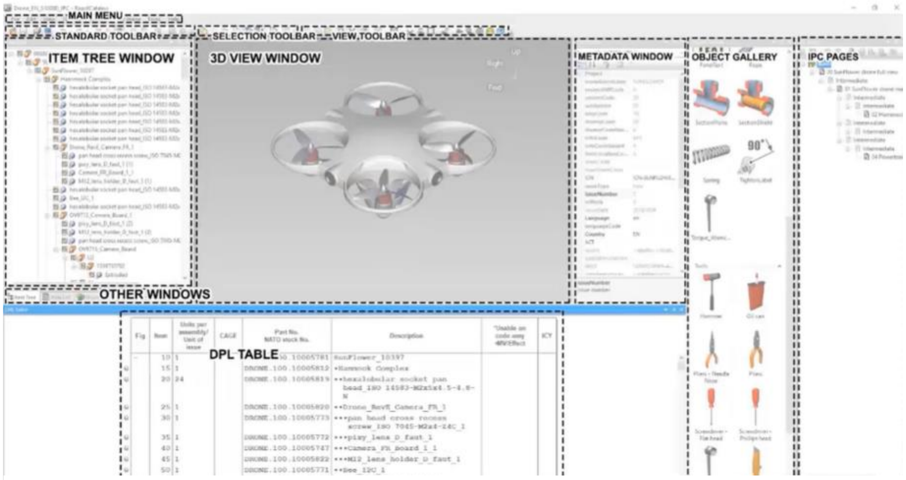

Figure 27: UI of RapidCatalog

○ **Preview and validate inside Teamcenter**

Use the preview tab on the instance *Cortona3D DITA Topic* in use on *Teamcenter* to inspect the published output. Validate: navigation, SBOM ↔ part links, exploded views, annotations, metadata etc., If issues are found, re-open the topic in *RapidCatalog*, make corrections, and re-publish. Record the revision and reason in the lifecycle/workflow.

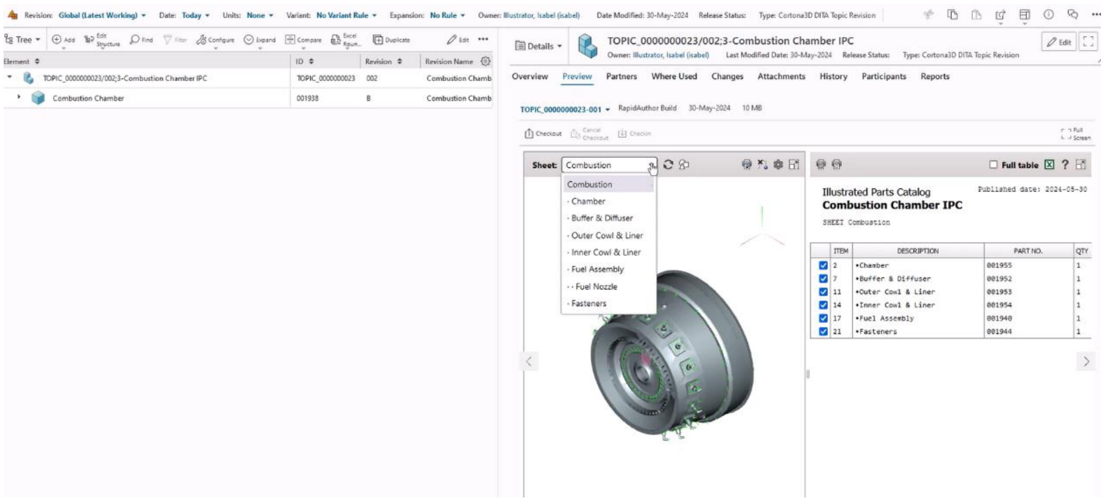

Figure 28: Preview of the output from RapidCatalog on Teamcenter

e) Ability to link various types of technical documents, such as service manuals, service bulletins, fitting instructions, to the part list, section, and individual spare part levels:

- **Current Approach:**

  Currently this process is accomplished in two steps,

- **Step 1:** A publication number is created by filling in the publication type, description, and other basic properties, as shown in the figure below.

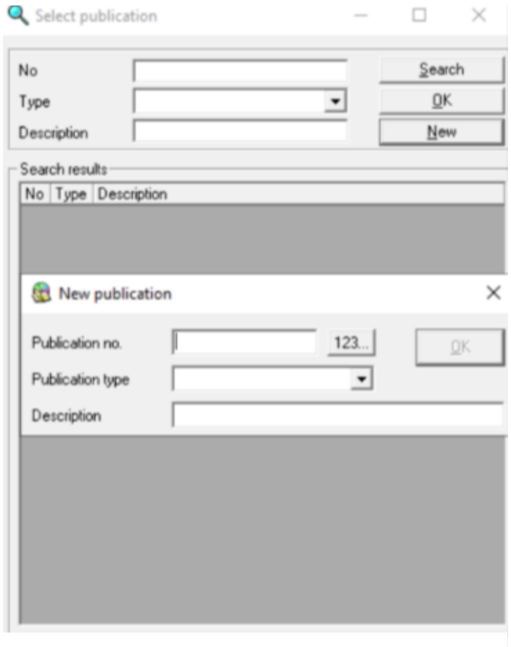

Figure 29: Creation of Publication Number

- **Step 2:** In another window, the publication is then selected, either the newly created one or an existing publication number, and keywords are assigned before linking it to the relevant products, product groups, or spare parts etc., as illustrated in the figure below.

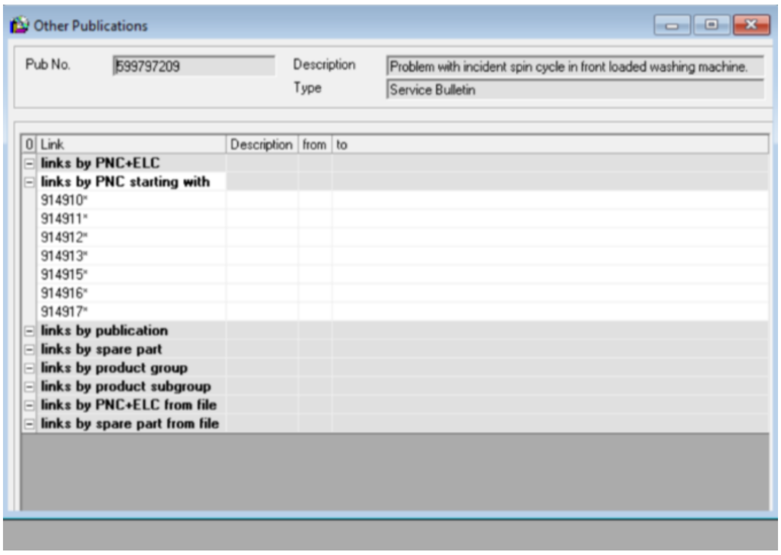

Figure 30: Linking the publication number to different levels of parts list

- **Proposed Solution:**

To fulfill the requirement of linking various types of technical documents such as service manuals, service bulletins, and fitting instructions, to the part list, section, and individual spare part levels, the proposed solution is essentially the same as that outlined for requirement (d), with the primary difference being the selection of the appropriate *Cortona3D Item Type* when creating the *Cortona3D DITA topic*. This method enables the creation of diverse document types through authoring in tools like *RapidManual*, *RapidIllustrator*, *RapidLearning*, and others. This approach is particularly recommended in scenarios where beginning with a blank document and retaining full flexibility over its structure, content, and layout offers a clear advantage.

An alternative approach is to leverage *Teamcenter SLM* through its *Service Planning* application, integrated with *RapidManual*, which serves as the foundation for this method of creating and linking the documents.

The *Service Planning* application enables the creation and management of structured service information for products throughout their lifecycle. As described with a help of figure 31 below, It provides a hierarchical framework made up of several objects for capturing, organizing, and linking service-related data, ensuring that the right information is available at the right level of detail.

- **Service Plan:** Associated with a neutral part, the service plan serves as the top-level container for all related service information. It organizes and manages the service containers that group maintenance requirements. Multiple service plans can be created for a single neutral part, allowing tailored service strategies for different contexts or configurations.
- **Service Container:** A hierarchical grouping mechanism for service requirements. A service plan may contain multiple service containers, and these can be nested to represent subassemblies or systems within systems.
- **Service Requirement:** Represents a specific maintenance requirement for an assembly or part. Service requirements are organized under service containers and define the scope of work needed for a particular component or system.
- **Work Card:** Details how to execute a service requirement. A work card contains the list of tasks, estimated effort, cost, and resources necessary to perform the maintenance. Multiple work cards can be defined for a single service requirement to capture different approaches or procedures.

- **Activity:** The most detailed level in the hierarchy, describing the specific steps a service technician must follow to complete the required service tasks. Activities ensure procedural clarity and can link directly to illustrations, instructions, or animations.

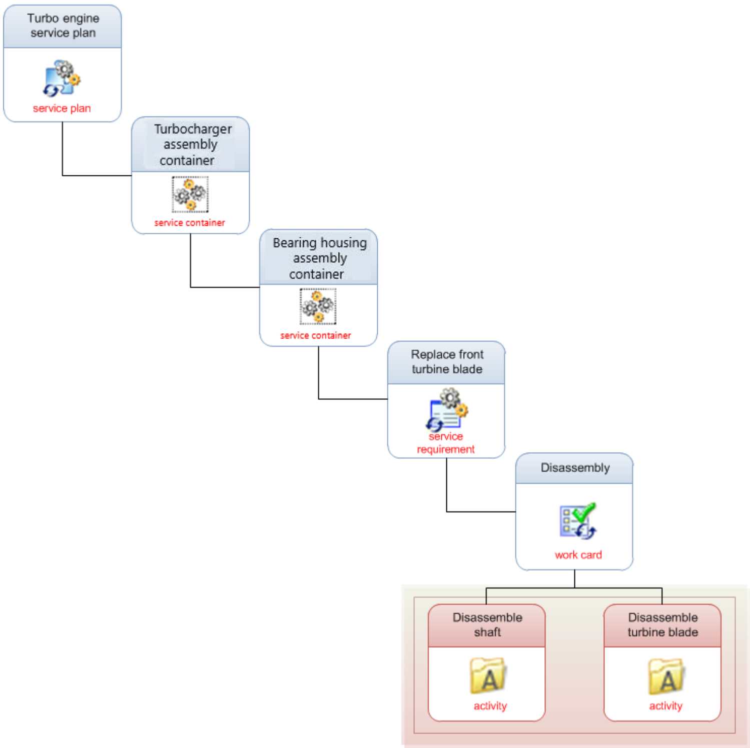

Figure 31: Structure of a Service Plan [19]

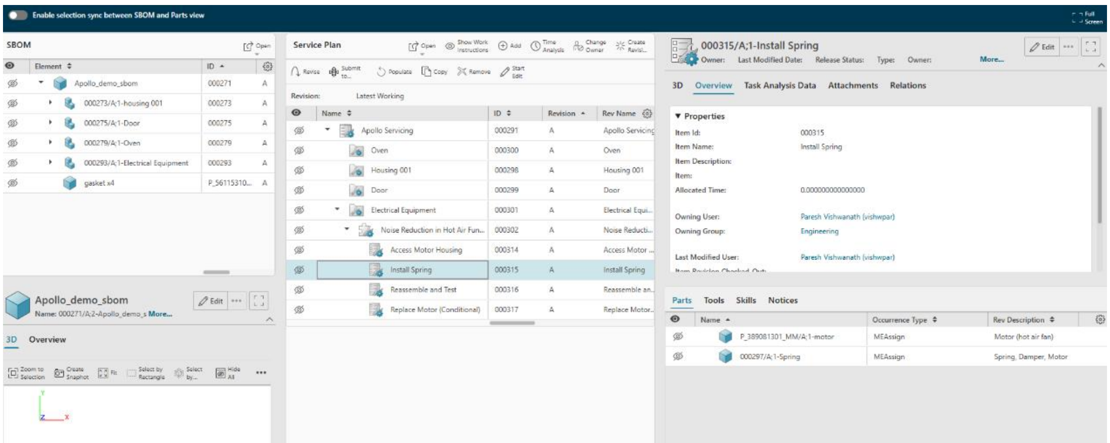

Figure 32: UI showing the objects organized in Service Planning Application on AWC

In the context of the proposed solution for this thesis project, each level of the hierarchy of the *service plan* can be mapped to corresponding levels of the generated SBOM. The top level of the SBOM can serve as the starting point for initiating the *service plan*, *service containers* can represent individual sections of the SBOM, and each *container* can hold the section-specific *service requirements*. This structure provides an organized and systematic approach to managing and presenting the information.

In addition, at each level of the hierarchy, it is possible to reference the exact part in the SBOM that the object pertains to. Relevant information such as the required tools, necessary skill levels, and any additional notices or cautions for the reader can also be specified, ensuring that the service context is complete and unambiguous, as shown in the figure 32. This is a recommended approach in cases where a document has to follow a predefined structure to ensure consistency and traceability.

The key advantage of this approach is that *service requirement* and *work card* objects can be directly transferred into *RapidManual* as shown in figures 25 & 26, where the details from the *service requirement* and its child objects are automatically converted into an interactive technical document. In most cases, however, some manual adjustments are still necessary to refine the final output.

Given that the specific details and capabilities of the *RapidManual* tool are outside the scope of this thesis project, they are not described here in depth. However, as briefly mentioned in the solution for requirement (d), the overall process remains broadly the same: cleaning up/altering the imported data tree, authoring: which in this case is comprising both procedure (animation) and document editing, where any added or modified animations are immediately reflected in the document and finally, publishing the completed content which is saved directly on *teamcenter* and can be visualized.

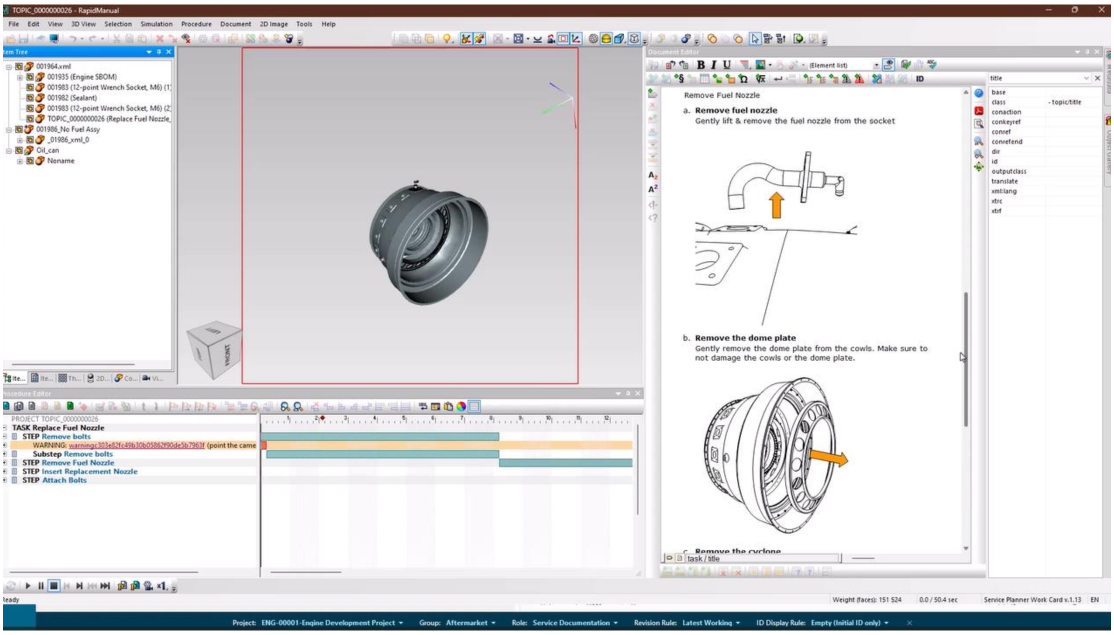

Figure 33: UI of RapidManual

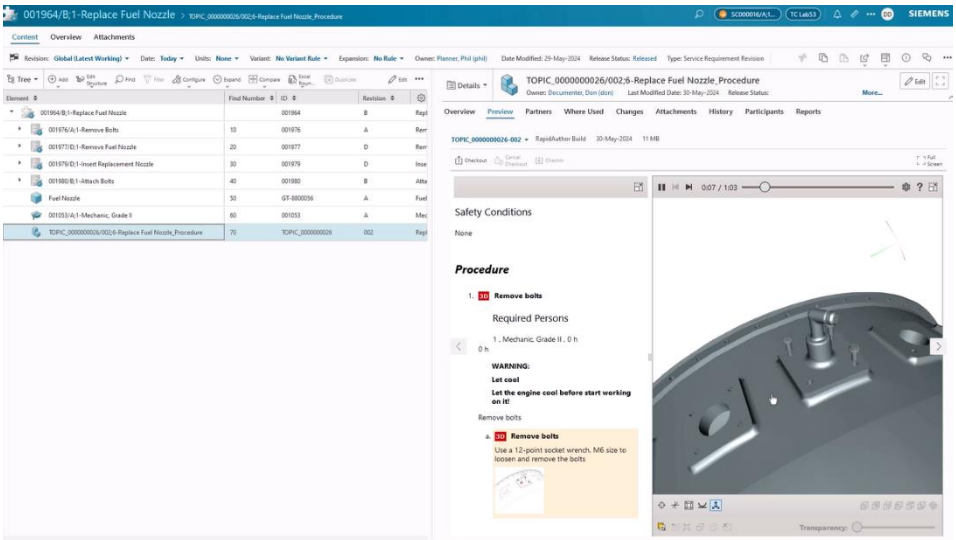

Figure 34: Preview of the output from RapidManual on Teamcenter

4.1.4 Change Management:

f) Capability to support status control, version control and post-release edits through a systematic change management process.

- **Current Approach:** Currently, there is no functionality to visualize the status of diagrams or documents (e.g., In Work, Under Review). Once finalized, they are released directly without intermediate status tracking. Additionally, *TDS* edit does not provide a systematic feature to revise part lists/spare parts/diagrams/documents while maintaining version control and preserving connections to previous versions.
- **Proposed Solution:** Each item in the proposed solutions, whether in the context of SBOM management (e.g., work package, SBOM itself as a part revision, or spare definition) or in the context of technical document management (e.g., Cortona3D DITA Topic object in *Teamcenter*), leverages *Teamcenter's* inherent capabilities to maintain:
    - Metadata and version control so that every iteration of the item is traceable, with the ability to preserve relationships between old and new revisions.
    - Workflow compatibility, enabling routing of the topic through systematic release/update processes within *Teamcenter* just like any other managed engineering item.

Discussions with the solution vendor, Siemens, indicated that in upcoming releases of *SLM*, a new *Service Change* change object will be introduced. This object will be designed to manage modifications within the service domain and will be routed through a dedicated service change workflow. Both the change object and its associated workflow will be configurable through *BMIDE*, allowing customization to align with the specific processes and requirements of the SDT.

Similar to other change objects in *Teamcenter*, the proposed *service change* object would encompass the following capabilities as described and illustrated in the figure 35 below:

- **Change summary:** Provides a detailed record of modifications (e.g., additions, removals, replacements, revisions), identifying the affected part or document revisions along with a concise description of the specific actions taken.

- **Impact and associations:** Establishes links to all impacted items, documents, BOMs, and requirements, enabling thorough impact analysis.
- **Workflow and approvals:** Supports configurable routing for review and approval, with role-based assignments, parallel or sequential flows, and defined mandatory tasks.
- **Traceability and audit:** Maintains a complete history of actions, decisions, comments, attachments, and status changes to ensure compliance and enable rollback when necessary.

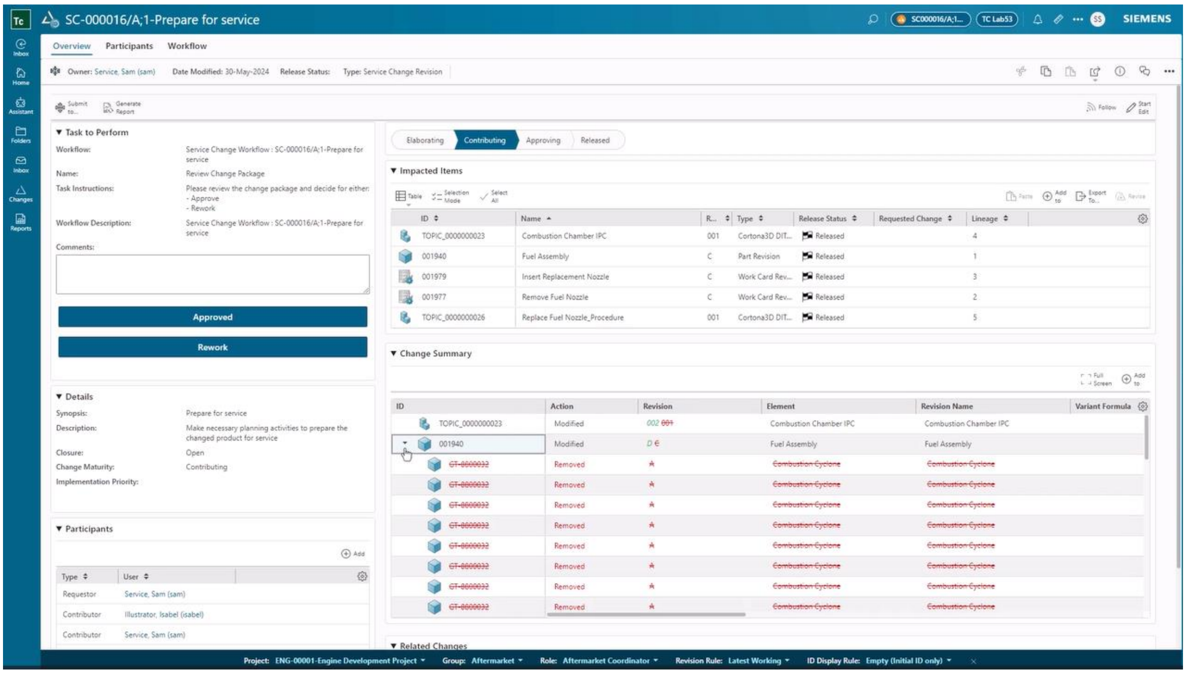

Figure 35: An Open Service Change in Contributing Stage of a Service Change Workflow

Developing dedicated workflows tailored to specific change requirements for different object types for example, replacing a part in an SBOM (where "replace" is the change requirement and the part within the SBOM is the object) would enhance this solution's flexibility and ensure its long-term effectiveness.

In addition, the service change object could be configured to both trigger and be triggered by other change objects, thereby preserving a continuous chain of change management activities. For instance, an approved problem report (as described in requirement (k) later in this report) submitted by a customer could automatically initiate a service change process when necessary.

4.2 Customer Viewpoint

This part of the results outlines the proposed solution for customers, primarily the field technicians who access and view data through *TDS Web*, based on the content created and managed by developers in *TDS Edit*.

For external, non-domain customers who must view or download data which is primarily managed on *Teamcenter*, multisite deployment is recommended as the foundational approach. A multisite setup enables controlled replication of necessary datasets to an external-facing instance, ensuring data segregation while maintaining synchronization with the internal PLM environment. This can form the technical backbone for providing limited, role-based access to selected information.

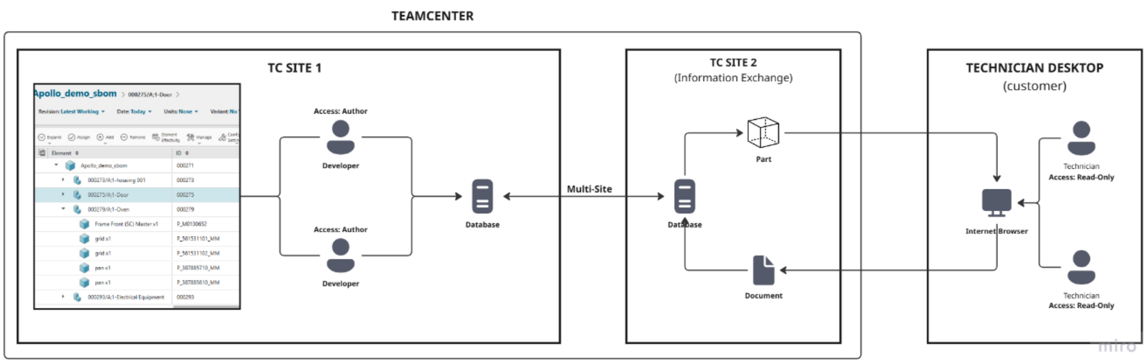

Figure 36: The concept of Multi-site on Teamcenter

This setup forms the technical backbone for providing limited, role-based access to specific information. As illustrated above, TC Site 1 hosts the developers from the SDT, who author SBOMs, spare definitions, documents, and related content. Selected data is then packaged into a data collection and pushed to another site, allowing only a designated group of users to access it, optionally within a limited time frame. Customers can access the published data on Site 2 directly from their internet browsers, without requiring a domain login, and are granted read-only permissions. However, the multisite functionality also enables customers to participate in workflows initiated by developers (and vice versa), allowing for secure, bi-directional communication.

In the context of this thesis project, *Teamcenter Supplier Connect* offers the most suitable out-of-the-box portal capability for the purpose described above. While originally designed as a broad supplier collaboration platform, supporting functions such as Request for Quotations (RFQs), document exchange, change management, and more. However, it can be repurposed to address the narrower needs of external customers in this case. Most importantly, the platform's existing integration within Electrolux's PLM ecosystem makes it an attractive candidate for transformation into a controlled, customer-facing portal for technicians. With minimal configuration, it can securely provide role-based access, enabling technicians to view relevant data, download necessary files, and submit or track problem reports, thereby fulfilling requirements (g) - (l).

g) The system must support user profile management and tiered access levels for different user groups:

Teamcenter Supplier Connect includes built-in user profile management capabilities, allowing administrators to create accounts for external and internal users, manage profile settings, reset credentials, and update personal information. Users can adjust their own preferences such as language, notification settings, and contact details directly within the portal.

Teamcenter Supplier Connect leverages the native *Role-Based Access Control (RBAC)* framework of *Teamcenter*, which manages access through Groups, Roles, and Privileges. This built-in capability ensures that access permissions are centrally controlled within the existing PLM environment, while still being applied seamlessly to the Supplier Connect portal. This enables administrators to:

- Create and maintain user accounts for both internal and external participants.
- Assign users to groups representing their organization or partner company.
- Apply specific roles that define the exact privileges and visibility each user has within the portal.

This structure supports SDT's proposed tiered access model for customers:

- Internal Electrolux Employees (Internal Limited): Restricted access to core functions and relevant documentation.
- Internal Electrolux Specialists (Internal Unlimited): Full internal access to all content and tools.
- External Basic Access: Spare part lists, part replacements, and cross-reference information.
- External Premium: All basic access content plus service manuals and selected service bulletins/videos.
- External Trusted Partner: All premium content plus remaining service bulletins/videos.

h) Customers should receive automated notifications when new spare part lists, service bulletins, or manuals are created or updated. These alerts must be filterable by brand, country, and product group

Teamcenter's workflow engine and *event subscription* capabilities enable automated notifications upon creation or revision of relevant items. By tagging business objects that contain spare part lists, manuals, and bulletins etc., with classification attributes like brand, country, and product group, notifications can be precisely filtered and targeted. This ensures that customers and other users of *Supplier Connect* receive only those alerts

i) A robust search panel should allow filtering by product number, model name, spare part number, part number, document type, and document number. The interface must support multiple languages and scripts.

Supplier Connect supports a user-friendly search panel built on *Teamcenter's* powerful, configurable search framework, including Active Workspace search. The search interface can be tailored to expose specific facets/properties such as product number, model name, spare or part number, document type, and document number. Furthermore, *Teamcenter* supports multi-language attribute values and UTF-8 encoding for scripts across multiple languages, enabling technicians worldwide to efficiently find relevant data.

j) Spare part lists should be structured and revisioned, divided into clear sections. Each part must be linked to images and display quantity per use along with the display of exploded views.

Siemens *Teamcenter's* integration with Cortona3D's *RapidAuthor for Teamcenter* Suite enables seamless visualization of published documents directly within *Teamcenter*, specifically under the *Cortona3D DITA Topic Revision business object*. Among these document types is the spare parts list, which, when integrated with *RapidCatalog*, generates an interactive and clearly sectioned spare parts list complete with detailed exploded views. Each part entry in the list includes essential metadata such as quantity per use, enhancing clarity and usability for technicians.

Furthermore, each entry in the SBOM corresponds to either a Part Revision business object or a Section business object within *Teamcenter*. These objects can have related documents, such as technical drawings, images, or 3D models, attached directly to them, ensuring comprehensive access to all relevant information for each component.

All of this detailed and interactive information is made accessible to customers and technicians through the *Supplier Connect* portal, with visibility strictly controlled according to each user's access rights and permissions.

k) Customers must be able to report issues and provide feedback through integrated forms.

Supplier Connect inherently provides a *Response Management* capability designed primarily to facilitate structured communication between suppliers and the host company. This module enables users to respond to requests such as RFQs, document change notifications, and quality feedback.

In the context of this thesis project, for the purpose of enabling customers (especially external, non-domain users) to submit problem reports and provide feedback, Supplier Connect offers a flexible framework but does not natively include a dedicated "problem report" submission form out-of-the-box.

To fulfill this requirement, the following approach could be typically implemented:

- **Custom Forms Configuration:** *Supplier Connect* allows configuration or embedding of custom forms tailored to customer needs. These forms can capture problem details, feedback, and other relevant data.
- **Workflow Integration:** Upon form submission, a *Teamcenter* workflow can be triggered to either:
  - Automatically create an instance of formal Problem Report (PR) business object (customized to the needs of SDT) linked to the submission, using a service or proxy user account.
  - Route the submission to an internal reviewer or quality team who verifies and promotes the submission into an official PR.
- **Status Tracking**: The created Problem Reports can be linked back to the original submission within *Supplier Connect*, allowing technicians to view and track the status (e.g., Pending, In Review, Fixed, Closed) directly in their portal workspace.
- **License and Security Efficiency:** This model avoids the need to assign expensive Contributor licenses to all customers while still enabling them to create and monitor problem reports with read/write interactions limited strictly to this function.

In summary, while *Supplier Connect* does not provide a dedicated problem report form out-of-the-box for partners, it supports extensible form integration and workflow automation to achieve this functionality securely and efficiently within the existing PLM ecosystem. Upon successful execution, the problem report will be created as shown in the figure below.

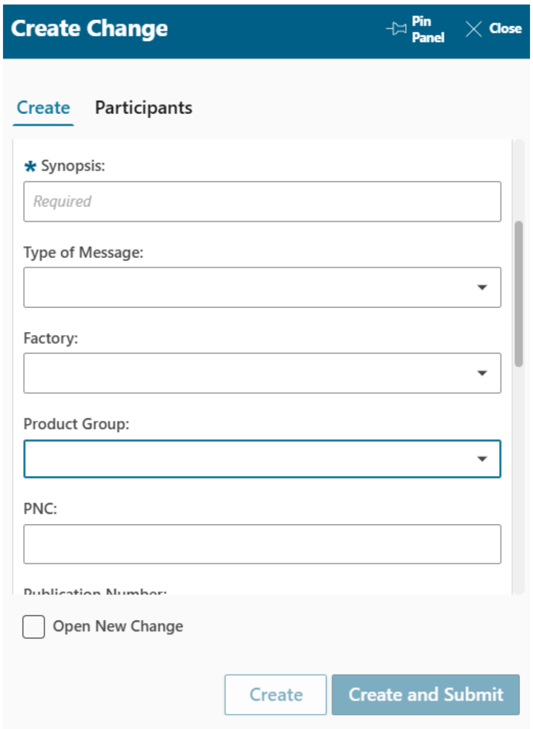

Figure 37: Dialogue box for creating the Problem Report

l) A statistics panel should offer tailored data extracts for specific customers, helping them analyze usage and trends.

To provide customers with actionable insights and usage analytics, *Teamcenter Reporting & Analytics (TcRA)* can be utilized to create customized dashboards and scheduled data extracts. These dashboards may include key performance indicators such as problem report (PR) counts, download activity etc.,

TcRA enables data security at the individual user or supplier level, ensuring that each technician or external user only accesses data they are authorized to see. Reports and dashboards can be embedded directly within the *Supplier Connect* portal or shared via scheduled email reports in common formats like CSV or Excel.

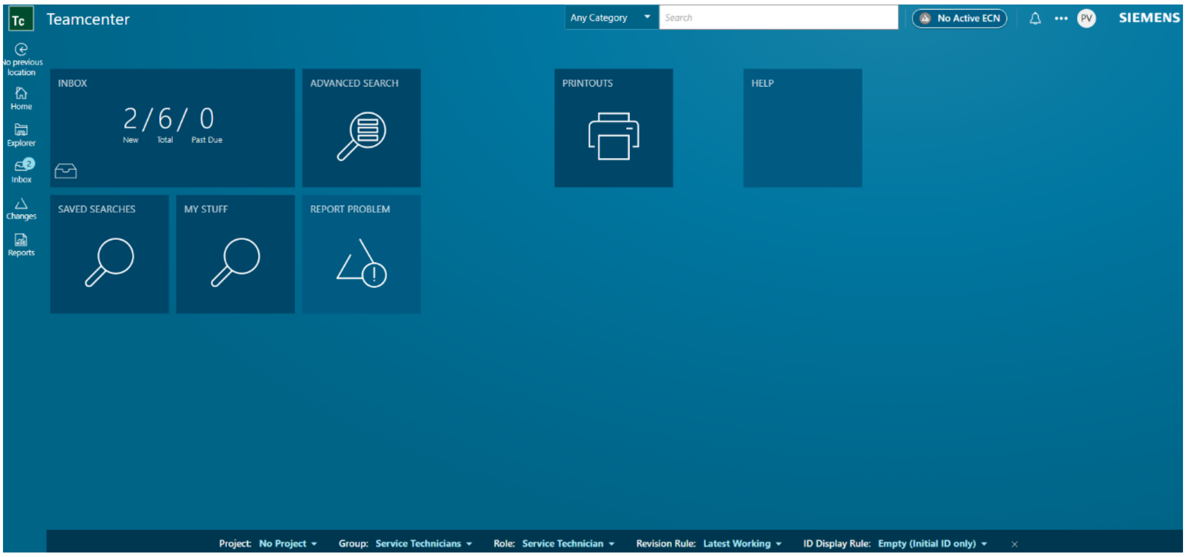

Figure 38: UI for Customer Viewpoint

Bringing all the requirements together, the customer user interface would provide features such as search, problem reporting, detail downloads, user profile management, and an inbox displaying statistics specific to the logged-in user as shown in the figure 38.

4.3 Integrations

4.3.1 Current State Data Transfer between TDS and REX

The integration between *TDS* and *REX* (refer to 2.2.5) is achieved through a batch-based file transfer mechanism. A dedicated executable program acts as the integration layer between the two systems. This program is responsible for extracting relevant spare parts data from *TDS* and preparing it in a format that can be consumed by *REX* and other downstream systems.

The integration process is initiated either on a scheduled basis or through predefined triggers. Once triggered, the integration program processes changes in spare part data, such as the creation of new spare parts or modifications to existing ones. Only relevant changes are selected for transfer to ensure efficient data handling.

After processing, the integration program generates outbound flatfiles that contain the structured spare parts information. These flatfiles follow a predefined format and schema that is understood by *REX*. The generated files are then placed into designated monitored directories, which serve as exchange points between systems.

REX continuously monitors these directories and automatically picks up the outbound files once they become available. The data is then processed further for spare parts operations, such as pricing, logistics, or service-related activities. To ensure traceability and operational transparency, log files are created for every execution of the integration program. These logs capture information about processed records, transferred data, and any errors encountered during execution. Additionally, transferred files are archived for audit and reference purposes.

Overall, the integration between *TDS* and *REX* relies on a stable, batch-oriented, file-based mechanism that has been designed to support controlled and traceable data exchange [21]

4.3.2 Future state data transfer between Teamcenter and REX

When *TDS* is replaced by *Teamcenter* as the authoring system for spare parts data, the fundamental integration requirements with *REX* remain unchanged. *REX* continues to expect spare parts information in a specific outbound file format and through the same monitored file-based interfaces.

In this future state, *Teamcenter* assumes full responsibility for the creation, management, and lifecycle control of spare parts data. Spare parts, their structures, and related attributes are authored and governed within *Teamcenter* using its product lifecycle management capabilities.

To facilitate integration with *REX*, *Teamcenter* can provide an export mechanism that replaces the functionality previously handled by the *TDS* integration program. This export mechanism can be implemented as a background service, dispatcher job, or scheduled task within the *Teamcenter* environment. Its role is to detect relevant changes in spare parts data and prepare outbound data packages accordingly.

Change detection can be driven by *Teamcenter* workflows, lifecycle transitions, or business rules. For example, spare parts data may only be exported once it reaches a defined release or approval state. This ensures that only validated and authorized data is transferred to downstream systems.

The export mechanism maps *Teamcenter* data attributes to the existing outbound flatfile structure required by *REX*. By preserving the same file format and directory structure, the downstream integration remains unaffected. The generated flatfiles are placed into the same monitored directories used previously, allowing *REX* to consume the data without any modification.

Similar to the current state, logging and traceability remain essential. Execution logs can be generated for each export run, capturing details about processed objects, generated files, and potential errors. These logs provide transparency and support troubleshooting and audit requirements.

By adopting this approach, *Teamcenter* effectively becomes a drop-in replacement for *TDS* from an integration perspective. While the internal authoring and governance of spare parts data is modernized, the external interface towards *REX* remains stable. This minimizes integration risk and enables a phased transition from the legacy system to a modern PLM-based architecture.

4.4 Migration

The migration of data from a legacy system to a modern Product Lifecycle Management (PLM) platform is a critical activity in PLM implementation projects. While it may appear to be a purely technical task, migration is fundamentally a structured transformation process that ensures business continuity while enabling the capabilities of the new system. Improperly executed migration is one of the most common sources of failure in PLM projects, highlighting the need for careful planning, thorough understanding, and methodical execution.

Legacy systems, such as the Technical Document System (*TDS*), are typically based on structured databases and have been in use for several years. Due to database-level validations, mandatory fields, and controlled data entry, legacy data quality is often sufficient. However, the complexity arises not from the data itself but from understanding its structure, relationships, and how it should be adapted to the target PLM system. Many stakeholders underestimate the challenges of migration, assuming that “moving data” is straightforward; in reality, success depends on detailed knowledge of both the source system and the target PLM environment.

A structured migration approach begins with a comprehensive analysis of the legacy data, including key objects, their attributes, and interdependencies. Conceptual mapping between the legacy system and the target system (*Teamcenter* in this case) provides the foundation for estimating effort, identifying potential gaps, and designing transformation rules. It is critical to fully understand the target system's data model and governance rules prior to migration, as post-migration changes to the PLM structure can introduce significant risks and inefficiencies.

Migration projects in industrial environments typically deal with large volumes of data. To mitigate performance issues, tool instability, and operational risk, migration is performed in controlled batches, which may be broken down by volume, category of data, or functional relevance. This staged approach allows incremental validation, reduces risk, and improves traceability. In addition, traceability and logging during migration are essential for monitoring errors, identifying root causes, and ensuring timely corrective actions.

From a procedural perspective, the migration process is more important than the specific tool used. While some companies rely on commercially available or custom-built migration tools, adherence to a structured methodology is critical. A recommended sequence includes:

- Trial runs with test imports to refine the migration process and define the optimal sequence for full-scale migration.
- Following the ETL (Export, Transform, Load) philosophy, with explicit attention to transformations, as 100% direct mapping is rarely feasible.
- Migrating items first, followed by relationships, to maintain structural integrity.
- Implementing reporting mechanisms to assess the success of exports and track issues.
- Taking a staged, incremental approach, as small issues can propagate and amplify if not detected early.

Modern PLM systems like *Teamcenter* enforce data integrity through system-controlled interfaces, lifecycle rules, and workflows. Therefore, migration activities must align with these principles, rather than bypassing them, to ensure that data behaves correctly post-migration. From a *SLM* perspective, accurate migration is particularly important for service-related data such as spare parts, product structures, and associated metadata. Errors introduced during migration can propagate into maintenance, service planning, and aftermarket operations, reducing operational efficiency and traceability.

In summary, data migration is a structured, multi-stage process that bridges legacy systems and modern PLM platforms. Success requires a deep understanding of both the source and target systems, a carefully planned execution strategy, staged execution, and robust traceability mechanisms. By treating migration as a controlled transformation process rather than a simple data transfer, organizations can ensure continuity, maintain data quality, and fully leverage the capabilities of modern PLM and *SLM* systems.

5 Discussion

This solution aimed to design and implement a *Teamcenter*-based framework for managing spare parts, replacing the outdated *TDS* system in response to a request from internal stakeholders, SDT, thus meets the requirements listed above. However, the objective was not only to address the requirements from both the developer's and customer's viewpoints but also to integrate industry best practices and the latest trends in spare part management. Throughout the design, considerations were made for future transitions, including data migration and implementation feasibility. Thus the framework for evaluating the feasibility of implementing the solution is outlined below at a high level.

5.1 Framework for analyzing Impact on Operational Efficiency and Costs

To assess the value and viability of the *Teamcenter*-based solution, a structured evaluation framework combining both quantitative and qualitative factors is proposed. The framework is grounded in best practices from PLM implementation literature, IT investment evaluation methodologies, and enterprise system assessment tools.

5.1.1 Alignment of Objectives

This section focuses on evaluating if the proposed solution is not only technologically sound but also strategically aligned with the broader organizational goals and it also assesses whether the solution addresses cross-departmental needs and effectively resolves pain point.

Table 8: Questions evaluating solution's alignment of objectives

Factor	Guiding Questions	Type
Strategic Fit	Does the solution align with business goals and digital transformation strategy?	Qualitative
Scope Coverage	Does it solve the intended problems and meet the requirements fully?	Qualitative

5.1.2 Quantitative Evaluation

- **Cost Analysis:**

Here, the financial feasibility of the solution is evaluated through a breakdown of implementation and operational expenses.

Table 9: Questions evaluating solution's financial feasibility

Factor	Metrics/Considerations	Type
Implementation Cost	Development cost, Training Cost	Quantitative
Operating Cost	Yearly licenses, admin cost, update/upgrade costs	Quantitative
Opportunity Cost	Cost of not implementing or continuing with legacy systems	Quantitative

The operating cost is further shaped by the selection of license types, which in this case would include:

- *Teamcenter* Author for *SLM*,
- *Teamcenter* Consumer for *SupplierConnect*,
- *RapidAuthor* and
- *RapidDeveloper*,

with quantities determined by the required number of developers and consumers. This stage is particularly critical, as it presents an opportunity to negotiate with Siemens and Cortona3D to secure the most favorable licensing terms and pricing.

- **Return on Investment (ROI):**

This sub-section measures the tangible benefits of the solution in terms of time and cost savings by capturing efficiency gains across key ares.

Table 10: Questions evaluating solution's ROI

Factor	Metrics/Considerations	Type
Time Saved	Reduction in time for tasks like BOM creation and management, change management, creation and management of technical documentation etc.,	Quantitative
Labour Cost Saved	Reduction in personnel hours per week/month	Quantitative

5.1.3 Qualitative Evaluation

- **User and Stakeholder Impact:**

The success of any digital solution depends heavily on its acceptance and usability. This section evaluates user adoption potential, identifying whether the interface and functionality are intuitive enough to encourage seamless adoption.

Table 11: Questions evalutaing solution's stakeholder impact

Factor	Guiding Questions	Type
User Adoption Potential	How easy is it for users to adapt to the new system?	Qualitative
Training Needs	How much training is needed?	Qualitative
Stakeholder Satisfaction	What feedback do users/stakeholders have?	Qualitative
Change Management Risk	How disruptive is the transition to the solution?	Qualitative

- **Process Improvement:**

The focus here is on the qualitative enhancements to business operations

Table 12: Questions evaluating the process improvemets due to solution

Factor	Guiding Questions	Type
Integration with Existing Systems	Does it integrate well with ERP, CAD, etc.?	Qualitative
Workflow Automation	Does it reduce manual interventions?	Qualitative
Data Consistency	Has master data quality improved?	Qualitative
Collaboration & Communication	Has inter-departmental collaboration improved?	Qualitative

5.1.4 Scalability and Future Readiness

This section examines the long-term viability of the solution.

Table 13: Questions evaluating solution's Scalability and Future Readiness

Factor	Guiding Questions	Type
Value Addition	Is the solution bringing any new features compared with the legacy system?	Qualitative
Scalability	Can the solution handle growing data, users, and processes?	Qualitative
Upgradability	Can it be easily upgraded in the future?	Qualitative
Modularity	Can new modules/functions be added with minimal disruption?	Qualitative
Vendor Support	Is Siemens reliable for long-term support?	Qualitative

5.1.5 Compliance and Risk

The compliance dimension evaluates whether the system meets relevant industry standards, such as ISO requirements, and supports robust traceability and audit functions.

Table 14: Questions to evaluate solution's compliance requirements

Factor	Questions to Consider	Type
Regulatory Compliance	Does the system support traceability, audits, ISO standards?	Qualitative
Data Security	Is sensitive data well protected in the system?	Qualitative
System Downtime Risk	Has availability improved vs. legacy systems?	Quantitative

5.1.6 Scorecard

The scorecard provides a consolidated view of both the quantitative and qualitative evaluations proposed in the sections above. *Each factor is weighted according to its strategic importance, with the suggested weights serving only as recommendations and subject to adjustment based on organizational priorities. The scoring process enables a structured assessment of the proposed solution, resulting in a final weighted score out of 5.0 that can support informed decision-making.

Table 15: Consolidated scorecard

Evaluation Factor	Weight*	Score (1–5)	Weighted Score
Alignment of Objectives	20%		
Cost Savings & ROI	20%		
User Acceptance	20%		
Process Efficiency	15%		
Scalability	10%		
Compliance & Risk Mitigation	15%		
Total	100%		**/5.0**

5.2 Implications:

Prior to this study, there was limited awareness within Electrolux regarding the full potential of *Teamcenter's SLM* capabilities, *RapidAuthor for Teamcenter*, and how their integration could be leveraged. This research has helped illuminate these possibilities, thereby bridging an important knowledge gap beyond simply addressing the SDT's requirement to replace the *TDS* system with *Teamcenter*. Hence, clear understanding these implications is essential for evaluating the solution's practical impact and guiding future developments. Hence, this section discusses the broader implications of the implemented solution, highlighting its key benefits as well as potential challenges.

5.2.1 Benefits:

As previously outlined, the solution not only meets the stakeholders' requirements but also delivers additional value as described below:

- **Replacement of outdated TDS with a robust, scalable PLM system:** The transition to *Teamcenter* offers a modern, flexible platform capable of supporting Electrolux's growing spare part management needs, overcoming the limitations of the legacy *TDS* infrastructure.
- **Single source of truth**: By centralizing data and providing access tailored to the needs of different stakeholders within the company, the system eliminates discrepancies in data management and usage across departments. This ensures that all users operate with consistent, up-to-date information, enhancing coordination, minimizing errors, and ultimately saving substantial resources.
- **Connected BOM philosophy:** Linking EBOMs with SBOMs ensures traceability and coherence across product lifecycles, facilitating better flow of data across domains, better change management and accurate identification. At Electrolux, with an already existing PLM environment across engineering domain and a plan to soon extend it to the manufacturing

level, extending this environment and fitting in the needs of the SDT to manage the lifecycle part of their aftermarket requirement will complete the loop nearing to cradle to grave philosophy.

- **Status and version control via systematic change management:** The dedicated service change management mechanism, built to accommodate flexible workflows across the service lifecycle, enforces strict control over revisions and statuses. By tracking statuses, changes and preserving links between versions, it prevents outdated or incorrect data from being utilized in service operations.
- **Structured documentation through service planning:** Provides a systematic approach to documentation while ensuring that all service-related information is organized in a clear and consistent manner. This enhances accessibility for customers by making it easier to find, understand, and follow service instructions.
- **Support for interactive, multimedia-rich documentation integrated with product data:** The ability to create engaging, interactive electronic 3D documentation and 2D diagrams improves customer understanding and reduces service errors, contributing to higher quality maintenance outcomes.
- **Conversion of native CAD data into interactive 3D technical publications:** This semi-automatic conversion eliminates the need to recreate models manually, saving time and ensuring technical accuracy.
- **Continuous synchronization of documentation content with the latest design**: The integration of *Teamcenter SLM* with *RapidAuthor for Teamcenter* enables keeping service documentation aligned with current product designs minimizes inconsistencies and rework, ultimately improving customer satisfaction and reducing lifecycle costs.

5.2.2 Challenges:

While the proposed solution clearly meets the requirements and offers added value, a few challenges have been identified that which must be addressed carefully to ensure successful adoption and long-term sustainability of the solution.

- **Additional customizations of the OOTB product and Rapidauthor suite:** To comprehensively meet the specific lifecycle requirements of the SDT within *Teamcenter*, additional customization of the OOTB *Teamcenter SLM* is required. Likewise, fully adapting the *Rapidauthor* suite to align with SDT's documentation standards necessitates customizing its specifications. These customizations demand careful planning and resource allocation to ensure system stability while addressing the team's unique business needs.
- **Data migration:** Migrating existing spare part data from legacy systems like *TDS* into *Teamcenter* poses a significant challenge, demanding rigorous data cleansing, mapping, and validation efforts. Ensuring data integrity during this transition is critical to avoid disruptions and maintain trust in the new system.
- **Integrations:** The framework must seamlessly integrate with other enterprise systems to enable a complete replacement of *TDS*. However, designing and maintaining these integrations can be challenging due to variations in data formats, communication protocols, and security requirements.
- **Organizational resistance and training:** Successful adoption of the new solution largely hinges on overcoming organizational resistance to change, which is influenced by the number of affected users and various other factors. Implementing comprehensive training programs and providing ongoing support are essential to equip SDT members and other users with the

necessary skills and confidence to effectively use the new tools, thereby promoting acceptance and minimizing productivity losses during the transition.

5.3 Future Work

Building on the findings and proposed solution in this thesis project, several next steps can be undertaken to move towards full-scale deployment and operational adoption:

- **Advanced Customization:**
    - Extend the OOTB configuration of *Teamcenter SLM* in accordance to the requirements captured, to include more detailed custom properties on the proposed model, refine existing relationships, and hide irrelevant OOTB properties to streamline the user experience by developing and configurign custom stylesheets to display only relevant attributes while ensuring information consistency across different user roles.
    - The OOTB model should be further extended to ensure seamless alignment and integration with Electrolux's existing templates in the PLM production environment.
    - Set up organization- and role-based access controls for both customer and developer sites, ensuring permission levels are tailored to operational needs and information security requirements.
- **Licensing Discussions with Siemens:**
    - Initiate formal discussions with Siemens to acquire the necessary licenses for *Teamcenter SLM* and *RapidAuthor for Teamcenter*.
    - Align license acquisition with project timelines, planned integration phases, and budget constraints.
- **Integration Testing between RapidAuthor and Teamcenter SLM:**
    - While this study used *Teamcenter SLM* and the standalone mode of the *RapidAuthor* suite (by Cortona3D), the proposed solution is based on an integrated framework.
    - Future work should include deploying *RapidAuthor for Teamcenter* and testing its integration with *Teamcenter SLM* to validate seamless data exchange and synchronization.
- **Development of Detailed Design Document Standards:**
    - Use *RapidSpecification* and *RapidConfiguration* components of *RapidDeveloper* to define and customize the input/output structures for *RapidAuthor* suite tools to align specific documentation requirements of SDT & Electrolux at large.
- **Business Process Design and Workflow Implementation:**
    - Define, document, and test workflows for service change management, creation/replacement/update of documents, Service BOMs, and spare definitions in accordance to the needs of different business regions and product lines.
    - Design workflows for handling problem reports, review/approval cycles, and communication between developers and customers.
    - Consider integrating service workflows with engineering workflows wherever necessary through workflow automation opportunities to reduce manual effort and improve traceability.

- **Detailed Data Migration Planning and Execution**
  - Following the knowledge of data models of the source system (*TDS*) and the target system (*Teamcenter*), develop a detailed data mapping specification at attribute level.
  - Perform trial migrations using the outlined methodology, validate data integrity, and fine-tune transformation rules before initiating full-scale migration.
- **Integration Framework Definition:**
  - As *TDS* currently interacts with both upstream and downstream systems, a future step will also be to design and implement an integration framework for the proposed solution that accommodates required data exchange formats, exchange protocols, and security considerations.
  - Test each integration endpoint to ensure compatibility and reliability.
- **Enablement of Customer Viewpoint using *SupplierConnect*:**
  - Since trial licenses for *SupplierConnect* were unavailable during this study, the customer viewpoint was only conceptually developed.
  - As a next step, acquire the necessary licenses and conduct practical testing of the customer viewpoint to validate feasibility, usability, and data access mechanisms.
- **User Training and Adoption Planning**:
  - Develop comprehensive training materials and sessions for various user roles (on both authoring and consuming sides), ensuring smooth adoption of the new system.
- **Detailed Performance Benchmarking and Optimization**
  - Based on the evaluation framework proposed, after initial deployment, measure system performance for publishing times, search response, and integration latency.
  - Optimize configurations to meet performance targets.
- **Governance and Continuous Improvement Framework**
  - Establish a governance model to manage change requests, system updates, and ongoing customization.
  - Define KPIs and feedback loops for continuous improvement of the service documentation process.

5.4 Future Scope

- **Integration with IoT and Predictive Maintenance Systems:** As Electrolux operates in the white goods sector and the industry increasingly shifts towards smart, connected appliances, the proposed solution could be expanded to fully leverage *Teamcenter's SLM* capabilities beyond its current scope of *SBOM creation*, *service planning*, and *service documentation* which maintains neutral structures. By maintaining and managing physical (real-world) instances of neutral structures, the system could evolve to support as-built and as-maintained configurations, extending well beyond the current scope of this thesis project. This enables utilization of *SLM*'s *physical structures* and *maintenance actions* functionalities to integrate with IoT-enabled appliances, thus supporting semi-automated service documentation updates, spare part recommendations, and maintenance activities driven by real-time product health data

- **AI-Assisted Authoring and Search:** Incorporating AI tools to assist developers in the creation of SBOMs, associated technical documentation, and thus to improve search accuracy for customers.
- **Augmented Reality (AR) and Interactive Manuals:** By further leveraging *Teamcenter SLM*'s integration with *TeamViewer*, published service documentation can be enriched with augmented reality (AR) instructions and interactive 3D visualizations. This would allow the customers to view step-by-step repair or maintenance procedures overlaid directly on the physical product through smart devices or AR headsets. Such capabilities can significantly improve efficiency during maintenance activities, reduce the likelihood of errors, and shorten training times for new customers by offering immersive, hands-on learning experiences.

6 Conclusion

This thesis project set out to address the knowledge gap at Electrolux regarding the transition of spare part management through from legacy the adoption of a modern PLM system like *teamcenter*. Guided by the first research question, “What role can modern PLM systems play in enhancing spare part management?”, the study examined current trends in PLM-enabled spare part management through literature review, industry case studies, and insights from internal and external experts. Based on these insights, a modern PLM system such as *Teamcenter* can contribute to spare part management by centralizing spare part and service data, by enabling integrated SBOM management, supporting structured workflows for documentation and change management, semi-automating parts of service documentation, and facilitating consistent and accessible information for both engineering and service teams. These high-level capabilities illustrated the potential of PLM to improve operational efficiency, reduce errors, and provide a foundation for connected and digital spare part management processes.

Building on this, the second research question, “What is an effective approach for managing engineering and service data in a PLM environment?”, highlighted the importance of establishing a single source of truth. By consolidating engineering and service data within a unified PLM environment, the proposed solution ensures information consistency, reduces redundancy, and enables seamless collaboration between engineering, service, and documentation teams. This approach also allows for structured management of changes and revisions, ensuring that all stakeholders have access to accurate and up-to-date information at all times.

The third research question, “How can these principles be applied to design a *Teamcenter*-based solution to replace the legacy spare part management system at Electrolux?”, guided the development of the proposed integrated solution. Leveraging *Teamcenter’s SLM* capabilities combined with the *RapidAuthor for Teamcenter* Suite, the framework addresses the requirements identified from internal stakeholders - SDT, and industry experts. The solution defines two primary perspectives, developer and customer viewpoints, and further organizes developer viewpoint into SBOM management, technical documentation management, and change management. Each supported by specific functionalities: SBOM management provides the ability to create and maintain SBOMs aligned with engineering data, including spare definitions with custom properties, organized into sections for modularity, and linked to engineering data without duplicating it; technical documentation management enables semi-automated generation of interactive 3D manuals directly from CAD data, ensuring consistency while reducing manual effort; and change management facilitates structured handling of revisions and updates across the service data described above.

While the proposed solution fulfills the immediate requirements, the study highlights several critical challenges for full-scale implementation, including extensive system customization, complex data migration, integration with other enterprise systems, and organizational change management. Successfully overcoming these challenges will require ongoing collaboration among IT specialists, SDT members, and the PLM team to ensure smooth adoption and fully realize the framework’s potential. Additionally, the study outlines the next steps for completing the full-scale transition and establishes a framework for evaluating the benefits of this implementation.

Looking ahead, the proposed solution lays the groundwork for expanding and modernizing spare part management. Potential future enhancements include integration with predictive maintenance systems, AI-assisted authoring and search, and augmented reality-enabled service instructions, establishing a foundation for fully connected engineering and service ecosystems. Successful implementation of this framework is expected to directly improve operational efficiency and reduce costs, while indirectly enhancing customer satisfaction and strengthening competitive advantage. Overall, this thesis project highlights the strategic value of leveraging modern PLM solutions to bridge engineering and service functions, offering a scalable roadmap for future initiatives in smart and connected spare part management.

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Appendices

Appendix A

Master Thesis: Transition of Spare Part Management System from TDS to Teamcenter PLM

External Interview with Ashish P Killedar

Technical Project Manager, Hitachi Energy & PLM Business Consultant

3rd of April 2025, 14.00-15.00 (UTC+2)

Participants:

- Ashish P Killedar
- Omkar Kharat
- Paresh Sakala Vishwanath

Agenda:

- Mutual Introduction (5 Minutes)
- Brief presentation of the thesis topic and our progress so far (5 Minutes)
- Discussion on Current Practices (10 Minutes)
- Discussion on the most Common Challenges (10 Minutes)
- Discussion on Best Practices (10 Minutes)
- Discussion on Future Trends (5 Minutes)
- Conclusion and Wrap-Up (5 Minutes)

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Electrolux Group

Discussion on Current Practices

The purpose of this section is to understand current/past experiences of the interviewee in the domain of spare part management/Service Lifecycle Management.

1. **What tools and systems are you using for spare part management?**

   (If company is not using PLM for SPM)

2. **Can you briefly describe the scope for spare part management using PLM in your organization?**

3. **Can you describe the process for spare part management in your organization?**

4. **Do you think PLM systems are necessary for spare-part management or 3rd party tools configured to the organization's business rule is the right way to go? (Optional)**

Discussion on the most Common Challenges

The purpose of this section is to understand the most common obstacles for an organization while managing spare parts both outside and within the PLM framework

1. **What are the main challenges you face in managing spare parts (both outside and within the PLM framework)?**

2. **How do these challenges impact your operations and maintenance processes?**

3. **What are your thoughts about managing spare parts for high volume product using PLM?**

4. **Managing Spare-part lifecycle as compared to managing Parts lifecycle. How is it managed in a same system? (Optional)**

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Discussion on the Best Practices

The purpose of this section is to understand the best practices followed by the organization to overcome the challenges discussed above and how does PLM play a role in it.

1. **What best practices have you implemented for effective spare part management?**

2. **How do you ensure data integrity and compatibility during system transitions (if any)?**

Discussion on the Future Trends

1. What future trends do you foresee in
    a. spare part management,
    b. service lifecycle management,
    c. Product Service Systems in the context of PLM systems?

Conclusion and Wrap-Up

- Summarize the key points discussed during the interview.
- Thank the interviewee for their time and insights.

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Appendix B

Figure 39: Conceptual Framework of the Proposed Solution

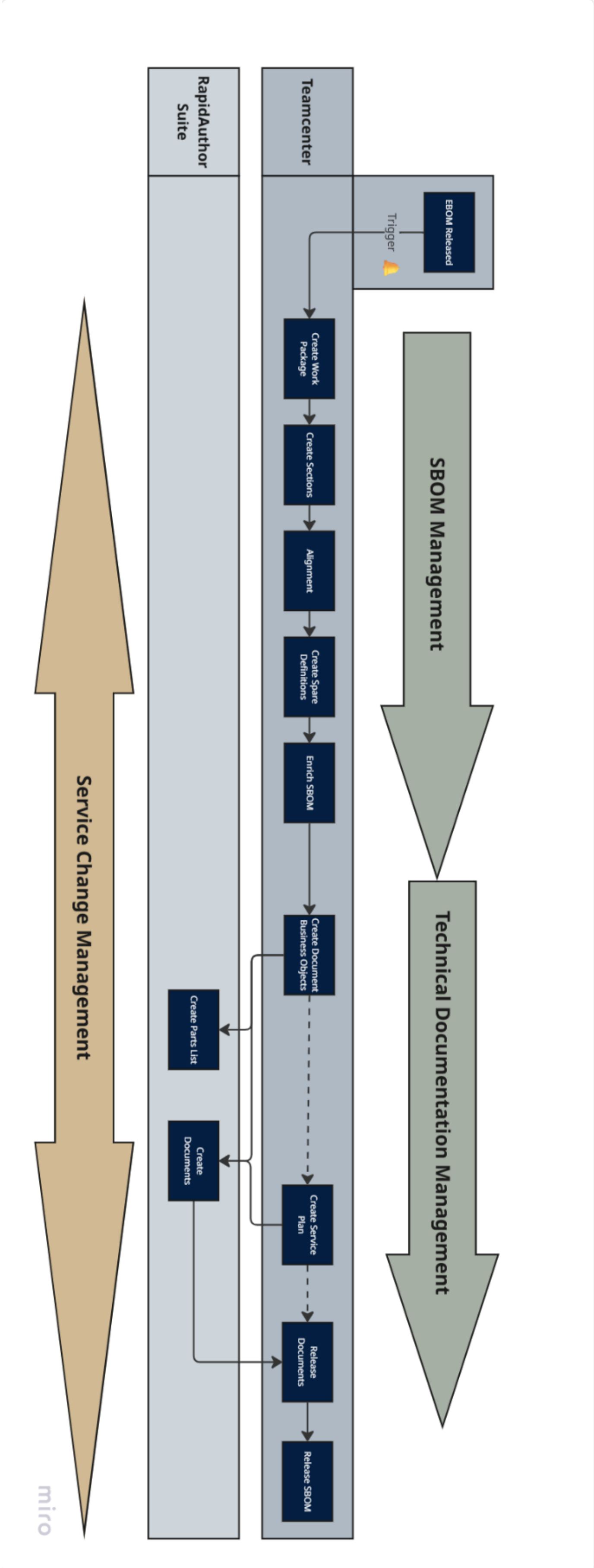
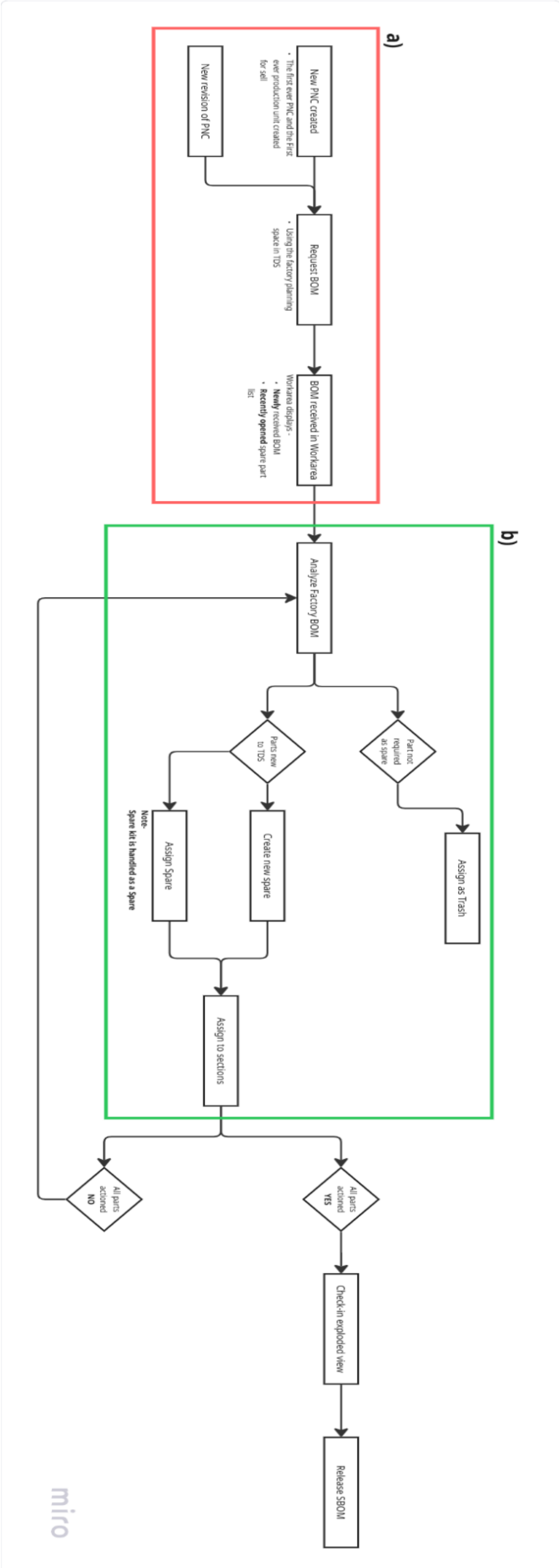


Figure 40: Current process of creation of spare parts list on TDS



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