Optimizing Cognitive Support & Standardization: Digital Transformation of Production Instruction Systems in Manufacturing

An evaluation of current system and possible digitalization solutions

Master's thesis in Production Engineering

Amanda Bergström Ohlsson
Linda Holmgren Faghihi

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
www.chalmers.se

Master's thesis 2025

Optimizing Cognitive Support & Standardization: Digital Transformation of Production Instruction Systems in Manufacturing

An evaluation of current system and possible digitalization solutions

AMANDA BERGSTRÖM OHLSSON
LINDA HOLMGREN FAGHIHI

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Industrial and Materials Science
Chalmers University of Technology
Gothenburg, Sweden 2025

Optimizing Cognitive Support & Standardization: Digital Transformation of Production Instruction Systems in Manufacturing
An evaluation of current system and possible digitalization solutions
Bergström Ohlsson, Amanda
Holmgren Faghihi, Linda

Supervisor: Dr. Salunkhe, Omkar, Industrial and Materials Science
Advisor: Haddadzade, Mohammad, Scania CV AB
Examiner: Prof. Stahre, Johan, Industrial and Materials Science

Master's Thesis 2025
Department of Industrial and Materials Science
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2025

Optimizing Cognitive Support & Standardization: Digital Transformation of Production Instruction Systems in Manufacturing
An evaluation of current system and possible digitalization solutions
Bergström Ohlsson, A. & Holmgren Faghihi, L.
Department of Industrial and Materials Science
Chalmers University of Technology

Abstract

In the face of increasing production complexity and higher quality demands in the manufacturing industry, effective cognitive support for operators has become crucial. This thesis investigates the current state of production instruction systems at Scania's transmission factory and explores opportunities for digital transformation to enhance efficiency, standardization, and user experience. The existing production instruction system at Scania CV AB, based on printed documents generated through the *ArtHur* software, presents significant challenges in terms of usability, cognitive load, and standardization across departments. Through a combination of a systematic literature review, qualitative methods, including interviews, Gemba walks, and workshops, and a benchmarking study with peer companies, key shortcomings and improvement areas were identified. A requirement specification was developed to guide the design of two conceptual solutions: one for immediate implementation based on improved standards, and one representing a state-of-the-art digital system. A pilot project was conducted to evaluate both concepts in a real production setting. Results demonstrate the potential of intuitive digital interfaces to reduce operator cognitive load, improve instruction accessibility, and support standardized procedures. The findings offer actionable recommendations for implementing more effective, user-centered instruction systems in machining environments.

Keywords: Cognitive support, work instructions, digital transformation, machining, standardization, Industry 4.0, user interface, production engineering.

Acknowledgements

We would like to express our sincere gratitude to Scania CV AB for providing us with the opportunity to conduct this thesis and for their valuable support throughout the project. A special thank you goes to our supervisor at Scania, Mohammad Haddadzade, for his continuous guidance, encouragement, and insights.

We are also deeply grateful to Chalmers University of Technology for the education and foundation that made this thesis possible. We would like to thank our academic supervisor, Dr. Omkar Salunkhe, as well as all professors and staff members who have contributed to our academic journey.

Furthermore, we would like to extend our appreciation to everyone who contributed to this thesis, including in-house employees at Scania who participated in interviews, as well as the industry experts and representatives from external companies who shared their valuable perspectives and experiences.

Your support has been instrumental in the completion of this work, and we are truly thankful.

Amanda Bergström Ohlsson & Linda Holmgren Faghihi, Gothenburg, 2025-05-18

Declaration of AI-tools for thesis report writing

This thesis has been written with the support of various AI-tools to enhance the writing process, improve sentence formulation, and correct spelling and grammar. All content and ideas were originally developed and formulated by the thesis authors.

AI-tools used:
ChatGPT: Utilized to enhance sentence structure, improve the flow of the text, and support clarity in written communication.

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AUI	Adaptive User Interface
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CMM	Coordinate-Measuring Machine
CNC	Computer Numerical Control
DX	Scania’s Transmission Factory Organization
DXF	Drawing Exchange Format
DXM	Scania’s Transmission Factory Manufacturing Organization
EAM	Enterprise Asset Management
ECO	Engineering Change Order
ERP	Enterprise Resource Planning
GDPR	General Data Protection Regulation
HMI	Human-Machine Interface
IPP	In-Process Parts
IoT	Internet of Things
IT	Information Technology
KPI	Key Performance Indicator
LMT	Local Management Team
MES	Manufacturing Execution System
ML	Machine Learning
OEM	Original Equipment Manufacturers
P&L	Production & Logistics
PWC	Planet Wheel Carrier
QR code	Quick-Response code
SLR	Systematic Literature Review
SOP	Standard Operating Procedure
SPS	Scania Production System
UFO	Underhåll Förebyggande Operatör (Maintenance Preventive Operator)

Contents

List of Acronyms ix

List of Figures xv

List of Tables xvii

1 Introduction 1
- 1.1 Background & Problem Statement 1
- 1.2 Aim & Research Question(s) 2
- 1.3 Scope & Delimitations 3

2 Project Background 5
- 2.1 Scania Transmission Factory 5
- 2.2 Instruction System Software - ArtHur 6
  - 2.2.1 Rigging Documents 7
  - 2.2.2 Processing Documents 7
  - 2.2.3 Quality Control Documents 7
  - 2.2.4 Correction Documents 7
- 2.3 Other Tools 8

3 Research Methods 9
- 3.1 Research Design 9
- 3.2 Systematic Literature Review 10
  - 3.2.1 Key Words & Search Terms 11
  - 3.2.2 Source Selection Criteria & Credibility Assessment 12
- 3.3 Qualitative Analysis 12
  - 3.3.1 Gemba Walk 12
  - 3.3.2 Interviews 13
  - 3.3.3 Workshops 13
- 3.4 Pilot Project 14

4 Case Study 15
- 4.1 Soft Turning Process at the PWC line 15
  - 4.1.1 Implementation of Gemba Walk 15
  - 4.1.2 In-house Interviews 16
  - 4.1.3 Case Study Workshop 17
- 4.2 Benchmarking 18
  - 4.2.1 Expert and Peer Company Interviews 18
  - 4.2.2 Company Visit 18

4.3 Pilot Study 19
4.3.1 Concept Creation 19
4.3.2 Testing of Concept 23

5 Results **25**
5.1 Findings from Systematic Literature Review 25
5.1.1 Cognitive Ergonomics 25
5.1.2 Design Principles for Cognitive Support 26
5.1.3 Production Instruction Systems 30
5.1.4 Standardization of Work Instructions 31
5.2 Findings from the Case Study 32
5.2.1 Gemba Walk 32
5.2.2 Interviews 35
5.2.3 Result of Workshop 44
5.3 Findings from the Benchmarking 50
5.3.1 Summary of interviews 50
5.3.2 Summary of company visit 53
5.4 Pilot Study Results 55
5.4.1 Specification of Requirements 55
5.4.2 Developed Concepts 56
5.4.3 Outcome of Pilot Project 70
5.4.4 Evaluation of Results 77

6 Discussion **81**
6.1 Instructions & Cognitive Support 81
6.2 Evaluation of the Pilot & Stakeholder Engagement 82
6.2.1 Preperations and Interview Reflections 82
6.2.2 Pilot Study Reflection 82
6.3 Feasibility & Scalability 84
6.3.1 Feasibility of Concepts 84
6.3.2 Challanges of Scaling Across DX 86
6.4 Benchmarking Evaluation & Reflection 87
6.4.1 Key Differences Between Scania and Benchmarking Peers 87
6.4.2 Lessons Learned 88
6.4.3 Reflections on Benchmarking Method 89
6.5 Human Factors & Standardization 89
6.6 Societal, Ethical & Environmental Considerations 91
6.6.1 Societal Considerations 91
6.6.2 Ethical Considerations 91
6.6.3 Environmental Considerations 92
6.7 Future Work & Implementations 92
6.7.1 Further Development of Standardization (Concept 1) 92
6.7.2 Bridging Concept 2 and Process Planning 93
6.7.3 Expanded Pilot Testing 93
6.7.4 Future Advancements Through Emerging Technologies 93

7 Conclusion **95**

Bibliography **97**

A Appendix A **I**

B Appendix B **V**

C Appendix C **IX**

D Appendix D **XXVII**

E Appendix E **XXXV**

List of Figures

2.1 The Scania House 5

3.1 Research design 10

4.1 Section 4 from the Requirement Specification, highlighting Requirements 4.4 and 4.6–4.8. 21

5.1 Complete Rigging Documentation Including Data Censoring. 46
5.2 Complete Correction Documentation Including Data Censoring. 47
5.3 Complete Quality Control Documentation Including Data Censoring. 48
5.4 Example of a beige 3D model component holder. 48
5.5 Complete Tool List Documentation Including Data Censoring. 49
5.6 The first process flow of the prototype. 57
5.7 Login page and main menu. 58
5.8 The search function - Start view. 58
5.9 The search function - Example of product breakdown. 59
5.10 Start page for chosen tempo in ArtHur. 59
5.11 The second process flow of the prototype, illustrating the various functions linked to each document type. 60
5.12 Rigging Document main view with update notification. 61
5.13 Main view of the Rigging Document, showing the pop-up box containing the update description. 61
5.14 Hamburger menu - Showcased in the Rigging Document. 62
5.15 Three dot menu - Showcased in the Rigging Document. 63
5.16 Rigging document - Procedure description located in the hamburger menu. 64
5.17 Rigging Document - Data sheet view with procedure description displayed in the hamburger menu. 64
5.18 Tool list document - Main view and view with pop-up box with tool information. 65
5.19 Quality Control Document - Main view and view with hamburger menu open. 65
5.20 Quality Control Document - Shows the view when filtered measurements for the selected tool when the turquoise button is clicked. 66
5.21 Processing Document - Main view with hamburger menu open. 67
5.22 Processing Document - Marking list for filtering measruements, with measurement 113 selected. 67
5.23 Correction Document - Main view with the hamburger menu open, and view with tool information displayed. 68
5.24 Interactive 3D-model document - Main view and view with hamburger menu open. 68

5.25 Layout page with hamburger menu open. 69

List of Tables

1.1 Objectives of the project 3

4.1 A list of the in-house interviewees, including their field of expertise. 16
4.2 A detailed list of all the operators who serve as process owners for the pilot project. 17
4.3 Industry experts interviewed, categorized by company type and number of representatives. 18

5.1 Table presenting a summary of design parameters for cognitive support . . 29

1

Introduction

This chapter presents the background and problem statement for the thesis, outlining the aim and research questions developed to explore improved ways of supporting operators for machining processes at a transmission factory operated by a major truck manufacturer in Sweden. Additionally, the chapter defines the scope and delimitations of the study.

1.1 Background & Problem Statement

Scania CV AB (hereafter referred to as Scania), a global leader in the design and manufacture of heavy-duty trucks, buses, and industrial engines [1], operates a highly complex transmission factory in Södertälje, focused on producing high-quality components for the gearboxes and industrial engines for Scania trucks (M. Haddadzade, personal communication, January, 2025). Scania's Transmission Factory Organization (DX) currently uses a production instruction system that is based on printed materials, generated by an internal software tool, *ArtHur*, which defines all necessary process steps for the manufacture of a part. For each part, it should provide a detailed sequence of operations, specify the required tools, and outline all relevant measurements, geometries, and tolerances from a quality perspective. Additionally, it should specify which tool is processing specific surfaces and include the quality control procedures (M. Haddadzade, personal communication, January, 2025). While effective, it faces several challenges that need to be addressed to support operators cognition and ensure more standardized production processes.

In today's globalized, fast-paced, and highly competitive manufacturing environment, companies like Scania face increasing pressure due to shorter innovation cycles and higher production demands [2], [3]. Maintaining good quality in production has become progressively challenging due to human error, highlighting the need for an improved instruction system to guide operators effectively, especially as there is a growing demand for machine-tool users to better understand machining processes [4], [5].

In complex production environments such as Scania's transmission factory, having effective and standardized work instructions is essential. They help operators reduce variation in their tasks, leading to more consistent quality in production [6], [7]. The instructions should guide operators and technicians through manufacturing processes, making their jobs easier, while ensuring efficiency, quality, and consistency [3]. Standardized work instructions simplifies training and documentation updates, ensuring consistent and efficient task performance. It also enables controlled experiments for process improvements, enhancing performance and organizational learning [7].

Currently, the instruction system at the transmission factory consists of four types of documents - *Processing Document, Rigging Document, Quality Control Document and Correction Document* - providing operators and technicians with the necessary information and support to effectively operate machinery along the production lines. However, these documents lack standardization, resulting in inconsistencies across different divisions. Each division follows its own approach, which creates difficulties for operators who may need to switch between production lines. The instructions often vary in structure and format, creating confusion and inefficiency when moving between different areas of production (M. Haddadzade, personal communication, January, 2025).

The transmission factory operators have also reported challenges in understanding technical drawings and process documentation (M. Haddadzade, personal communication, January, 2025). Measuring protocols often does not align with the format or content of the *Processing*- and *Quality Control Documents*, causing confusion. As a result, operators spend excessive time searching through multiple papers to locate the correct parameters, measurements, or specifications, and then cross-checking them across different documents. In addition, many operators do not consistently use *Rigging*- or *Processing* documentation when setting up machines or verifying operations. This lack of consistency further complicates standardization efforts and impacts efficiency on the production floor [3]. The problem is further intensified when operators rely entirely on memory instead of using the documentation. If updates from process planners are not printed or reviewed, they may go unnoticed, leading operators to follow outdated procedures (M. Haddadzade, personal communication, January, 2025).

These challenges suggest that the current method of presenting work instructions and process information at DX is inefficient, leading to inconsistencies, misunderstandings, and decreased operational efficiency [8]. In complex environments, well-designed work instructions can significantly reduce the cognitive load on operators, allowing them to focus on their tasks without being overwhelmed by information [9]. To improve cognitive assistance, it is essential to improve the way information is structured, presented and accessed on the production floor. A more intuitive, standardized, and user-friendly system can reduce mental workload, support decision-making, and improve overall efficiency and job satisfaction among operators in production processes [7]–[9].

1.2 Aim & Research Question(s)

The aim of this thesis is to develop a more efficient way of presenting information within a manufacturing environment to improve the cognitive assistance of operators in machining processes in truck transmission manufacturing.

To support this aim, three research questions have been formulated.

- What are the key strengths and weaknesses of the current production instruction system, and how do these impact operational efficiency and user experience?
- How do state-of-the-art work instruction systems in similar industries address common challenges, and what best practices can be adapted for the current system?
- What are the specific functional and technical requirements for an improved production instruction system, and how can these be effectively integrated into a tailored

solution that meets both organizational goals and user needs?

Objectives

The project objectives were subsequently defined to effectively support the exploration and investigation of the research questions.

Table 1.1: Objectives of the project

1. Analyze the Current System
Conduct a comprehensive analysis of the existing production instruction system to identify strengths, weaknesses, and opportunities for improvement.
2. Explore the State of the Art
Investigate state-of-the-art solutions and best practices for work instruction systems in similar industries to establish a benchmark.
3. Identify Requirements and Propose Improvements
Define key requirements for an improved system and evaluate potential solutions to address identified gaps and enhance system performance.
4. Develop a Solution
Design a feasible solution tailored to meet the outlined requirements and align with organisational goals.
5. Test the Proposed Solution
Implement and test the proposed solution in a pilot setting to evaluate its effectiveness and identify any necessary adjustments.
6. Review and Provide Recommendations
Conduct a thorough review of the testing outcomes and provide actionable recommendations for the implementation of the improved system.

1.3 Scope & Delimitations

The scope of the master thesis is primarily focused on production instruction systems within the automotive industry, concentrating exclusively on machining operations while excluding broader operational systems and assembly processes. The research is confined to evaluating currently available work instruction systems and platforms, and is conducted under regulations from Chalmers University of Technology within a 20-week full-time study period. The examination only looks at the instruction system and how operators are supported, not at financial aspects or total implementation costs. A pilot project is included, limited to a single production line and process, which implies that the findings might not fully represent the potential impacts of a wider implementation across various processes or production lines. Feedback and user engagement will be gathered from a predetermined group of participants, which might not reflect the entire array of possible perspectives within the industry.

2

Project Background

This chapter provides contextual information about the project environment. It introduces *the Scania Way*, describes the Transmission Factory where the case study was conducted, and outlines relevant software and tools used throughout the project. This background helps frame the setting and resources that influenced the research approach.

2.1 Scania Transmission Factory

Scania's transmission factory in Södertälje, Sweden, manufactures the core volume of key components for TRATON's gearboxes and rear axles, including axles, synchronizers, shafts, bevel gears, and gear wheels. These components are produced with a focus on precision and world-class industrialization standards.

The factory follows *the Scania Way*, an operational strategy inspired by Lean Management principles, emphasizing efficiency, continuous improvement, and operational excellence. A key symbol of this system is the Scania House, representing the Scania Production System (SPS), where the foundation represents the core values, and the floors, walls, and roof embody the operational principles, see Figure 2.1. Scania's aim with this is to stay flexible and resilient, and to meet future requirements.

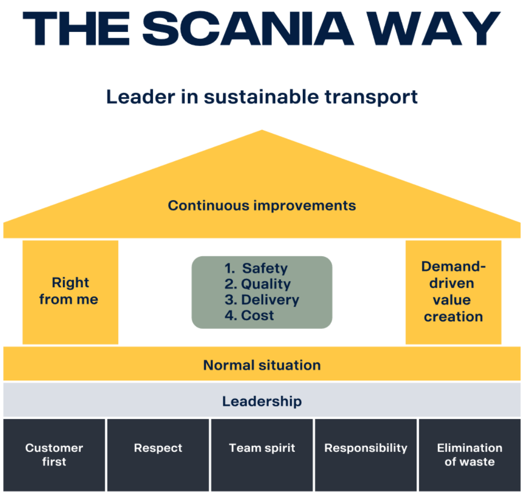


Figure 2.1: The Scania House

For many years, DX has relied on paper-based production instructions for operators involved in various manufacturing processes, such as rigging, processing, quality control, and correction. These instructions are created by process planners using a combination of CATIA V5, a Computer-Aided Design (CAD) software developed by Dassault Systèmes [10], and the instruction system *ArtHur*. However, this method is not only time-consuming for process planners but also lacks standardized procedures, resulting in significant inefficiencies.

One clear example of this inefficiency is the excessive volume of documentation. For a single Planet Wheel Carrier (PWC) article in *ArtHur*, the main instruction document spans 69 pages. The measurement protocol alone comprises 44 pages (when printing only the measurement-related pages), and an additional 155 pages are dedicated to graphs, bringing the total to 199 pages. Given that measurements are taken up to five times per day, this results in nearly 1,000 printed pages daily. If the article is produced throughout the year, this amounts to approximately 365,000 pages annually (M. Haddadzade, personal communication, April, 2025).

2.2 Instruction System Software - ArtHur

Arthur is a software used for creating instructional documents in the transmission factory. It is an older system, with its last update dating back to the early 2000s, around 2004. IBM Maximo, an Enterprise Asset Management (EAM) system that helps organizations manage assets, maintenance, and operations efficiently [11], is integrated with *Arthur* to display inventory data for tools and other resources. In this report, IBM Maximo is referred to simply as *Maximo*. While *Maximo* is widely used, its functionality will not be explored in detail in this thesis beyond potential integration opportunities, as it falls outside the study's scope.

In *Arthur*, product components are categorized either by product group or individually. Each components article number consists of seven digits, but in production, only the last three digits are primarily used for identification. At the second level of information in *Arthur*, the manufacturing process is detailed through a sequence of operations. Each operation has a unique numerical code that specifies the type of process being performed. For example, 030 represents soft machining, 020 is turning, and 140 is hardening. These operations are listed in the exact order required for production. If there are two parallel machines for the same operation, the operation number appears twice in the list, with one marked as an alternative machine using the letter A (e.g., 030A). However, this is not applied consistently across the entire transmission factory. For example, turning is often not referred to as OP 020, but instead by a different operation number.

At the third level, each operation is further divided into specific tempos, which define the individual machining steps within an operation. For example, in soft machining (030), there may be three tempos: hobbing, gear milling, and chamfering. The tempos follow a structured sequence to ensure proper workflow. Every tempo sequence begins with Automation, which dictates the robotic movements necessary for executing the machining steps in the operation. The automation tempo is not included in the master thesis, as they are not directly operated by the operators.

At the final level of *Arthur*, you find the instructional documents required to operate the different machines, providing essential guidance for production processes. For each tempo, there's usually a *Rigging Document*, a *Processing Document*, a *Quality Control Document*, and a *Correction Document*. This can vary depending on the machining process. Their structure and content are further detailed in the following subsections.

2.2.1 Rigging Documents

The *Rigging Document* outlines the preparation process for machines or robots, detailing the necessary tools and geometries. It serves as a critical guide to ensure that the equipment is accurately configured to handle specific parts or processes. The document includes essential information such as machine number, tool numbers and schematic drawings or 3D visuals that illustrate the proper positioning of tools in relation to one another. Additionally, it specifies the date of creation and the type of article it pertains to, providing a complete reference for the rigging process.

2.2.2 Processing Documents

The *Processing Document* offers detailed instructions on how a component should be machined, outlining the part's geometries throughout various manufacturing processes. It incorporates 2D CAD drawings that visually emphasize the surfaces to be treated. However, the presentation of these visuals can vary depending on the process planner, as there is currently no standardized format in place. The document sometimes specifies the quality control tools and measurements for each geometry, along with the corresponding tolerances. Additionally, it includes crucial details such as the date, article, machine specifications, and symbols that describe the types of measurements being applied.

2.2.3 Quality Control Documents

The *Quality Control Document* specify the required measurements and tolerances for each part to ensure it meets the necessary standards. This documents provide detailed guidelines on how to measure and verify the quality of the machined component. In some cases, quality control information may also be integrated directly into the processing document. The quality control document also outlines the frequency with which certain measurements need to be taken. It includes essential details such as the printing date, article number, machine number, and other critical information to ensure accurate tracking and compliance with quality standards.

2.2.4 Correction Documents

Correction Documents provide a comprehensive overview of the tool processes applied to each surface of the article. Like *Processing Documents*, they may include CAD drawings that highlight the areas being treated, showcasing the specific geometries and tools used on the various surfaces. However, due to the absence of a standardized format, these visuals can vary significantly in appearance, leading to inconsistencies in how the information is presented. Like the other documents, *Correction Documents* also include essential details such as the date, article number, machine number, and printing date.

2.3 Other Tools

In addition to the *ArtHur* instructional documents, there are specific standards, or data sheets, for each machine process. The data sheets provide detailed guidelines on what needs to be done for each process, and also why and how the task should be performed. The standards are prepared by the manufacturing organization and are stored in a binder near the respective machine for easy access.

Each standard is divided into sections, including startup, processing, tool changes, setup, Underhåll Förebyggande Operatör (UFO, Maintenance Preventive Operator), daily inspections, shutdown, cleaning routines, measurement adjustments, common issues, and rework procedures.

3

Research Methods

This chapter outlines the methodological framework used in the study. It begins with the overall research design, followed by a systematic literature review to establish a theoretical foundation. The chapter concludes with an explanation of the qualitative analysis approach, including data collection through interviews and thematic analysis to derive key insights.

3.1 Research Design

The research design was guided by the objectives outlined in Table 1.1, ensuring a structured and goal-oriented approach. As seen in Figure 3.1, it begins with a current state analysis, incorporating a literature study, observations, and interviews with operators, process planners, Scania digitalization teams, and industry experts. This step was crucial for gaining a deep understanding of existing challenges, workflows, and inefficiencies in production instruction systems. Additionally, the literature study provided theoretical insights and best practices, complementing the empirical findings from industry observations and interviews.

The current state analysis was conducted to facilitate benchmarking and provide insights into the industry's status. This enables Scania to evaluate its instruction system against those of other Original Equipment Manufacturers (OEMs) and suppliers and identify opportunities for competitive enhancement. By concentrating on companies within the manufacturing sector, especially those involved in machining processes, the research maintained its intended scope and relevance to the industry.

A requirement specification was then developed based on insights from the initial state analysis. This specification provided a structured framework for designing a new production instruction system, ensuring that the proposed solutions directly addressed real-world issues. Additionally, expert input and an assessment of the state of the art in production instruction systems helped integrate both industry best practices and emerging innovations.

To balance short-term feasibility with long-term transformation, the generated concepts were categorized into "Direct Implementation" and "State of the Art." The first one included solutions that could be used at Scania right away, while the second one looked at more advanced ideas for the future.

These concepts were then tested through a pilot study, involving a specific process and selected operators and process planners. This step ensured that the proposed solutions were evaluated in a real-world setting, allowing for empirical validation and refinement based on practical feedback.

This research method is particularly strong because it prioritizes a thorough understanding of both internal challenges and external industry benchmarks before proposing solutions. By integrating qualitative insights from industry experts and a literature study, the approach ensures practical applicability. Additionally, the quantitative analysis of production requirements and empirical validation through a pilot project contribute to long-term innovation. Ultimately, this method not only addresses Scania's immediate needs but also positions the company competitively within the industry, supporting continuous improvement and digital transformation in machining processes.

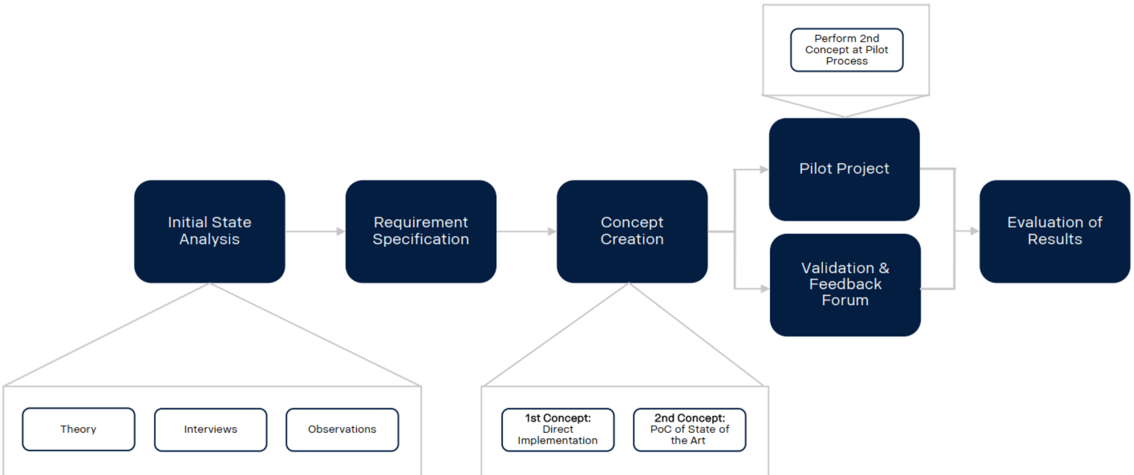


Figure 3.1: Research design

3.2 Systematic Literature Review

A Systematic Literature Review (SLR) is a structured and transparent method for identifying, evaluating, and synthesizing existing research on a specific topic [12], [13]. It is particularly effective for measuring the effects of interventions, re-evaluating evidence, identifying inconsistencies, and guiding future research in well-explored areas. Conducting an SLR prior to empirical research provides a robust theoretical foundation and helps inform the formulation of relevant research questions [13].

For this thesis, the SLR method was chosen to understand the current state of knowledge on production instructions in transmission manufacturing. The process involved defining research questions, developing search strategies, and applying inclusion and exclusion criteria to identify relevant literature in an unbiased and comprehensive manner. This systematic approach ensured credible findings that aligned with the study's scope and revealed knowledge gaps, which guided the design of further empirical work, including semi-structured interviews. While the SLR method provides a solid foundation, it can limit creativity by focusing on existing literature, a consideration taken into account during the review process [13].

The SLR was conducted in a step-by-step manner, tailored to the scope and objectives of the thesis. To ensure reliable and unbiased findings, data was collected following established regulations and methods, including the use of specific keywords, search terms, source selection criteria, and credibility assessments. This systematic approach was applied both prior to and during the semi-structured interviews to ensure the relevance and robustness of the research questions posed.

The review was organized into key thematic areas: *cognitive support, standardization, possible solutions, digitalization initiatives, and ethics*. These topics were selected based on their relevance to research on production instructions in transmission manufacturing and designed to cover both theoretical foundations and practical implications. The structure of the literature review provided a solid framework for understanding the broader context and identifying key factors influencing the development, implementation, and optimization of production instructions.

Relevant articles and data were collected from reputable databases such as Scopus, Semantic Scholar, ScienceDirect, Chalmers Library, and Web of Science. These databases provided diverse academic coverage, ensuring a well-rounded exploration of the topic from various perspectives.

3.2.1 Key Words & Search Terms

Keywords were chosen to reflect the central concepts of the research and to encompass various related terms that could potentially appear in the literature. The list of keywords aimed to ensure a wide-reaching search while focusing on the most relevant topics within the context of production instructions in the automotive industry and associated technologies. Moreover, boolean queries were designed to combine these keywords in different configurations, allowing for an inclusive yet focused search.

- **Examples of Keywords:** Production, Instructions, Information, User interface, Cognitive support, Industry 4.0, Automotive, Trucks, Standardization, Internet of Things (IoT), Lean Manufacturing, Industry, Automation, Work instructions

- **Examples of Boolean Queries Used:**
  - (Production OR Instructions OR Work instructions OR Standardization) AND ("Automotive" OR Trucks) AND ("Industry 4.0" OR IoT OR Automation OR "Lean Manufacturing") AND (Cognitive support OR "User interface" OR Information)
  - ("production" OR "manufacturing" OR "fabrication") AND ("instruction" OR "guidance" OR "direction" OR "protocol") AND ("system" OR "framework" OR "model" OR "architecture") AND ("automotive" OR "vehicle" OR "car" OR "transportation") AND ("efficiency" OR "optimization" OR "performance" OR "productivity") AND ("automation" OR "robotics" OR "technology" OR "innovation")

To refine the search process, Scopus AI, an Artificial Intelligence (AI) research function in Scopus [14], was used to enhance query development by exploring alternative and more specific search terms. This ensured that the queries captured all relevant studies and research areas, addressing potential gaps in the initial keyword selection. The AI tool also helped identify additional keywords and related terms for a more comprehensive literature review. In addition to using keywords and Boolean queries, search parameters were set to include publications from 2000 onward for studies on human cognitive abilities and from 2010 for those related to production instruction systems, ensuring the inclusion of the latest developments in the field.

3.2.2 Source Selection Criteria & Credibility Assessment

It is important to ensure that the sources used are reliable, relevant, and credible. The selection of sources is therefore based on several key criteria to ensure reliable and well-rounded information. In addition, to ensure that the analysis is balanced, the sources will be divided into three categories: supporting, complementary, and contrasting.

A critical aspect of source selection is the expertise, academic background, and qualifications of the author. Authors who are recognized experts in the field or who have significant academic credentials are generally more reliable. Peer-reviewed articles are also preferred for their rigorous evaluation process. Additionally, factors such as the publication date, the publisher's reputation, and the purpose of the text must be considered. For rapidly evolving areas such as digitalization, using up-to-date sources is essential. Finally, Cabells was utilized to verify the credibility and legitimacy of the articles, ensuring their relevance and academic rigor [15].

3.3 Qualitative Analysis

To develop a comprehensive understanding of the current state, a qualitative analysis was conducted. This method involves the systematic gathering of data through direct observations and the interpretation of textual material, guided by a structured, step-by-step analytical process. Qualitative analysis is particularly effective for investigating complex contexts where diverse perspectives are essential to capture. While it is often time- and resource-intensive, it provides in-depth, high-quality insights [16]. In this study, qualitative data were collected using three primary methods: *Gemba Walks*, *Interviews* and *Workshops*. The decision to adopt a qualitative approach was further reinforced by the limited availability of quantitative data, especially given that production instruction systems within machining processes have not been as extensively explored as those used in assembly operations.

3.3.1 Gemba Walk

A Gemba Walk is a fundamental practice in lean management that emphasizes direct observation and engagement with the actual work being done. The term originates from the Japanese word Gemba, meaning "the real place," referring to the place where value is created, such as a factory floor or a production line. It is often paired with the principle of Genchi Genbutsu, meaning "go and see for yourself," which encourages leaders and managers to step away from their offices and experience operations firsthand [17].

The purpose of a Gemba Walk is to develop a deep, firsthand understanding of the current processes, workflows, and challenges by physically going to the source of the work. This practice involves actively observing how tasks are performed, interacting with employees and operators, asking questions, and collecting relevant information to gain insight into daily operations. Rather than relying solely on reports or data, leaders use Gemba Walks to uncover real-world issues, identify inefficiencies, and recognize opportunities for improvement [17].

Effective Gemba Walks are built on four essential elements: Location, Observation, Teaming, and Reflection [17];

- **Location** refers to being present at the actual site where work takes place.
- **Observation** involves watching the processes in action without interfering, to understand the flow and detect deviations or waste.
- **Teaming** highlights the importance of collaboration and open dialogue with employees, encouraging mutual understanding and problem-solving.
- **Reflection** means taking time after the walk to analyze findings, draw conclusions, and determine potential improvement actions.

3.3.2 Interviews

Semi-structured interviews are widely recognized as an effective method for gaining in-depth insights into individual perspectives, as they enable a more nuanced and personalized understanding that goes beyond generalized conclusions [18]. This approach is particularly beneficial because it balances a structured focus on key topics with the flexibility for interviewees to elaborate on relevant ideas, introduce additional points, and provide deeper insights into the subject matter [18]. By combining predetermined questions with the openness to explore emerging themes, semi-structured interviews offer a comprehensive framework for rich, qualitative data collection.

All interviews were recorded and transcribed with the interviewees' prior consent. This approach ensured accuracy in capturing the participants' responses, minimized the risk of misinterpretation, and allowed for thorough analysis of the data. It also enabled the researchers to revisit the conversations as needed, facilitating deeper reflection and comparison across interviews.

3.3.3 Workshops

Workshops are increasingly recognized as a valuable and versatile qualitative research method across various disciplines. They offer a structured yet dynamic environment for participant collaboration and co-creation, enabling the collection of rich, multidimensional data [19], [20]. Eden and Ackermann [20] emphasize that well-structured workshops can serve both as data collection tools and as processes for facilitating organizational change. Through participant interactions and the creation of artifacts such as cognitive maps and decision models, workshops generate diverse qualitative data. Systematic analysis of these materials is essential for drawing meaningful insights.

The workshop process typically includes four key phases: diagnosis, planning, facilitation, and analysis [19]. Effective facilitation and clear role definitions are critical for managing group dynamics and ensuring alignment with research objectives. Data gathered from workshops may include field notes, audio and video recordings, photographs, and physical artifacts like models or sketches [19]. These materials can complement and enrich data from other methods such as interviews and focus groups.

Key advantages of workshops include promoting active participation and co-creation, fostering innovative solutions, and enhancing the depth and validity of research findings when integrated with other qualitative methods [19], [21].

3.4 Pilot Project

Pilot projects play a crucial role in supporting successful organizational change initiatives, particularly when introducing new methodologies or ways of working. They serve as an initial test case that allows an organization to experiment, learn, and adapt before implementing changes on a larger scale [22], [23]. This includes evaluating recruitment, retention, intervention fidelity, adherence, acceptability, and participant engagement [22].

One of the primary benefits of pilot projects is their ability to reduce uncertainty and risk. They create an opportunity to observe how new methods perform in a real-world setting and to identify potential challenges early in the process. This makes pilot projects a strategic tool for informed decision-making and continuous improvement [23]. They help in identifying and solving logistical problems, which can be addressed before the main study, thereby improving its design and implementation. Finally, the results can suggest necessary modifications, increasing the likelihood of success in future trials [22], [23].

When designing a pilot project, the primary aim is to assess the feasibility of the study rather than to evaluate its effectiveness. Key elements to consider include the ability to recruit and retain participants, the extent to which the intervention is delivered as intended, participant adherence, and overall acceptability. It is also important to account for the characteristics of the target population, particularly if the intervention has been adapted for a new or more diverse group [22].

Pilot projects typically involve small sample sizes, which are not intended for estimating effect sizes or drawing conclusions about effectiveness. Instead, the focus is on testing procedures and identifying potential issues before a larger study is conducted [22], [23]. Data collection methods should be evaluated for clarity, reliability, and ease of use [22]. Finally, any analysis should be interpreted with caution, as the findings are meant to inform the design and implementation of future research rather than provide definitive results [22], [23].

4

Case Study

This chapter outlines the methodological approach used to conduct the case study. It describes the context of the pilot production line, the benchmarking process through interviews with industry representatives, and the design and execution of the pilot study. Together, these components detail how empirical data was collected and analyzed to explore the implementation of digital work instructions in a manufacturing setting.

4.1 Soft Turning Process at the PWC line

As part of the case study, interviews and observations were conducted across all of Scania's transmission factories in Södertälje. These initial activities provided an in-depth understanding of the diverse processes within the facilities and enabled the identification of a suitable process that could serve as a candidate for a pilot project. The pilot process chosen was a soft turning operation on the PWC line, as such processes are widespread across production lines. Furthermore, this specific process was identified as a best practice due to its well-developed instructions and the operators' strong commitment to their work. This made it an ideal candidate for a detailed investigation of the state-of-the-art instruction system at Scania's transmission factory and for exploring potential improvements.

The decision to choose a pilot process was informed by the insights gained through these interviews and observations, which allowed for a more focused analysis of the process and the identification of immediate opportunities for enhancement. This approach also enabled the evaluation of potential implementations within a controlled environment, facilitating iterative testing and minimizing risk. While the pilot process provided a valuable testbed, it is essential to first trial concepts with a smaller group to assess their feasibility and effectiveness before broader application and up-scaling.

4.1.1 Implementation of Gemba Walk

Gemba Walks were conducted at the outset of the case study, during which the research team, accompanied by company supervisor Mohammad Haddadzade, toured all transmission factory buildings at Scania Södertälje to gain an overall understanding of the production environment. Additional Gemba Walks were carried out at the selected pilot process line to develop a deeper insight into the specific work context, familiarize with the operators, observe work practices, and engage in dialogue through questions and reflections.

4.1.2 In-house Interviews

The semi-structured interviews included in-house personnel such as process planners, operators, and technicians within the company, see Table 4.1 & 4.2. The interview questions were carefully constructed with the literature in mind, ensuring alignment with key concepts and theories relevant to the study. The questions were then tailored to the specific role and perspective of each participant. For example, operators were asked questions such as "What works best and worst right now?" and "Where do you look at the instruction first?" to understand their hands-on experience with production instructions. They were also asked to identify what aspects of the instructions are easy to understand and which parts are difficult. In contrast, process planners were approached from a creation standpoint, exploring how production instructions are developed, refined, and implemented in daily operations.

Table 4.1: A list of the in-house interviewees, including their field of expertise.

Role	**Interviewee number**
Process Planners	1
	2
	3
	4
	5
Technicians	1
	2
	3
	4
	5
Machining Operators	1
	2
	3
	4
	5
	6
	7
	8
	9
	10
	11
	12
	13

Table 4.2: A detailed list of all the operators who serve as process owners for the pilot project.

Role	Number
Pilot Project Operators	11
	12
	13

4.1.3 Case Study Workshop

To gain deeper insights into the use of *ArtHur* instructions within the selected pilot process, a workshop was conducted with one of the line's team leader's and a technician specializing in tool management. The team leader had previously been interviewed and is listed in Table 4.2, whereas the technician, although not part of the earlier interviews, is included among the in-house interviewees in Table 4.1 due to their participation in the workshop. Other operators who are process owners were unfortunately unable to attend the workshop due to various scheduling and operational constraints.

The purpose of the workshop was to identify the critical information that should be included in the instruction documents, determine which content could be removed or simplified, and uncover any missing features that could improve daily operations.

The workshop took place directly on the production line, fostering an open and relaxed atmosphere that encouraged informal yet productive discussions. Creating an environment with appropriate lighting, adequate space, manageable noise levels, and suitable furniture arrangements is crucial. Ensuring sufficient accessibility and comfort for all participants supports effective knowledge transfer, as these environmental factors significantly influence group collaboration and communication [24].

For the workshop, the relevant documents related to the soft tuning of the selected article were printed. These included two rigging documents, one detailing the machine setup for the article, and the other specifying the tools and cutting inserts used for both rough and finish turning, along with the processing document, the quality control document, and the correction document. Together with the line team leader and the tool management technician, each document was reviewed in detail. Questions were posed regarding the purpose and meaning of various features, including the interpretation and relevance of specific abbreviations in relation to different tasks and stages of the process. The aim was to identify which elements are actively used in practice and which could potentially be omitted or hidden to improve clarity. Furthermore, additional features that would support daily operations were identified and subsequently added to the requirements specification.

The desired changes, new insights, and clarifications regarding the content of the documents were noted directly on the printed copies to indicate the specific areas under discussion. In addition, all comments were documented in digital form in a Word document. There, the feedback was structured according to each document, with an image of the document placed first, followed by the corresponding comments listed underneath.

4.2 Benchmarking

This section describes the benchmarking methods used to gather external input on current practices in manufacturing. Expert and peer company interviews, along with a site visit to an advanced production facility, were conducted to collect qualitative data on digital transformation and process optimization. These activities aimed to complement internal findings and inform the analysis with industry-relevant insights.

4.2.1 Expert and Peer Company Interviews

In addition to in-house personnel, interviews were also conducted with subject matter experts and representatives from other manufacturing companies with processing operations. These external stakeholders offered broader, strategic insights into the current state of the art, emerging trends, and the key challenges and innovations within the field. Their perspectives enriched the study by contextualizing in-house findings within the wider manufacturing landscape.

Table 4.3: Industry experts interviewed, categorized by company type and number of representatives.

Type of Company	**Number of interviews**
Automotive supplier	3
OEM	4
Scania departments	2

4.2.2 Company Visit

To gain a practical understanding of the production systems of other companies and ongoing efforts in digital transformation, a company visit was conducted at a leading manufacturing facility in Sweden. This facility represents a highly advanced manufacturing environment characterized by automation, digital integration, and lean production principles. The factory is part of the Global Lighthouse Network, a recognition issued by the World Economic Forum, and combines Computer Numerical Control (CNC) machining, robotics, and Automated Guided Vehicles (AGVs) to enhance efficiency and precision [25]. This innovative environment made it an ideal choice for the company visit, as it aligns with the objectives of this thesis to explore opportunities for digitalization and process optimization in production systems.

The visit took place on the 12th of March 2025, where the team was given a tour of the facilities, engaging in discussions with key personnel, and the primary objectives for this visit was to:

- Observe the current production processes and workflows at the facility.
- Examine the existing production instruction systems and tools currently in use.
- Identify potential areas for improvement through digitalization, automation, and process optimization.

- Gather insights from company representatives about their challenges and strategies with respect to digital transformation and production efficiency.

During the visit, the two plant factories were explored and production processes were discussed in detail. Notable activities, including the use of traditional and digital work instructions, were observed and discussed with the staff. The team engaged with the company's experts to better understand the technical and organizational aspects of their current systems and how they plan to address the challenges posed by the evolving technological demands.

4.3 Pilot Study

This section describes the methodology used to develop and evaluate two conceptual solutions for a new Production Instruction System at Scania's Transmission Factory. The pilot study involved translating requirements, gathered through interviews, benchmarking, and literature, into concrete concepts using iterative design and prototyping methods. Through brainstorming, concept development, and interface design in Figma, two alternatives were created: one based on direct implementation and another on state-of-the-art development. These concepts were later tested in a real production environment to assess usability, functionality, and alignment with stakeholder needs.

4.3.1 Concept Creation

Two concepts were developed for Scania's Production Instruction System: an improved paper-based standard and a future-oriented digital prototype. Based on defined requirements, the concepts were created through brainstorming, stakeholder input, and prototyping in Word and Figma.

Requirements Specification
A requirement specification was developed by synthesizing insights from interviews conducted at the factory, benchmarking data, and relevant literature. This specification was used to assess and validate the final functionality and usability of the Production Instruction System for Scania's Transmission Factory in Södertälje. The specification compiles all system criteria, categorized as requirements *(R)* or desired requirements *(DR)*, under various subheadings such as functionality, performance, information content, ergonomics, and security. Each criterion is linked to specific stakeholders, including process planners, operators, literature sources, thesis workers, and Scania itself, ensuring that the requirements align with user needs and organizational objectives. The General Data Protection Regulation (GDPR) [26], a data protection law established by the European Union to govern how organizations collect, use, store, and share personal data of individuals within the EU, was also taken into account.

Brainstorming Sessions
The concept creation process, based on the requirements outlined in the specification, began with brainstorming sessions using a whiteboard and Microsoft PowerPoint, a collaborative design tool that facilitated the sharing and visualization of ideas in real time [27]. Iterative brainstorming was preferred, as it allows for continuous refinement of ideas and alignment with practical considerations, leading to a more feasible final solution [28],

[29]. This approach fosters creativity, learning, and flexibility, while enhancing solution quality and error detection, crucial for coordination in complex projects [29].

Feedback from process planners and operators at the pilot process informed each iteration. However, while iteration improves design, it can also increase time, cost, and complexity, leading to rework and planning uncertainties. Excessive iteration without clear goals may hinder progress and decision-making, and rigid tools can impede iteration management [29]. To address these challenges, clear objectives were set for each iteration, balancing continuous improvement with the need for efficient progress.

Creation of Concepts
After the brainstorming and refinement, the concept development phase began, with the work divided into two distinct concepts:

Concept 1: Direct Implementation
For the direct implementation, the primary focus was on designing a standard for creating instructions to improve cognitive ergonomics, as described in Section 5.4.1 of the report and detailed in *Section 4* of the requirement specification, since the majority of these elements can be immediately adjusted under current conditions. The only requirements that were not applicable to the new standard were *Requirements 4.4* and *4.6–4.8*, highlighted in beige and red, respectively, in Figure 4.1. *Requirement 4.4* is partially applicable, as it can be addressed by marking steps in the rigging document; however, it cannot be fulfilled in the sense of displaying the steps one at a time. *Requirements 4.6–4.8* require a smart system, which cannot be implemented using paper-based instructions. The overarching goal of this concept was to align all stakeholders with established standards to facilitate progress toward the implementation of a new system. To achieve this, a thorough analysis of the existing standards was conducted, comparing them with relevant literature and the instruction content requirements outlined in the requirement specification.

4	Ergonomics (Instructions)					
4.1	Color coding of tools	***Each tool category should have a distinct, standardized color code applied consistently across all instructions.***	R		Manual review.	Operators
4.2	Tools used on the same surfaces (unpolished turning and fine turning) should be visually linked for clear identification.	***The system must provide a clear visual link between tools used on the same surfaces (rough turning and fine turning) through color coding, symbols, or annotations, ensuring 100% clarity.***	DR		Manual review.	Operators
4.2	Color coding of adjustable dimensions	***Adjustable dimensions must be highlighted using a predefined and consistent color scheme across all instructions.***	R		Manual review.	Operators
4.3	Color coding of processed surfaces	***Processed surfaces should be marked with a standard color across all visual instructions.***	R		Manual review.	Operators
4.4	Step-by-step guidence for instructions	***All instructions must be structured in a clear, numbered sequence with a logical flow.***	R		Manual review.	Literature & Operators
4.5	Suffciently large text size	***The text size must be at least 12pt for general instructions and 16pt for key warnings or safety notes.***	R		Measure font sizes using digital tools or print layout settings.Confirm that all standard text meets or exceeds 12pt. Confirm that all warnings/safety notes are at least 16pt and clearly distinguishable.	Operators
4.6	Adaptable to different age groups	***Instructions should provide options for text enlargement and high-contrast modes for enhanced readability.***	DR		Manual review.	Literature
4.7	Adaptable to different experience levels	***The system must offer both detailed and simplified instruction modes to accommodate beginners and experienced operators.***	DR		Manual review.	Literature & Operators.
4.8	The instructions shall display task status	***The system should show clear task progression indicators (e.g., Not Started, In Progress, Completed).***	DR		Manual review.	Literature
4.9	Text, images, measurement points shall be visually linked using elements such as arrows, lines, or other graphical elements to enchance clarity and readability	***Instructions must include arrows, lines, or highlights to clearly associate text with images and measurement points. Should follow a standard practice.***	R		Manual review.	Operators
4.10	Only relevant information is displayed	***Instructions should be task-specific, displaying only necessary information for the current step.***	R		Manual review.	Literature & Operators
4.11	Symbols shall follow industry standards where applicable and include explanatory labels when necessary to enhance user comprehension	***All symbols must comply with ISO, ANSI, or industry-specific standards where applicable. Symbols should include brief text descriptions when necessary for clarity.***	DR		Manual review.	Operators
4.12	Reduced and consistent terminology	***Instruction terminology must be standardized and limited to essential terms. A predefined terminology list should be used, reducing variations in phrasing by at least 90% across documents.***	R		Manual review, checking with industry standards and operator knowledge level.	Operators & Thesis Workers
4.13	Key points are highlighted	***Critical information (e.g., safety steps, key measurements) must be bolded, colored, or boxed for emphasis. Should follow a standard practice.***	R		Manual review.	Operators & Thesis Workers
4.15	Appropriate number of information levels	***three levels (e.g., overview, step-by-step details, troubleshooting).***	R		Manual review.	Thesis Workers
4.16	The instruction has simple language	***The language should be concise and free of technical jargon unless necessary.***	R		Manual review, checking with industry standards and operator knowledge level.	Operators & Thesis Workers
4.17	Visualizations should have at least one 3D-picture	***Each instruction must contain at least one 3D-rendered image or model of the component or tool.***	R		Manual review.	Operators & Thesis Workers

Figure 4.1: Section 4 from the Requirement Specification, highlighting Requirements 4.4 and 4.6–4.8.

Concept 2: State-of-the-Art Concept Development
The purpose of developing this concept was to create a foundational model that could serve as a stepping stone for future advancements. This concept is built upon insights derived from the SLR, supplemented by findings from interviews with companies in similar industries and the applicable requirements outlined in the requirement specification. By integrating theoretical knowledge with real-world practices, the concept seeks to bridge the gap between research and practical application.

Furthermore, this concept could serve as a process blueprint if Scania decides to invest in a more digitalized approach to presenting and organizing operator support. It offers a structured framework illustrating how digital tools can improve accessibility and clarity in operator-facing information and procedures.

The requirements that could neither be implemented nor tested in the prototype are marked in red in Appendix A. *Requirement 4.4*, marked in beige, is, as previously mentioned for Concept 1, only partially applicable. It can be addressed by marking the steps in the rigging document; however, full implementation would require a backend system capable of automatically displaying the steps one at a time. The requirements marked in red could not be fulfilled or evaluated because they depend on a complete software infrastructure and a fully developed pilot project, in which the prototype is tested in a real production setting over, at least, an entire workday.

Requirements 6.2 and *6.5* were acknowledged during the development of the concept but were not directly tested in this study. Insights obtained from an OEM with operations comparable to Scania, further described in Section 5.3.1, revealed the use of a hybrid instruction system, combining digital screens with the option to print paper-based instructions. The functionality related to printed materials was not included in the prototype evaluation. Instead, the focus was placed on engaging in dialogue with operators to assess whether the digital solution alone, would be sufficient for practical use, or if there remained a perceived need to retain the ability to print instructions. This was based on the findings mentioned in Section 5.1.3, regarding a hybrid solution.

Design Process

The design for Concept 1 was created using Microsoft Word, a software for creating, editing, and formatting text documents [30], and a pre-made Scania template specifically intended for creating standards. In contrast, the design for Concept 2 was developed using Figma, an online, collaborative, cloud-based design tool. Figma's functionality allows for the creation and testing of designs for websites, mobile apps, and other digital products and experiences [31]. Its online accessibility and real-time collaboration features made it an ideal choice for iterative design and teamwork, allowing the concept to evolve efficiently through shared input and continuous feedback.

The decision to use Figma was based on the goal of showcasing the functional design of the new concept. At this stage, back-end programming was not involved; rather, Figma served as a tool to visualize the user interface and the overall structure. The design file allowed for the creation of multiple pages, each with its own canvas, facilitating easy organization of different parts of the project. Key features, such as adding shapes, text, images, and other layers, along with asset selection through the navigation panel and fine-tuning elements using the properties panel, were essential in this process [31].

Through Figma's prototyping features, various layers of information could be linked interactively, creating a realistic and intuitive representation of how the final product might function.

Prototyping in Figma

Using the design mode in Figma, various features were developed as individual layers, with each layer representing a different page of the concept. These pages revealed new information through user interactions, effectively simulating a realistic navigation experience. Building on the document format used in the pilot process, *ArtHur* documents were integrated into the design as screenshots to visually demonstrate how they would be incorporated into the new system.

The State of the Art Solution Figma prototype was designed to match the dimensions of an iPad Pro 11". However, the prototype was to be displayed on a Galaxy Tab Active2, as this was the tablet available within the department at the time. Since Figma did not support the exact screen dimensions of this device, minor discrepancies in size were anticipated. However, the size compatibility between the iPad Pro 11" and the Galaxy Tab Active2 was deemed sufficient to effectively showcase the functionality of the prototype. The decision not to acquire a new tablet was based on financial and environmental considerations. Procuring a new device would have required entering a two-year lease, which was considered unjustifiable given the limited and temporary needs of the project.

4.3.2 Testing of Concept

To evaluate the effectiveness of the two proposed concepts, each was tested with its relevant stakeholders.

Concept 1 - Direct Implementation
Since the concept primarily affects process planners and their workflow, it was evaluated through a feedback forum rather than a pilot project. Implementing a pilot would have required developing new instructions from scratch to test in production, a time-consuming task that exceeded the project's scope. Instead, the proposed standard was presented in a forum, where process planners could assess its feasibility, identify potential challenges, and suggest modifications or removals to better align it with their workflow.

The standard was distributed to all participants of the Process Planner Leadership Forum allowing ample time for review and identification of strengths and weaknesses. During the Process Planner Leadership Forum meeting, the standard was discussed openly, giving participants the opportunity to share their thoughts. Additionally, a questionnaire was developed to gather further feedback, enabling evaluation of the responses in more detail.

The evaluation of the new standard was guided by the following Key Performance Indicators (KPIs):

- How satisfied are users with the clarity and structure of the new production instruction standard?
- How well does the new standard align with existing production planning processes?
- To what extent does the new standard help reduce errors or inconsistencies in production instructions?
- How much time does the new standard save (or require) in the instruction creation process?

Concept 2 - State-of-the-Art Concept Development
To present the prototype effectively, both the Galaxy Tab Active2 and a large screen located at the production line were used. This setup allowed all participants to view the content simultaneously and engage in discussion without difficulty. Due to scheduling constraints, the presentation was divided into two sessions to ensure maximum participation. However, one of the operators had recently transitioned to the night shift and was therefore unable to attend either session.

The first session included three participants: the line's team leader, a technician specializing in tool management, and the line manager. The second session involved one of the operators, as the other was unavailable due to the aforementioned shift change.

During the sessions, discussions about the prototype were held while navigating through the interface on the screen. Notes were taken to capture feedback, suggestions, and reactions in real time. At the end of each session, participants were also asked to complete a survey evaluating the prototype. The survey focused on its functionality, design, areas for improvement, and feasibility for implementation.

The evaluation was guided by three KPIs:

- Can the information be presented in a format other than paper?
- Is it easier for the operator to navigate?
- Do the operators prefer the new way of presenting instructions?

5 Results

This chapter presents the key findings from the research. It includes insights from the systematic literature review, results from the case study at the pilot line, benchmarking outcomes from industry interviews, and findings from the pilot study. Together, these results form the empirical foundation for the subsequent analysis and discussion.

5.1 Findings from Systematic Literature Review

This section presents the key findings from the literature review, organized into four main areas: cognitive ergonomics, design principles for cognitive support, production instruction systems, and the standardization of work instructions. Each subsection explores relevant concepts, frameworks, and practices identified in the literature, providing insights into their application and importance in the context of production instruction systems. These findings form the basis for further empirical research and the development of the study's research questions.

5.1.1 Cognitive Ergonomics

According to Britannica [32], cognition can be defined as "a state or experience of knowing that can be distinguished from an experience of feeling or willing". It includes all mental activities, both conscious and unconsciousness, through which knowledge is gained. This includes the ability to sense and interpret information (perceiving), identify and understand things (recognizing), form ideas (conceiving), and make logical judgments (reasoning). Essentially, cognition covers all the ways in which information is processed.

Based on the definition of cognition presented by Britannica [32] , Adams and Berlin [33] also state that cognition "is the overall process of handling information" and that cognitive abilities involve skills, experience, generalization, and categorization. Cognitive elements in a workplace relate to sensory and mental inputs that help our brains interpret tasks or find solutions to problems [33]. A well-designed work system can reduce the impact of fatigue by minimizing the probability to perform incorrect or dangerous actions. Fatigue and stress can shift the brain from high-functioning thought to survival mode, leading to mistakes or accidents. Poorly designed tasks can cause chronic fatigue, de-motivation, poor health, and absenteeism. Generally, humans struggle to maintain focus for extended periods. To help maintain attention, it's important to provide enough cognitive support to keep the brain engaged and alert. This can be achieved through visual aids, touch (haptics), lighting, and sounds [33].

Moreover, as automation and technology continues to advance in today's manufacturing industry, the complexity of tasks that operators must perform also increases [34]–[36]. This rapid technology development also suggest that the work operators are expected to perform will include a wider range of tasks, i.e more forecasting and proactive work [36]. Therefore, it is important to find ways to support the operators in term of cognitive load, stress, disturbances handling, and new methods are needed in terms of decreasing complexity in assembly tasks. Human flexibility and the capacity to adapt to operational variations, make rapid decisions, and address deviations from standard production procedures are still favored over robotic alternatives [33]. As stated beforehand, human adaptability and learning don't always prevent mistakes. Misunderstandings, errors, or risky choices can still happen, leading to costly problems or safety risks. In production, using the same assembly line and operators for multiple product variants can lead to confusion and mistakes due to subtle differences between products. This often results in defects and quality issues, leading to extra costs and rework.

5.1.2 Design Principles for Cognitive Support

Designing for cognitive support means creating instructions that engage the human senses [33]. Receiving information, humans have a perceptual limitation and the short-term recall of events is limited [37]. It is therefore important to design work instructions with cognitive support in mind. According to Adams & Berlin [33] people perceive their environment through the five senses, vision, hearing, touch, smell, and taste, with vision being the most dominant. Hearing and touch follow, while smell and taste are less commonly used for conveying information. Essentially, senses gather information about our surroundings by detecting stimuli through specialized receptors, which then send signals via nerves to the brain for processing. In a workplace, the dominant senses that transmit signals to the brain are visual, auditory, and tactile cues, such as vibrations.

The senses
Humans have a horizontal field of view spanning approximately 170 degrees. However,the peripheral areas are mainly suited for detecting movement rather than processing fine detail. Therefore, critical information should be displayed within the central field of vision. Key factors influencing human visual perception include *contrast, color, dark-adapted vision, depth perception, movement detection, and glare.*

Designing visual displays requires carefully considering the *intensity* of the information presented. The light reaching the eyes should avoid glare, but also not be too dim to prevent difficulty in distinguishing contrasts or colors. This is particularly crucial for displays and signs. It is also advisable to use a limited *color-coding* system when conveying critical information [33], [38], or provide an alternative system to ensure that individuals, such as those with color blindness, can interpret the colors accurately. Colors like orange and magenta can symbolize "danger" and "caution," while blue and green can represent "protection" and "cleanness." Combining colors with patterns, such as black stripes, can enhance these symbolic effects. Following specific guidelines for color-pattern combinations can maximize the effectiveness of hierarchical information design [38]. The *strength of lightning* is also important to consider, since different task can require different lightning strengths to be sufficient. There exist specific standards and regulations concerning recommended lightning in different work environments. For humans to be able to distinguish between different symbols from their backgorund, it is important that it exist sufficient *contrast.* This is especially important when it comes to written information and alarm signals. Moreover, the human field of vision must be considered when determining where to place information for optimal perception. Key factors include the proper viewing distance and the required *angle of vision*, which reflects the neck position necessary for comfortable and clear viewing. Visual acuity declines with age, particularly in detecting low contrast, small symbols, and subtle stimuli. This makes effective task lighting and clear visual cues, with sufficient size and duration, crucial when designing tasks, interfaces, and environments for a diverse workforce [33].

Sound effectively complements vision, especially when visual channels are overloaded. It is also useful for capturing attention, warning of danger, indicating distance, and confirming actions as correct or incorrect. However, hearing abilities decline or change with age. Some individuals may struggle to perceive high-pitched frequencies, and hearing loss can also result from prolonged exposure to noisy environments or injury. Therefore, it is essential to design audio cues with these variations in mind. Adams and Berlin [33] suggest that *loudness, pitch/frequency* and *location* are parameters that influence sound and hearing. Loudness refers to sound waves and their different amplitudes, and the ear has limits for how much it can tolerate before being damaged. Pitch, or frequency, determines the "tone" of a sound, and variations in pitch arranged in sequence can be recognized by the human ear as melodies or meaningful signals. Stereo hearing allows humans to locate the direction of a sound by comparing differences in loudness and pitch between both ears. This accuracy enables "sound illusions" that mimic moving sounds, achieved by recording with two microphones spaced like human ears, therefore it is important to consider the location or direction of sound.

The tactile sense, or haptics, allows us to feel pressure, temperature, and vibrations through nerve receptors in the skin. Our hands are especially sensitive, but all skin can detect even the slightest touches.

Clarity, Readability & Consistency

When designing instructions, it is crucial to use clear and concise language to reduce confusion and avoid ambiguous or vague terms [39], [40]. Additionally, instructions should be complete and sufficient, including only relevant information that aligns with the user's capabilities [40], [41]. Repetition should also be avoided, as excessive repetition can lead to confusion and make the instructions harder to follow. [40].

Furthermore, the terminology and symbol used should be consistent throughout the instructions to avoid confusion and support memory [33], [40]. Consistent terminology helps to reinforce mental models, allowing workers to anticipate what comes next and reducing the likelihood of errors [33].

Relevance and Timeliness

Timely access to information is vital in industrial settings, especially when tasks require precise execution. Providing instructions in real-time ensures that operators receive the necessary guidance exactly when they need it, significantly reducing the potential for errors [39], [42]. Real-time, step-by-step instructions allow workers to make informed decisions promptly, minimizing delays and enhancing both efficiency and productivity. When instructions are delivered at the right moment, the workflow remains uninterrupted, ensuring smooth task completion. Any delay in receiving critical guidance can not only disrupt the process but also increase the likelihood of mistakes, undermining overall performance [39],

[40], [42].

Design Parameters
To ensure effective communication, instructions must be organized into clear, sequential steps. This structure enables operators to follow the process efficiently, minimizing the risk of missing critical actions. Key steps, as well as potential error points, should be explicitly highlighted to capture the operator's attention and mitigate common mistakes. It is essential that the design incorporates feedback from operators who have tested the initial instructions, enabling adjustments to be made based on real-world usage and challenges [39]. The instructions should also integrate a user guide, reuse familiar functions and patterns, and ensure intuitive navigation to enhance usability [43].

The timing and focus of information delivery are crucial factors in effective work instructions. Content should be delivered at the appropriate moment, ensuring that operators receive only the relevant information for each stage of the task, thereby reducing confusion and avoiding unnecessary details [41]–[43]. The system should prioritize the essentials, presenting an appropriate level of information without overwhelming the operator. To further enhance clarity, an effective system should use color coding to highlight critical information, while also ensuring that the contrast and intensity are optimized for visibility and accessibility [33].

Finally, the system design must address the diverse needs of users, taking into account factors such as age, vision, and hearing impairments [41]. It is also essential to employ a reduced and consistent terminology throughout [39], [40], [43]. In addition, user experience levels, whether novice or expert, should be considered when designing work instructions. For beginner operators, instructions should be educational and offer clear guidance to ensure they can learn and perform tasks effectively. For expert operators, the system should provide advanced support that enhances efficiency, focusing on relevant information and reducing cognitive load. The system should offer options that cater to both skill levels, ensuring that each operator, regardless of experience, can engage with the instructions in a way that suits their needs, leading to increased usage [33], [40], [41], [44].

For a comprehensive summary of all the design parameters to consider when developing an effective and user-friendly system, refer to Table 5.1, which details the key principles.

Table 5.1: Table presenting a summary of design parameters for cognitive support

User Experience & Usability
Integrated User Guide
Step-by-Step Guidance
Correct Timing of Information
Intuitive Navigation
Reuse of Similar Functions/Use Familiar Patterns
Feedback Integration
Highlighting of Key Points
Display Task Status
Accessibility & Inclusivity
Reduced & Consistent Terminology
Simplified Language
Cater to diverse needs (age, vision, hearing)
Consideration of Experience (novice vs expert)
Visual Design
Present Only Essential Information
Appropriate Number of Information Levels
Color Code Critical Information
Contrast & Intensity

Technology and Advanced Systems for Cognitive Support
To further enhance the effectiveness of work instructions, a variety of advanced systems can be integrated into the process. Picking by Light is one such system that leverages visual cues and sensors to guide operators through each task. By providing clear, intuitive visual indicators, this system ensures that the correct actions are performed, significantly reducing the risk of errors and improving overall task accuracy [33], [42]. Similarly, Pick by Voice offers spoken, real-time instructions, allowing operators to remain fully engaged with their tasks without the need to constantly refer to a screen. This voice-directed guidance not only improves focus but also ensures that tasks are executed with precision, all while allowing operators to work hands-free [33].

Another technology is Poka Yoke, a robust mistake-proofing system designed to preemptively identify and alert operators when a potential error is about to occur. By providing immediate feedback and alerts, Poka Yoke helps to avoid costly mistakes, thereby improving both operational productivity and product quality. Additionally, Barcode Systems present a cost-effective alternative to more complex light-based systems by utilizing optical scanners to deliver real-time data on parts and quantities. This ensures that operators have access to accurate and up-to-date information, streamlining workflows, improving efficiency, and preventing inventory discrepancies [33].

These advanced systems, combined with traditional carriers of information, are essential for optimizing work instructions, with their effectiveness often being determined by the type of information carrier used. Information carriers can be classified into three categories: mobile, semi-mobile, and stationary [42]. Mobile carriers provide flexibility and portability, allowing operators to access instructions across various locations. Stationary carriers are fixed in one place and offer consistent access to information within a specific area. Semi-mobile carriers offer a balance, combining some degree of mobility while remaining anchored to a designated space. The choice of an appropriate carrier depends on the specific task requirements, the work environment, and the nature of the information being conveyed. Integrating the right carrier with advanced systems ensures that operators have timely, accurate, and contextually relevant instructions, improving overall efficiency and reducing the risk of errors [42].

Further advance systems can be implemented, such as Adaptive User Interface (AUI). Implementing such a system can enhance digital instruction systems in manufacturing by reducing cognitive load and improving efficiency. These interfaces adjust to individual operators' needs, experience levels, and cognitive load, preventing information overload and speeding up task execution. Personalized interactions increase engagement and job satisfaction, while real-time feedback helps operators improve performance [45].

However, challenges arise when multiple operators need to the AUI system simultaneously, complicating user identification and customization. Integration with Industry 4.0 technologies, such as AI, IoT, and data analytics, can address these challenges by predicting operator needs and adjusting the system accordingly. Ultimately, adaptive Human-Machine Interfaces (HMIs) can drive higher productivity, fewer errors, and better worker well-being, supporting the goals of lean manufacturing and digital transformation [45].

5.1.3 Production Instruction Systems

Traditionally, instructions have been presented on printed papers. However, with the rise of smarter automation, partly driven by Industry 4.0, machining processes are becoming more complex. This shift places greater demands on production staff, as their tasks are also becoming more challenging since they need to work with more complex machines and have more knowledge about the automation. This shift requires the adoption of digital work instructions to support high-quality work and maintain competitiveness in the market [46], [47].

To enhance operational efficiency and knowledge transfer, companies should prioritize investment in digital work instructions, gradually phasing out traditional paper-based systems [47]. Digital instructions are particularly advantageous for tasks that require frequent updates or are subject to rapid changes. Compared to paper-based methods, animated and interactive digital instructions provide more comprehensive information, reduce cognitive load, and offer a more engaging learning experience. The interactivity inherent in digital instructions also allows operators greater self-control over their learning process, potentially boosting motivation and improving learning outcomes [47].

While the benefits of digital instructions are clear, research on their comparative effectiveness in manufacturing settings remains limited [47]. Existing studies, however, suggest that digital tools, such as text, 3D animations, and Augmented Reality (AR), significantly enhance work performance by reducing error rates, shortening task completion times, and improving overall efficiency [46], [47]. Specifically, AR-based instructions provide robust cognitive support, especially for less experienced workers, and are highly effective in reducing cognitive load, which in turn accelerates the learning process [46]. However, when it comes to presenting digital and paper-based instructions simultaneously may increase cognitive load and divide attention, potentially hindering learning and reducing overall effectiveness [47]. This consideration is therefore important when designing instructional systems.

As companies adopt digitalization, integrating advanced systems fosters innovation, streamlines operations, enhances supply chains and communication, optimizes assets, and boosts productivity - ultimately driving profitability and growth [48]. To fully realize these benefits, digital work instructions must account for task complexity and user capabilities, supported by the development of employees' digital skills [49]. These systems must also be robust enough to withstand harsh industrial conditions, including gases, humidity, temperature fluctuations, and varying climates [50].

With technology advancing rapidly, user needs and expectations are evolving just as fast. This calls for a shift from a techno-centric approach to a human-centric one, where design and implementation are rooted in human values and address ethical concerns such as privacy, autonomy, and trust [51].

By bringing these considerations to the forefront, it is possible to ensure that technological solutions not only meet functional requirements but also adhere to established ethical principles. This approach is crucial for cultivating user trust and promoting wider acceptance, thereby ensuring that technological innovations are not only sustainable and user-centered, but also ethically sound and socially responsible [51].

5.1.4 Standardization of Work Instructions

Standardization is a fundamental driver of consistency, efficiency, and continuous process improvement [52]. When employees rely on poor-quality work instructions, they become less efficient and experience lower job satisfaction. The negative impact of poor-quality data and information extends beyond individual performance, contributing to decreased customer satisfaction, increased operational costs, inefficient decision-making, and overall reduced performance [40]. In contrast, by establishing standardized processes, organizations lay a foundation for both stability and adaptability, essential for maintaining high quality across global production [6].

Standardization also supports continuous improvement [33], by enabling controlled experiments to assess the impact of process parameters [52]. Furthermore, it streamlines infrastructure by reducing the need for extensive support systems, improving knowledge transfer, promoting collaboration across roles and departments, and minimizing duplication of efforts [52], [53]. By removing the reliance on individual approaches, standardization reduces the cognitive load associated with recalling personalized methods, leading to greater efficiency and ultimately enhancing productivity [33], [52].

While Standard Operating Procedures (SOPs) play a crucial role in ensuring consistency, efficiency, and quality in production processes, they can limit worker autonomy, which may negatively impact motivation and creativity. Research indicates that SOPs, by providing rigid guidelines, can diminish intrinsic motivation, reducing workers' sense of responsibility and self-determination. However, an effective way to counteract this is by actively involving workers in the development and refinement of SOPs. This collaborative approach fosters a sense of ownership and control, thus improving both motivation and creativity while maintaining the essential benefits of standardized procedures [52].

From a continuous improvement perspective, worker involvement in the design of SOPs ensures that these procedures are not only practical and efficient, but are also closely aligned with the realities of daily tasks. This participation serves to enhance intrinsic motivation by fostering a sense of autonomy, competence, and relatedness among workers. Furthermore, allowing workers to engage in the development of SOPs is particularly important, as it cultivates their sense of agency and the belief that they can make a meaningful impact on the processes they are directly involved with. Such engagement is a critical consideration when designing new instruction systems, for instance. However, despite its theoretical benefits, practical constraints, such as time limitations and production pressures, often inhibit substantial worker involvement, which can lead to disengagement, diminished motivation, and ultimately job dissatisfaction [52].

5.2 Findings from the Case Study

This section presents the empirical findings from the conducted case study. It includes insights gathered through Gemba walks, interviews, and workshops, highlighting observed challenges, current practices, and opportunities for improvement within the studied environment.

5.2.1 Gemba Walk

The Gemba Walks conducted in the transmission factory buildings and in more detaile at the selected pilot line offered the research team valuable firsthand insight into the layout, workflows, and overall operational context at Scania Södertälje. These observations provided a deeper understanding of the production environment, revealing the complexity and interdependence of the various processes involved.

Production Plant Gemba Walk
DX is divided into three separate buildings, each dedicated to producing different components for the gearbox. The buildings are located in close proximity to one another, within walking distance-separated only by a small road. All three buildings contain areas for hardening processes; however, these areas vary in size and usage. This suggests that certain hardening facilities are utilized more extensively than others. Some lines also have inductive hardening processes and therefore do not use the larger hardening machines.

The production lines across the different buildings follow a generally consistent structure. Typically, each line begins with a series of soft machining processes. Once this stage is complete, the components undergo hardening. If inductive hardening is used for the component, this process is integrated directly into the line. Otherwise, the components are transported to a separate hardening area. Following hardening, the components continue through a sequence of hard machining processes.

The number and type of processes included in both the soft and hard machining stages vary depending on the specific component being produced, leading to some differences between lines. There is no manual handling between the machining processes, component transitions are fully automated utilizing a gantry- or conveyor system.

When components are ready for hardening, they are collected using a pallet lifter with an attached train, loaded, and then transported to the appropriate hardening area. Once hardened, the components are returned to the hard machining section of the line and reintroduced using an ergonomic manual lifting tool. The component then proceeds through the hard machining processes before being lifted off the line and packed into wooden boxes with hard plastic separators.

The working environment in the production buildings for operators can be somewhat dirty and noisy. A distinct smell of lubricants is noticeable in several of the buildings, and the presence of hardening departments in some areas contributes to higher temperatures and elevated sound levels. Because of the hardening processes, one of the buildings and parts of the other buildings have high levels of carbon monoxide. This makes it impossible for pregnant women to work there.

The level of organization varies between different production lines. Some lines appear more structured and are equipped with better facilities for breaks, team meetings, and access to computers and screens. In certain buildings, renovations have been carried out to create dedicated pulse meeting areas, separated from the production floor by walls. These spaces often include large screens for team use during meetings, as well as more spacious seating areas where teams can gather for discussions, take breaks, or hold structured pulse meetings. However, there are also lines that lack this kind of setup. Instead, they may only have a stationary computer, a whiteboard, and a smaller seating area located directly adjacent to the production line and its ongoing operations.

One consistent feature across all production lines, however, is the presence of a whiteboard used to communicate status updates. They are usually located close to the pulse area and the processes. These boards provide an overview of the current production situation, allowing upcoming shifts to understand what has occurred during previous shifts, also called UFO. Teams also use the whiteboards to pin important documents or notices. Typically, the boards are structured with taped sections and labeled headings in permanent marker or printed text, providing clear guidance on where and how information should be recorded.

Another key observation from the Gemba Walk was the varied use of the *ArtHur* documents across different production lines. The walk offered a first impression of how these documents are utilized in practice, revealing that they appeared in significantly different formats depending on the line, product components, and product families. In most cases, the documents were attached directly to machines using magnets. Some lines used plastic folders to protect the papers, while others had the documents fastened directly without any protection. Some lines also had several documents for different product components attached to the machines, suggesting that they did not only display the documentation for the component being produced at the time of the Gemba Walk, but also for other components regularly manufactured on the same line. Notably, some machines or processes did not have any visible documentation at all, raising questions about whether those documents were stored elsewhere or simply not in use.

The content and appearance of the documents also varied considerably. Some were very simple and lacked complete information, while others were detailed with measurements and tolerances. Visually, some included color-coded elements, 3D model visualizations of components and tools, whereas others only featured sectioned technical drawings.

Pilot Process Gemba Walk
Subsequent Gemba Walks at the selected pilot process enabled the team to gain a deeper understanding of the specific work context, become familiar with the operators, and observe daily work practices in action. These interactions created opportunities for meaningful conversations, during which operators could share their experiences, raise challenges, and reflect on current procedures.

The selected pilot process line stood out as being notably organized compared to other observed lines. All relevant documents, such as the rigging document, tool data, processing instructions, quality control documentation, and correction records, related to the specific product component being produced were neatly attached to the machines using plastic folders with integrated magnets. This practical setup allowed operators to easily remove documents for manual measurements and reattach them without the added step of handling loose magnets. Additionally, all measurement protocols generated by the automated measuring machine were also affixed to the machine alongside the *ArtHur* documents, ensuring that all necessary information was clearly visible and easily accessible at the point of use. Standards developed by the manufacturing group were also available, providing detailed explanations of what tasks should be performed, how they should be carried out, and why they are necessary. These standards covered various operations, uch as rigging or tool changes, and were organized in binders for each component of the product. The binders were stored in a cabinet located near the machines and the meeting area.

The Gemba Walk also provided the opportunity to closely observe how different documents are used in practice. It became evident that the most frequently used document by the operators is the *Quality Control Document*, particularly during stable, cyclic operations when the process is running without issues. The *Quality Control Document* is considered a governing document that directs operational adjustments - if a measurement deviates from the specified values, machine parameters must be updated accordingly. This document is used for manual measurement of components. Manual measurements are carried out at predetermined intervals, with the frequency varying depending on the component's tolerance requirements, the specific process, and its position in the overall production sequence, since tolerances typically become tighter in later stages of production. Generally, manual measurements are performed on every 10th or 20th processed component. The required frequency, along with the specific measuring tool to be used, is clearly stated on each quality control document.

In addition, the production system is pre-programmed to follow these measurement frequencies. The gantry system automatically diverts the components selected for measurement, ensuring compliance with the set intervals. More extensive measurements, performed using an automated measuring machine, are conducted once per shift and after a setup for a new product component. In these cases, the operator places the component on a trolley and transports it to the measuring room or the automated measuring machine. The system then generates a measurement protocol that highlights any deviations or out-of-tolerance values.

When setting up for a new component following the completion of another, the rigging document is the most important reference. As the production follows a batch-based system, setup operations are not performed daily but typically occur around two to three times per week. The duration of these setups can vary significantly depending on the extent of the changes required in the machine. Setup times generally range from approximately 45 minutes to up to two hours.

During rigging operations, operators are required to replace various parts of the machine, including the cutting tools. Cutting tool changes also occur during regular processing, either after a predefined number of operations or in response to tool breakage. Then the rigging document is most important, in combination with the standard where the operator finds more detailed instructions on how to perform the rigging. The work is not reffered to as cyclic, since it only happens a few times per week.

The *Processing Document* and the *Correction Document* are not used cyclically in daily operations. The processing document is primarily used by technicians when changes need to be made to the machine program, as it contains all the relevant measurements associated with the specific machining process. The *Correction Document* is mainly used for troubleshooting, helping operators or technicians identify which cutting tools influence specific surfaces or areas of the component.

The insights gathered during the Gemba Walks contributed to a grounded understanding of both broader patterns and local variations, forming a strong foundation for further analysis and development within the case study.

5.2.2 Interviews

The current production instruction system possesses several strengths that positively impact operational efficiency and user experience. Notable features include color coding, which enhances readability and allows for quick identification of key information. Similarly, 3D images provide valuable visual guidance, helping reduce errors and improve comprehension. However, both features are inconsistently applied across departments, limiting their overall effectiveness.

Another appreciated aspect is the use of portable paper instructions, which provides flexibility as operators can carry the instructions between workstations and attach them to machines. Additionally, technical drawings, both 2D and 3D, are highly valued for their clarity and accuracy. However, depending on the operator's level of expertise, these can sometimes be difficult to understand. Laminated documents contribute to durability and legibility over time, ensuring that essential instructions remain intact in a demanding production environment. Yet, this feature is also applied inconsistently.

Operators rely heavily on documentation throughout their workday, particularly rigging and processing instructions, which are vital for rigging, quality control, and troubleshooting. These documents are accessed through *ArtHur*, the central system used for instructions. Depending on the workstation and operator preference, instructions may be printed, laminated, or stored digitally. Experienced workers tend to use the instructions less frequently due to their familiarity, whereas novice operators rely on them more heavily. However, a general observation is that the current system works well for experienced workers, likely due to their expertise and familiarity, which may not be the case for new employees.

Despite these strengths, several challenges and inefficiencies exist. One key issue is the inconsistent formatting of instructions. Although standard templates and formatting guidelines do exist, process planners are either unaware of them or choose not to use them consistently. This lack of adherence leads to variations in font, structure, and image style, making documents harder to interpret and more prone to errors. Process planners note that this inconsistency complicates both the creation and understanding of instructions. Furthermore, combining multiple pages, that belong to the same instruction, into a single document is often not possible, resulting in lost or misaligned pages during printing.

The *ArtHur* system itself presents several limitations. Both operators and process planners find it slow and unintuitive, especially for new users. *ArtHur* lacks features such as automatic update notifications, revision tracking, and integration with other systems like CAD (e.g. CATIA V5) and EAM systems (e.g. *Maximo*). This poor integration results in excessive manual data transfer, contributing to delays and inaccuracies. For instance, process planners report difficulties when exporting content from CATIA V5 to *ArtHur* due to formatting issues, which affect the quality and clarity of the final instructions. Additionally, *ArtHur* does not support opening multiple documents simultaneously, which makes it difficult for the user to compare them.

The structure and content of the instructions also receive mixed feedback. While some operators appreciate the level of detail, others find them overly complex or overloaded with redundant information. Essential data such as tool numbers, tolerances, and references are sometimes buried in excessive detail, making it difficult to quickly identify relevant steps. Furthermore, the language and symbols used in technical drawings are occasionally difficult to understand. While operators suggest simplification, process planners attribute this to a knowledge gap and emphasize the need for better training on commonly used symbols.

Issues related to document updates further hinder efficiency. Operators sometimes work with outdated paper instructions, unaware of changes due to the lack of update notifications. Old documents are not always discarded properly, leading to confusion. Moreover, many operators are unaware of *ArtHur*'s search functionality, leading to unnecessary time spent locating instructions. The manual process of updating instructions across multiple documents further increases the risk of inconsistencies and errors. However, the search tree in *ArtHur* is a well-appreciated feature.

The printing process is time-consuming, prompting a shift toward digital screens. While this saves time, it introduces its own challenges, particularly when tools and instructions are not updated in sync. This is especially problematic in quality-sensitive operations, where measurement errors may occur due to misaligned information. Process planners also point out the excessive time spent editing documents in *ArtHur*, especially when adjusting tables or formatting text, contributing to workflow inefficiencies.

In the measurement room, updates are sometimes made independently of *ArtHur* and are not communicated back to the system, resulting in discrepancies. Likewise, when suppliers discontinue tools, these changes are often not reflected in *ArtHur*, creating confusion about inventory and tool availability.

In summary, while the current instruction system has beneficial elements such as visual aids, portability, and support from team leaders, it is undermined by outdated tools, poor integration, inconsistent formatting, and a lack of standardization. Both operators and process planners recognize the need for clearer, more uniform instructions and better system functionality to ensure efficient and accurate operations. Addressing these issues through better system design, standardized templates, training, and improved software integration will be key to enhancing performance and reducing quality risks.

Insights from the Pilot Process
The pilot process involved operators with varying levels of experience. However, operators demonstrated a high level of interest and engagement, allowing them to develop a strong understanding of the process. The current instruction system integrates visual elements such as 3D images and color-coded information to enhance clarity and usability.

The *ArtHur* system primarily provides information on what something is, but does not offer guidance on how tasks should be performed. While detailed task execution standards exist, they have not yet been integrated into *ArtHur* and are instead managed by production, stored in a physical binder at the machine. This setup presents an opportunity to improve the integration and accessibility of digital work instructions within the production environment. At this specific station, operators mention that they prefer physical binders over digital formats, emphasizing the need for instructions to be readily available at the machine. However, there is also a positive attitude toward new technology among some operators, indicating potential openness to digital solutions if they are designed to be user-friendly and seamlessly integrated into the workflow.

Several challenges exist regarding work instructions. Blueprints and technical drawings are highly complex and require a significant level of expertise to interpret. The current three-day training on reading blueprints and measurement protocols is deemed insufficient, and additional training is necessary. Furthermore, CNC training lacks detailed guidance on interpreting technical drawings.

Accessing and using instructions within *ArtHur* is generally straightforward, though tolerances and measurements remain the most critical aspects. Operators prefer 3D images to understand components and dimensions, and color coding significantly enhances comprehension, particularly for new employees. Notably, the introduction of color coding and 3D images was suggested by the operators themselves. When reviewing a document, they generally begin by checking the date, then the drawing, followed by the 3D image.

To enhance the instruction system, several improvements are recommended. Manual measurements should be distinctly separated from machine-generated dimensions within documentation. Additionally, incorporating a list of symbols in *ArtHur* would help operators better understand technical drawings, as some tend to overlook symbols and focus solely on measurements and tolerances. Providing step-by-step guidance would also be beneficial for rigging operations. While such instructions do exist today, they are currently separate from the *ArtHur* documentation. Production develops data sheets that outline critical tasks, which consists of manufacturing personnel responsible for preparing these guidelines. These data sheets are compiled in binders specific to each process, stored in cabinets close to the machine.

Support and problem-solving mechanisms are in place to assist operators. Assistance can be requested via email from process planners, who generally provide prompt responses.

Operators can also seek help from team leaders, more experienced colleagues or technicians working directly on the production lines; however, these technicians are only available during daytime shifts and not during night shifts. As a result, operators often rely on their own experience to diagnose tool-related issues and carry out troubleshooting independently. For these kind of operations operators as well as technicians have mounted that they would appreciate more supportive features to support when trouble shooting what has gone wrong.

Regarding documentation format, paper instructions are stored at machines, laminated for durability, and discarded when an article is updated. Digital alternatives, such as Quick-Response (QR) codes, have been tested for daily check-tasks but were not well received. Operators were hesitant to use their personal mobile phones for work-related activities, and some experienced difficulty reading digital formats. Additionally, while there is some resistance to digital tools in this setting, there are also signs of openness and positive attitudes toward their potential benefits - largely influenced by how examples of such solutions were presented.

Feedback and continuous improvement efforts are supported through weekly improvement meetings held on Mondays for one hour. These meetings serve as a platform for discussing potential enhancements. While the group manager occasionally participates, Team Leaders typically facilitate discussions and relay feedback via email or Microsoft Teams, a workspace for real-time collaboration and communication [54]. Challenges frequently arise with new articles, particularly new articles, where incorrect tolerances are often discovered during rigging, leading to mismatches between tolerances, measurements, and *ArtHur* data.

Measurement and quality control procedures are well-defined. Soft-turn measurements are performed every tenth piece, approximately every 25 minutes, taking around three minutes per measurement. Measurements using Coordinate-Measuring Machines (CMMs), which take approximately 30 minutes, are conducted once per shift for quality control. While some machines have automated rigging capabilities, others require manual setup.

Key Takeaways

- **Blueprints/technical drawings are too complex** — need clearer visual aids and better training.
- **Operators prefer 3D images and color coding** for clarity.
- **Digital solutions face resistance**, primarily due to usability and accessibility issues.
- **Instructions must remain at the machine**, as operators need them **physically available** and **portable**.
- **Regular improvement meetings help**, but issues with new articles persist.
- **Measurement protocols and tool impact need better integration** into instructions.

Insights From Another Department Using ArtHur
An interviewee working as a process planner in the engine manufacturing department at Scania in Södertälje described operations that closely resemble those of the transmission factory. The department is responsible for the strategic production of engine components and contributes to the product development process by providing expertise related to the components they manufacture. The main difference lies in the nature of the components, engine-related rather than transmission, as well as some variations in specific processes. The interviewee's role includes ensuring that procured machines meet quality standards, and involves preparing and maintaining *ArtHur* documents, ensuring they are well-structured, visually clear, and up to date.

ArtHur is used as the main instruction system within the department, but it is viewed as outdated and inflexible. This is based on the perception that the software interface appears old and that many tasks require manual effort, such as trimming drawings before importing them into the system.

Standardized templates are not employed, leading to variations in documents across different departments and individuals. While a consistent structure is generally followed in terms of the document types available to operators and technicians, such as rigging documentation, wear part information, and quality-related documents (e.g., measurement frequencies, tolerances), the instructions often include technical drawings and, in certain cases, real images. Although information from machine suppliers is sometimes incorporated, the creation of instructions is not a collaborative process. Step-by-step instructions are not widely implemented. Based on observations, the use of color coding and 3D images is absent. Process planners are tasked with preparing documents using *ArtHur* and tools like CATIA V5, with other software selections varying according to individual user preferences..

As in the DX department, instructions are printed on paper. However, unlike most DX departments, printed instructions here are produced during the rollout of a new article or component and then archived in binders for future use, and not thrown away.

There are no formal standards for documentation development. Updates to instructions are planned and communicated informally (e.g., "changes will happen Wednesday at 13:00"), with operators being notified directly. However, change tracking in the documentation is not practiced. Updates typically rely on ad-hoc feedback, mainly triggered by production issues.

There appears to be no structured process for training new staff in using work instructions. New employees are generally expected to have CNC experience and to learn through on-the-job training by shadowing experienced colleagues. There is no formal introduction to the *ArtHur* system; instead, users learn through self-guided exploration.

Some digital integration exists, such as qs-STAT, a statistical analysis software by Q-DAS (Hexagon) used for evaluating and visualizing quality-related production data [55], which automatically collects quality data from machines. Beyond this, the digital maturity and integration of tools are described as limited.

ArtHur is used for instruction presentation but is not well integrated with other systems.

The software is perceived as outdated and difficult to work with. Greater integration with tools used in document preparation, such as CATIA V5 and *Maximo*, is seen as a potential improvement to simplify workflows.

Interview with Smart Factory Lab at Scania
The Smart Factory Lab at Scania functions as an internal innovation hub, supporting Scania Production & Logistics (P&L) by evaluating and implementing cutting-edge technologies. A key criterion for their involvement is that only technologies considered genuinely innovative fall within their scope. If a solution is not deemed sufficiently novel, it is not their role to support its implementation in production. Consequently, the topic addressed in this thesis does not fall directly under their area of responsibility.

The interviewee, an expert in work instructions within the assembly department, has extensively studied the development and application of work instructions in production. Their insights provided a deeper understanding of current practices and challenges in the field, particularly in relation to the use of paper-based instructions and the limitations of digital solutions in some contexts.

Despite advancements in digital tools, the interviewee noted that many companies still rely on paper-based work instructions. In some cases, paper is seen as more practical, particularly in environments where mobility is needed. For stationary work, digital screens can be more appropriate. There is also uncertainty about how effective current instructions truly are, and introducing change among personnel remains a significant challenge. One example of inefficiency raised during the interview was the large volume of paper printed daily, often at high cost due to color cartridges, with each instruction sheet typically used for only a few seconds before being discarded.

To illustrate how work instructions and learning processes are currently applied in practice, the interviewee described the typical structure of onboarding in assembly work. The training process begins with the trainee observing the workflow, followed by an explanation from the trainer about what is being done and why. Next, the trainee performs selected tasks while verbalizing their reasoning. In the final stage, the trainee completes the full sequence independently, with the trainer providing corrective feedback when necessary. This hands-on approach is designed not only to enhance technical understanding but also to promote reflective learning.

Organizational Challenges Impacting Instruction Efficiency
The primary challenge with the current system lies in training and the varying levels of competence across the workforce. Addressing these gaps in knowledge and experience could significantly improve both efficiency and user satisfaction. This issue is particularly critical given the high turnover rates among operators, which aggravate inconsistencies in competence and proficiency. A new system must, therefore, be intuitive and accessible for both new and experienced workers. This will ensure smooth transitions and support varying skill levels, maintaining operational efficiency while reducing the need for extensive training.

Throughout the interview phase, it became clear that certain organizational issues are contributing to inefficiencies in the instruction system's design and functionality. One key issue is the inconsistency in training, particularly in reading and interpreting *ArtHur* instructions. When asked about their training in technical drawings, symbols, and their meanings, operators shared varied responses. Many had prior experience from vocational schools, CNC machining programs, or previous work in machining processes, which helped them understand technical drawings and measurement symbols. Notably, operators who received training at the vocational school in Södertälje spoke highly of its quality.

Several operators mentioned that the speed of their learning often depends on the experience of the assigned mentor. This mentorship greatly influences how quickly new operators learn to operate machines effectively. Some operators even referred to "The Black Book," a comprehensive guide to CNC machining, to better understand specific symbols. Interestingly, many operators had never heard of this resource, yet they acknowledged its potential value.

These discrepancies in knowledge stem from differences in prior education, work experience, and the quality of mentorship. A key takeaway is that there is significant variability in operators' ability to interpret technical drawings and symbols, which is crucial for effectively using *ArtHur* instructions and operating machines.

Operators generally agree that the learning curve is influenced by an individual's interest and willingness to learn. Most operators, technicians, and team leaders are eager to share their knowledge, provided that trainees ask questions and demonstrate a genuine interest in understanding processes, troubleshooting, and problem-solving. However, there was one instance where a team leader refused to share certain insights, suggesting that some knowledge should come with experience rather than formal instruction.

To address these challenges and ensure long-term success, a standardized and structured training program should be implemented. This program should include formal instruction on interpreting technical drawings, measurement symbols, and best practices for using *ArtHur*. Additionally, a more consistent mentorship system is necessary to bridge knowledge gaps and improve learning outcomes.

Another organizational challenge identified during the interviews with process planners is the limited understanding of certain program functions, particularly regarding file exports from CAD systems to *ArtHur*. While standards for exporting technical drawings exist, including guidelines for font size, image dimensions, and symbol usage, these are not always followed. Process planners noted inconsistencies in the formatting of exported files, such as changes in font size, missing elements, or visual discrepancies in *ArtHur*.

One key issue is the outdated nature of the established standards, which have not been updated since 2018. Many process planners were unaware of the existence of these standards, leading them to follow outdated structures. Additionally, the lack of formal training in *ArtHur* has contributed to inefficiencies. Currently, there is no dedicated course or structured education program to teach process planners the capabilities and limitations of *ArtHur*, nor to share best practices. As a result, most process planners rely on trial and error or informal mentorship to learn how to use the system, which leads to inconsistencies and inefficiencies.

Process planners also expressed frustration with the handling of specific operations, such as documenting tool replacements. There is uncertainty about how to document when an outgoing tool should be used until the remaining stock is depleted before switching to a new one. To address this, standardized procedures are needed. One potential solution could be to integrate *ArtHur* with *Maximo*, the tool inventory system. This would allow process planners to specify both primary and backup tools, ensuring a seamless transition when the primary tool is out of stock.

Furthermore, the quality team and process planners responsible for preparing article documents must maintain continuous communication, particularly regarding dimensions and tolerances. To streamline this process, an automated notification system could be implemented to ensure timely updates between the measurement room, process planners, and *ArtHur*, reducing the risk of misalignment and quality issues. This was a proposal generated by technicians.

The communication of updates to *ArtHur* documents is another area that requires attention. Currently, process planners use different methods to relay updates. Some inform the team leader in person, while others send emails, making it the team leader's responsibility to communicate changes to operators. Some process planners highlight updates in color and include text boxes explaining modifications, which has proven effective, especially when operators rely on familiarity with the documents rather than frequently checking them for changes.

However, ensuring that operators on subsequent shifts are informed of updates remains a challenge. Currently, shift handovers are the primary method of communicating relevant information. This process could be standardized and improved to ensure that operators always have access to the latest instructions.

When it comes to printed *ArtHur* documents, there is inconsistency in how they are stored and displayed across production lines. While the standard is that all necessary documents should be clearly displayed on the machine, observations reveal that this is not always followed. Some documents are scattered across desks and shelves, while others are stored in large binders that may contain outdated versions. This can cause confusion for operators about which documents are relevant and should be used.

Moreover, outdated documents must be discarded when a new article is introduced to the line. However, some production lines simply place the new document over the old one in a plastic folder, which poses a risk. If the new document slips out without the operator noticing, the old instructions could remain visible, leading to the use of incorrect measurements and potential defects in the final product.

Identified Areas for Improvement/Suggestions
Several key areas have been identified to enhance the efficiency and usability of the current instruction system. Insights from operators and process planners have led to valuable suggestions aimed at refining the system and addressing its limitations.

1. Standardization

A significant concern raised by both operators and process planners is the need for better standardization in the instruction system. Operators have stressed the importance of clearer formatting and improved organization to enhance usability. Process planners concur, emphasizing that standardized templates would improve clarity and consistency across all instructions, making them easier to follow and more reliable. Standardization is seen as essential to streamlining the process and ensuring a uniform user experience.

In addition, process planners suggest adopting a structured approach to discussing updates to instructions during Local Management Team (LMT) meetings or process planner manager forums. This would ensure that updates are properly coordinated and in line with the needs of operations.

2. Accessibility and Digital Tools

Improving the accessibility of instructions is a critical area for enhancement. Operators have highlighted the need for quicker access to instructions, proposing an upgraded search function in *ArtHur*. Additionally, some operators have suggested the adoption of digital tools, such as tablets or iPads, to enable faster access during operations. However, resistance to new technology must be addressed to facilitate smooth adoption. Not all operators are in favor of this transition, so a comprehensive strategy to ensure a seamless shift to digital tools is necessary.

Process planners have expressed the need for the ability to have multiple documents open simultaneously within the system would be a valuable feature. This would make it easier for process planners to compare and update different instructions without needing to open and close documents repeatedly. Moreover, integrating *ArtHur* with other software systems is seen as essential for streamlining workflows and reducing manual data entry, ultimately improving system efficiency.

3. Notification System

The absence of a notification system to alert operators when instructions are updated is a significant problem. Without it, operators might use outdated information, leading to errors. To address this, operators have suggested implementing an automatic notification system that would inform them whenever there is an update to the instructions. This would help ensure they always have the latest information, reducing the risk of mistakes.

Process planners also recommend automating communication between *ArtHur* and other software systems, which would cut down on manual data transfers and improve efficiency. Additionally, they suggest setting up a formal feedback system for users to easily track and provide input on instructions. This would support ongoing improvements to the system and ensure it remains aligned with operational needs.

4. Visual Aids and Clarity

Visual aids are essential in enhancing the clarity of instructions. Operators have suggested incorporating more intuitive images, color coding, and step-by-step breakdowns to improve instruction usability. Some have even recommended interactive 3D CAD drawings, especially for troubleshooting tasks, to provide a clearer visualization of complex processes. Process planners support these suggestions, noting that 3D visuals and color coding would improve machine adjustments and overall understanding.

5. Transition to a Paperless Environment

A strong desire for a paperless environment has been expressed by some operators. Reducing unnecessary printouts and increasing digital accessibility would eliminate delays associated with printing and reduce clutter in the workspace. Furthermore, operators have suggested implementing a live feedback mechanism, allowing them to provide comments on unclear instructions in real-time. This would enable immediate revisions and continuous improvement, ensuring that instructions remain up-to-date and relevant.

6. Streamlining Information

Operators have emphasized the need for instructions to focus only on the most relevant information. For example, when a measurement adjustment is required, they would prefer the instructions to highlight only the necessary measurements, eliminating extraneous details. This would make it easier for operators to access critical information quickly, improving both efficiency and accuracy.

Process planners recommend adding a tool life tracking feature within *ArtHur*. This would allow for monitoring the usage and condition of tools, preventing accidental changes and ensuring that operators use the correct tools at the right times. Additionally, when tools become obsolete, the system should automatically ensure they are phased out properly, reducing errors and ensuring smoother transitions.

5.2.3 Result of Workshop

The purpose of the internal workshop was to validate the usability and structure of current instruction documents within the *ArtHur* system and to identify improvements aligned with operator and technician needs. The workshop included discussions around core document content, layout, and navigation. Below is a summary of key findings and improvement suggestions, categorized by document type and system function.

ArtHur - Search Page Functionality
Feedback from the workshop highlighted the need for an improved search function within the *ArtHur* system. Participants expressed that a simple and intuitive search feature would greatly enhance usability. Specifically, the ability to search by article name, department, or similar relevant filters was suggested to streamline access to needed information. Furthermore, the existing search tree function in *ArtHur* was appreciated by users, indicating that some current elements of the system are effective and could be built upon. It was also noted that all information displayed on the search page, except for the "Show Document" option, holds value for operators and workshop technicians. Enhancing the search functionality would thus support more efficient workflows and reduce time spent locating relevant documents.

General Document Structure
Participants agreed that certain information fields should be consistently placed at the top of each instruction document to ensure clarity, traceability, and alignment with Scania's documentation standards. These include:

- Scania logo (mandatory requirement)

- Responsible person/department for publishing
- Tempo designation
- Date of issue (to ensure the document is up to date)
- Article name
- Article number
- Machine number
- Marking (the number applied to the article after processing, such as a traceability number)
- Operation number (used for program measurement in gauge max)
- Engineering Change Order (ECO)

See the top of Figures 5.1, 5.2, 5.3, 5.5 to see how the above information is structured in the different documents. Additionally, revision details should be clearly indicated to track document changes over time.

Rigging Document
During the workshop, participants highlighted a need for clearer sequencing in the *Rigging Document*. Specifically, it was suggested that each step or task should be numbered to indicate the correct order of operations. This would support a more intuitive and standardized workflow, reducing the risk of mistakes during setup.

Additionally, the boxes representing each component in the document should follow the same color-coding as the actual components themselves. Consistent visual alignment between the document and physical parts would enhance recognition, streamline the rigging process, and improve overall usability for both new and experienced personnel.

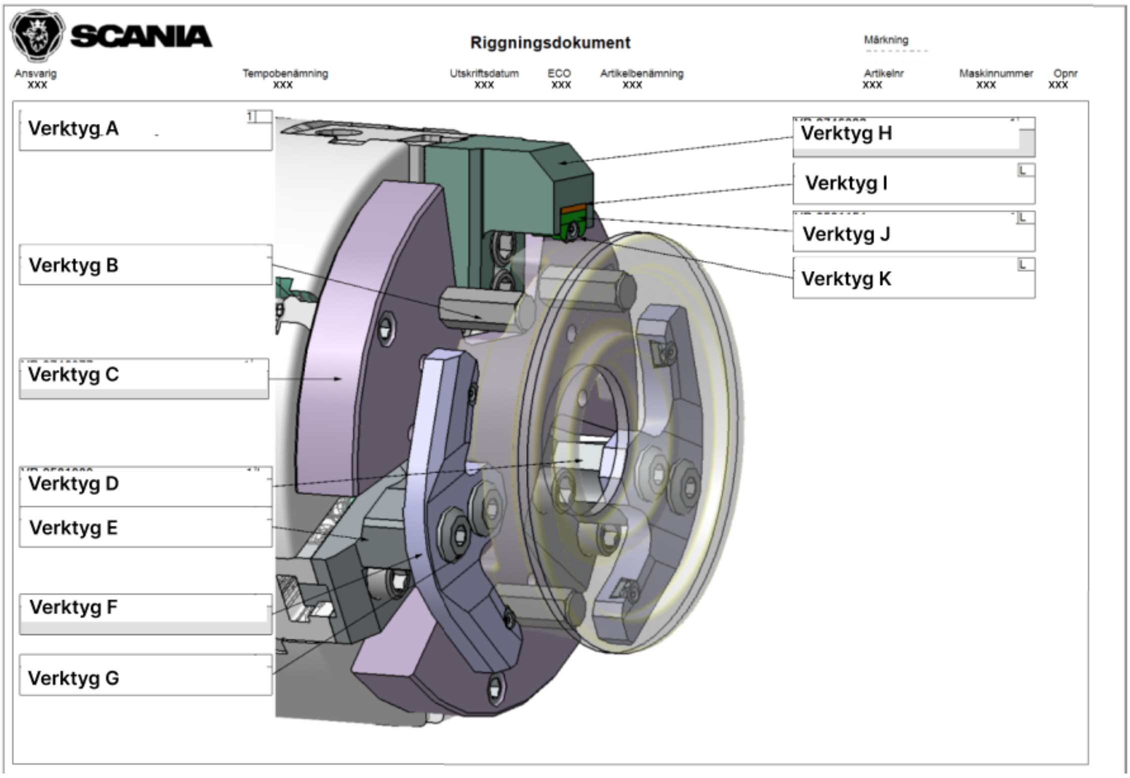


Figure 5.1: Complete Rigging Documentation Including Data Censoring.

Processing Document

The workshop revealed that the *Processing Document* is rarely used by operators in daily work. Instead, it is primarily utilized by workshop technicians and the metrology department. Despite its limited use among operators, several aspects of the document were discussed in terms of value and potential improvement. Due to Scanias confidentiality regulations, a representation of this document could not be included in this report

Participants agreed that the revision information is relevant and should remain visible. However, it was suggested that updates could be more intuitively presented, for instance, by using color coding to highlight changes, to enhance clarity. On the other hand, the long reference number added after a revision update was considered unnecessary and potentially confusing. A more user-friendly approach, such as integrating this data into a collapsible section or placing it within a separate “details” view in a digital interface, was proposed.

The document plays a crucial role in relation to machine programming, as all listed dimensions are important for making corrections in the machine programs. Therefore, ensuring the availability and clarity of this information is essential for operator understanding and task execution. Moreover, the blue dimensions, primarily intended for the metrology department, were also considered important for operators to understand the full processing context.

Correction document

Feedback from the workshop emphasized the need for enhanced interactivity within the *Correction Document*. It was suggested that users should be able to click on the processing surface or tool number to quickly navigate to the page with detailed information for that specific tool. This functionality would streamline the workflow and save time for operators who need to verify or adjust tool specifications.

Additionally, it was noted that the start and end points as well as direction of the processing operation on the article should be clearly marked. By indicating these points, operators would have a better understanding of the exact section being worked on, reducing confusion and improving the accuracy of corrections made during the process.

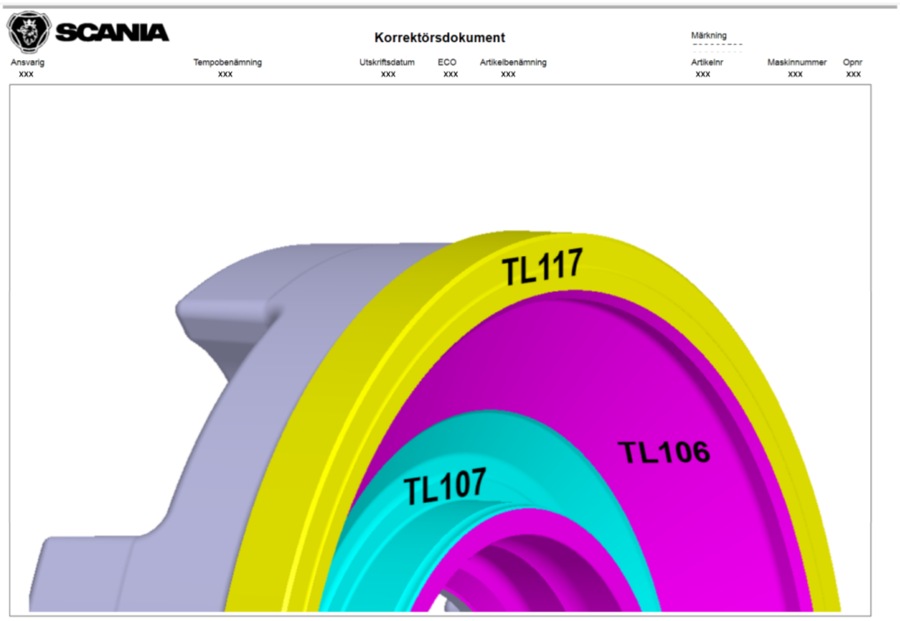


Figure 5.2: Complete Correction Documentation Including Data Censoring.

Quality Control Document

Workshop participants provided several insights regarding the current structure and use of the *Quality Control Document*. A key point raised was that only the dimensions requiring manual measurement should be visualized in the document. This would help reduce visual clutter and streamline the operator's focus during inspections.

It was also noted that the quality control management section does not need to be constantly visible, as the portal responsible for distributing articles for measurement is already programmed based on the measurement frequency defined in *ArtHur*. This automation reduces the need for repeated reference to the control logic during manual checks. The management section presents the measuring frequencies, shown on the right side of the document in Figure 5.3.

To support accurate quality assurance processes, participants emphasized the importance of including position numbers, measurement frequencies, tool numbers, and quantity of tools - as visually represented in the current documentation. Moreover, measurement positions should be color-coded in alignment with the corresponding cutting tools, which

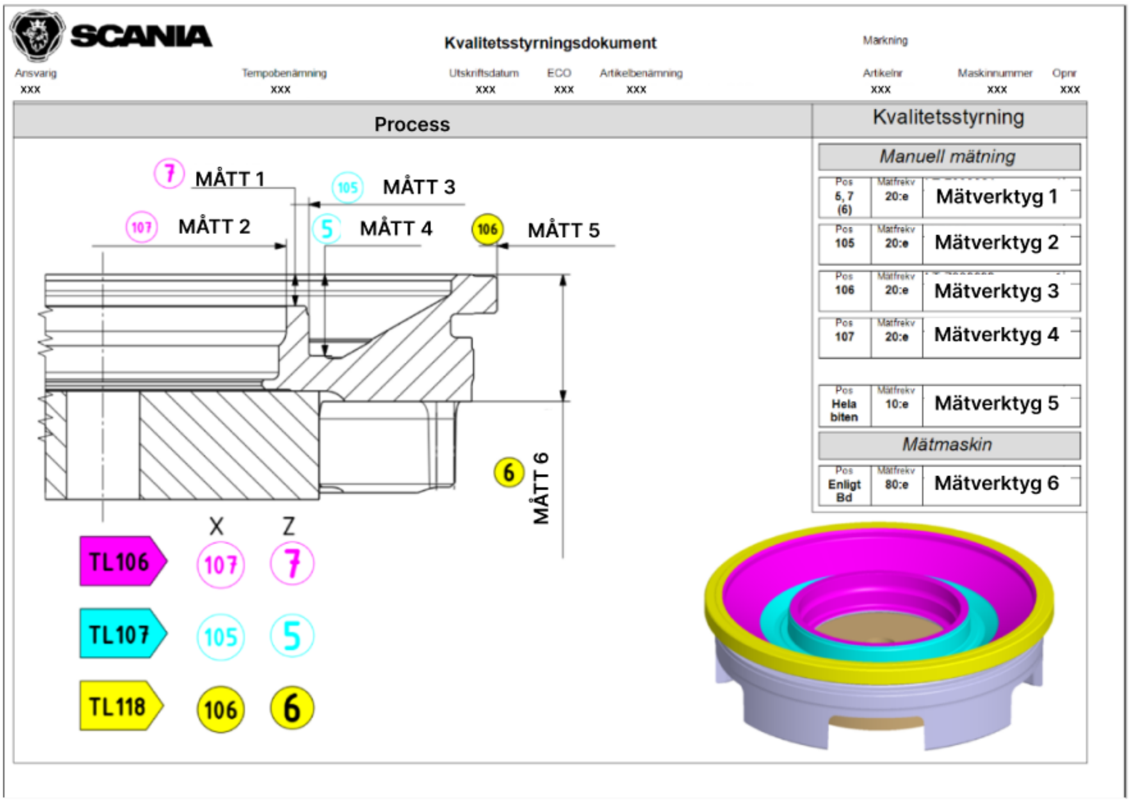


Figure 5.3: Complete Quality Control Documentation Including Data Censoring.

would improve clarity and usability for operators.

The holder in the center of the 3D model, specifically the beige component, see Figure 5.4, was identified as lacking clarity and should be made more distinguishable to better interpret the part orientation and context. Additionally, dimension corrections are often made based on areas influenced by the fine cutting tools, reinforcing the need for clear and precise visual guidance.

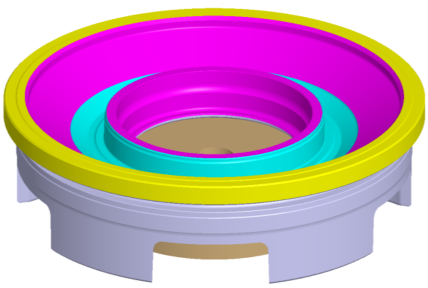


Figure 5.4: Example of a beige 3D model component holder.

Finally, there was a strong desire for full visibility of the technical drawing of the component, including all relevant dimensions. Participants suggested implementing an interactive solution where the complete technical drawing is accessible via a clickable thumbnail or preview box, allowing users to zoom in on specific areas for more detailed inspection.

Tool List Document (Rigging Document)

Feedback from the workshop indicated that the use of 3D model images in the *Tool List document*, which is currently classified as a *Rigging Document*, is highly appreciated and considered more effective than using real-life photographs, see Figure 5.5. The clarity and consistency provided by rendered visuals help operators and technicians better understand the tool configurations.

A key point raised concerned the color coding of cutting tools. Currently, only the polished cuts are color-coded, while tools for unpolished surfaces remain uncolored. Participants suggested that tools for unpolished surfaces which affect the same surface areas as their corresponding finish tools should be color-coded in the same way. For example, a tool for unpolished surfaces, processes the same area as a polishing tool, and should therefore share its color code to indicate the connection. This would support a clearer visual understanding of tool sequencing and surface impact.

Additionally, there was clarification and feedback regarding the text boxes within the document. The top box above each tool represents the adapter, the bottom box (at the base of each tool section) refers to the cutting insert/tool, and the side boxes (right or left) describe the cutting head or tool holder. To improve clarity, especially for new users, it was suggested that arrows be drawn between the tool name and its respective cutting head and adapter. This would simplify understanding of which component is which.

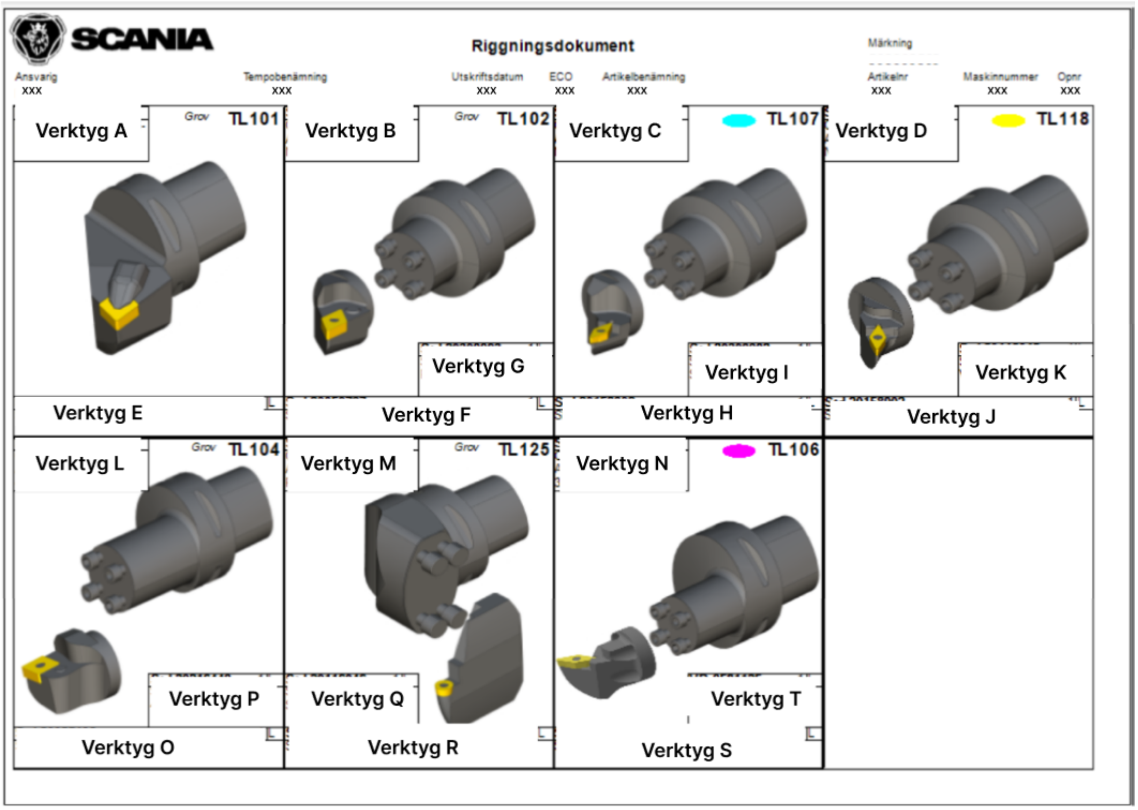


Figure 5.5: Complete Tool List Documentation Including Data Censoring.

Participants also emphasized the importance of being able to access detailed spare parts information directly in the document. This could be implemented by adding an additional text box or clickable button labeled “Reservdelar” (Spare Parts), linking to a list of relevant components for each tool. Ideally, this spare parts list should be printable, so operators can take it with them to the tool storage. The spare parts section should also clarify whether an item is a standard part (Std-number) provided by the supplier, or a special part (tool number) unique to a specific tool or process. It was mentioned that including tool life data could also be beneficial for planning replacements. A functional integration with *Maximo* was also proposed, either by updating the tool list directly or providing warnings if a tool is being phased out. This would ensure that outdated tools are not mistakenly used in operations.

5.3 Findings from the Benchmarking

This section summarizes insights from interviews and company visit with OEMs and suppliers on their approaches to work instructions and digitalization. The findings cover instruction formats, development processes, digital tool usage, training practices, and challenges in implementation. Expert input on best practices in instruction design is also included, providing a basis for identifying improvement areas and digitalization opportunities.

5.3.1 Summary of interviews

To understand current practices and future directions for digitalizing production instructions in manufacturing and machining industries, a series of interviews were conducted across a range of organizations, from large OEMs to smaller supplier companies. The findings are presented thematically to highlight recurring practices, challenges, and innovations.

Structure and Format of Work Instructions
Smaller supplier companies often rely on traditional work instruction formats. In one case, instructions are created using Word documents and printed for use on the shop floor. These documents serve more as memory aids for experienced operators rather than as step-by-step guides. New employees are onboarded primarily through informal shadowing, with no structured training timeline or assessment process.

Another supplier uses a digital document management system that stores machine operation instructions in Excel format. Although operators have access to computers, most still prefer to print instructions. These documents are minimalistic and focus mainly on measurement data and tools, assuming the operator already understands the broader process.

In contrast, one OEM has implemented a structured and highly digitalized system based on the "Define Work" methodology. This includes Define Work Sheets that specify what tasks must be done at each station, embedded video demonstrations for visual guidance, and Job Breakdown Sheets outlining the what, why, and how of each step. Visual elements such as diagrams and arrows further enhance clarity. Instructions are accessed via iPads or mobile devices at the workstation, and the approach is designed for both training and operational efficiency.

Another OEM. that manufactures similar parts and operates comparable processes, uses a hybrid system combining SharePoint, a cloud-based collaboration service [56], and bigger touchscreen stations across the factory. While instructions are stored digitally and regularly updated, many operators still use printed versions due to convenience. These documents tend to include procedural steps, safety measures, and measurement protocols.

Instruction Development and Maintenance
Across both OEMs and suppliers, instruction documents are typically created by technicians, production leaders, or designated quality teams. Updates are made reactively based on feedback or process changes, though some organizations have more formalized review cycles. One OEM, for instance, applies layered audits and regular operational meetings to ensure instruction compliance and continuous improvement.

In another OEM, the instruction development process involves multiple stakeholders - from production managers and technicians to operators. This cross-functional collaboration ensures that instructions are not only technically correct but also practical and user-friendly. The documents are continuously refined based on feedback and performance data.

Digital Tools and Integration
Digital maturity varies widely. Most supplier companies focus on digitalization in quality control and data collection rather than work instruction delivery. In one case, measurement data is manually entered into a digital database, though efforts are being made to automate this process.

Another supplier piloted the use of tablets for digital instruction access, but the project was discontinued due to high costs and harsh working conditions. Despite using a web-based system for storing documents, integration with broader Manufacturing Execution System (MES) or Enterprise Resource Planning (ERP) systems is limited.

OEMs generally demonstrate a higher degree of digital integration. For example, one OEM integrates instructional content with platforms such as SharePoint, and SAP, an ERP system [57], as well as internally developed applications for issue tracking and process improvement. Another OEM initially pursued a large-scale system to manage everything from customer orders to machine instructions, though the project was paused due to complexity.

Operator Training and Knowledge Management
Supplier companies often rely on informal training, where new operators learn by shadowing experienced colleagues. The absence of formal evaluation makes it difficult to ensure consistency and readiness.

OEMs, on the other hand, employ structured onboarding programs. These may include mandatory e-learning, hands-on mentorship, and role-specific instruction. In one case, operators even participate in the creation of instructional videos, reinforcing engagement and ownership.

Challenges in Digital Implementation
The implementation of digital tools in manufacturing organizations presents a variety of challenges, many of which are common across different sectors, although the nature and impact of these challenges can vary.

One of the primary obstacles faced by organizations is operator resistance. Many employees are more familiar with traditional, paper-based systems and often struggle to adapt to new digital tools. This resistance is especially pronounced where digital tools are adopted inconsistently, and operators are seldom involved in the development process. Overcoming this resistance requires a strong commitment to digitalization, with companies focusing on systems that fully replace paper-based methods, rather than offering them as an alternative.

Another significant challenge for OEMs is the integration of new digital tools with existing legacy infrastructure. Many organizations still rely on older systems like SAP and SharePoint, but the process of synchronizing these legacy systems with new digital tools remains complex. A successful digital transformation requires building a robust and scalable foundational system capable of identifying and leveraging relevant data. The presence of multiple disconnected software solutions complicates the integration process and can undermine overall efficiency.

In addition, there is often a disconnect between Information Technology (IT) development and the needs of the production floor. Digital solutions are frequently developed by IT teams without sufficient input from operators or production experts, leading to systems that do not fully align with operational requirements. This misalignment can create inefficiencies and prevent the optimization of digital systems. The knowledge gap between IT teams and production teams exacerbates this issue, as IT professionals often lack a deep understanding of production processes, making it harder to create solutions that meet the actual needs of the production floor.

Cybersecurity and data protection also remain ongoing concerns, especially for digitally advanced organizations. Some OEMs report daily cyberattack attempts, underscoring the need for robust IT oversight and security measures. Protecting sensitive production data and ensuring the integrity of digital systems are vital components of successful digital implementation.

Finally, the implementation of modern production instruction systems presents its own set of challenges, particularly related to the complexity of these systems. Operators' prior experience and familiarity with digital tools can significantly affect their ability to adapt to new systems. Many operators are still more comfortable with traditional paper-based instructions and may face difficulties transitioning to digital platforms. However, leading companies have committed to eliminating paper methods entirely, recognizing that the full benefits of digitalization can only be realized by removing the old, paper-based processes.

Component & Machining Complexity vs. Digitalization Potential
Production instruction systems in machining processes are evolving toward digitalization, automation, and smart manufacturing technologies. While many industry leaders in production instruction systems are transitioning from paper-based methods to digital work instructions for improved standardization, accessibility, and efficiency, some companies, particularly in industries with more complex operations, still rely on traditional paper-based instructions. This reliance is often due to challenges in automating processes and a lack of infrastructure to support digital systems.

There is a clear correlation between the complexity of a product or machining process and the feasibility of automation, which in turn affects the implementation of digital work instructions. More complex products often require intricate machining operations that are difficult to automate, making manual intervention essential. In such cases, operators rely heavily on paper-based instructions for tasks like machine setup, adjustments, and troubleshooting, as they need quick and flexible access to information.

As process complexity increases, the need for dynamic, adaptable instruction systems grows. However, this also presents challenges in digitizing work instructions, as traditional static digital solutions may not provide the required level of flexibility. In contrast, highly automated processes benefit from more standardized and stationary instructions, as machines can configure themselves with minimal human input. Therefore, while digital work instructions are easier to implement in automated environments, integrating them into complex, manual-intensive processes requires advanced, context-aware solutions that can adapt to varying conditions in real time.

Expert Insights on Instruction Design
An expert in operator information design emphasized that effective instruction must account for task complexity, product variance, and operator experience. It was recommended that minimalistic, visual-first formats be used for fast-paced environments, while more detailed content should be provided for complex or customizable tasks.

Best practices include:

- Tailoring content based on cycle time and prior knowledge
- Using visuals and avoiding cognitive overload
- Providing seperate documentation for "what to do" and "how to do" and "why to do".
- Integrating QR-code-based systems for quick access to relevant instructions.

The expert also stressed the importance of involving operators early in development to reduce resistance and improve adoption. Strategies like Kaizen workshops and pilot projects were highlighted as effective means for gaining management buy-in and iteratively refining solutions.

The study reveals a wide spectrum of approaches to work instructions and digitalization, influenced heavily by company size, role in the supply chain, and organizational maturity. OEMs tend to have more structured, digital-first approaches, while suppliers still rely on more manual, experience-based systems. However, all companies face common challenges in user engagement, system integration, and cost justification for management buy-in, offering a clear roadmap for targeted improvements in future implementations.

5.3.2 Summary of company visit

The visited facility represents a highly advanced manufacturing environment characterized by automation, digital integration, and lean production principles. The production layout is designed to optimize material flow, minimize waste, and reduce downtime.

Key observations from their production system:

- High levels of automation, driven by Sweden's labor costs, which encourage investment in advanced machinery.
- Fully automated night shifts, eliminating the need for human operators.
- A flexible, piece-based production approach to accommodate customer customization requirements.
- Operators transitioning from manual tasks to technical roles, primarily overseeing and optimizing machine operations.
- The extensive use of monitoring systems, sensors, and digital twins for real-time process optimization and predictive maintenance.

Digital Work Instructions
The company has implemented a highly structured approach to digital work instructions. The transition from paper-based documentation to digital solutions has improved accessibility, standardization, and efficiency, while also reducing paper usage. Key components of their system include:

- **Bar Code-Based Instruction System with Digital Displays**
  Work instructions are linked to a digital platform and accessed via bar codes. Operators scan the codes using scanners to retrieve essential details such as required tools, material lists, order details, and instructions. This system ensures quick, easy, and accurate access to up-to-date instructions, reducing errors and improving operational efficiency by integrating a bar code system for flexible access.
- **Integration with Manufacturing Execution Systems**
  The digital work instructions are dynamically updated and synchronized with the MES, ensuring that operators always have the latest process information.
- **Standardization and Flexibility**
  The use of QR codes ensures universal accessibility, enabling greater flexibility for operators across different tasks and stations.

Advanced Digitalization Initiatives & Future Developments
Beyond digital work instructions, the facility has implemented a range of advanced digital tools contributing to overall operational efficiency:

- **Maximo & Power BI**
  Operators log production data into *Maximo* (tickets), which is analyzed in Microsoft Power BI, a data visualization and business analytics tool [58].
- **AI-Driven Maintenance Support**
  An initiative is underway to train an AI-based assistant using historical ticket data from *Maximo*, including both issues and their corresponding solutions, to predict machine failures. This is aimed at reducing troubleshooting time and enhancing maintenance efficiency.

- **Machine Status Indicators**
  Machines are equipped with visual indicators (red/green light) to quickly communicate with operators if stoppages occur.

- **AI-Assisted Quality Control**
  Automated inspection systems handle initial quality assessment before human verification, improving efficiency.

- **Digital Twins**
  The factory operates with digital twins of machines and tools, enabling real-time monitoring of the entire factory.

Implications for Production Instruction Systems
The observations from the visit provide a strong foundation for the study on digital work instructions within manufacturing. The findings suggest several key factors that could be applied to other production environments, including:

- The importance of integrating digital work instructions with existing MES systems.
- The role of QR-based documentation in improving instruction accessibility and reducing paper dependency.
- The effectiveness of real-time operator feedback in maintaining up-to-date and relevant instructions.
- The potential benefits of predictive maintenance and AI-driven process optimization.

These insights will help the study to assess how similar digital work instruction systems could be implemented or improved within Scania's production environment. The comparison between the visited facility's approach and the current state of digital work instructions at Scania will provide a basis for formulating concrete recommendations for process improvements.

5.4 Pilot Study Results

This section summarizes the key outcomes of the pilot project, including requirement specification, concept implementation, and evaluation. While not complete, the results provide a solid foundation for future development and reflect input from various stakeholders across the organization.

5.4.1 Specification of Requirements

The requirement specification was developed to evaluate and verify the final functionality and usability of the Production Instruction System for Scania's Transmission Factory in Södertälje, derived from the insights from the in-house and industry interviews, along with the observations that have been made and the SLR, see Appendix B. The specification compiles all system criteria, categorized as requirements *(R)* or desired requirements *(DR)*, under various subheadings such as functionality, performance, information content, ergonomics, and security. Each criterion is linked to specific stakeholders, including process planners, operators, literature sources, thesis workers, and Scania itself, ensuring that the requirements align with user needs and organizational objectives.

For example, the system must support real-time updates, intuitive search functionality, and interactive 3D models, ensuring efficiency and usability for operators. Additionally, security aspects such as authentication and data protection were included to comply with GDPR. Criteria classified as desired requirements (DR) indicate features that would enhance the system but are not critical for its core functionality. These were assigned a weighting to reflect their impact, allowing prioritization based on their importance to usability and system performance.

By structuring the requirement specification in this way, the research ensures that the final system is both practical and forward-looking, addressing current operational challenges while also considering future scalability and industry best practices.

It is important to note that the requirement specification presented in this thesis is not fully comprehensive. While aimed to capture the most relevant and critical aspects, some elements may need to be supplemented in the future. Additionally, certain points that fall outside the formal scope of this master thesis have been included since they are considered valuable for future development and implementation efforts of an updated version of the support system for operators.

5.4.2 Developed Concepts

This section describes the developed concepts, their relevant content and features.

Concept 1 - Direct Implementation
The document for a new standard was divided into two sections; one detailing *ArtHur*'s document structure, article naming conventions, and operation numbers, and the other outlining the structure and content requirements for various article instruction documents. See Appendix C for the complete standard. Due to Scania's confidentiality regulations, information such as tool names, article numbers, article names, technical drawings, measurements, process and tempo names, as well as employee names, has been censored.

In section two, before detailing the guidelines for each document, it starts with general guidelines. These cover the appropriate fonts, font sizes for various titles and measurements, and acceptable colors for color coding. It also specifies the colors to use for marking updates, revisions, and phasing out tools.

The article instruction documents where divided into *Processing Document* (Bearbetningsdokument), *Rigging Document* (Riggningsdokument), *Correction Document* (Korrektörsdokument), *Quality Control Document* (Kvalitetsstyrningsdokument) and an additional *Tool List Document* (Verktygsförteckning). The *Tool List Document* was initially a secondary rigging document. However, internal interviews revealed this was confusing, leading to the suggestion that it should be a standalone document.

All article instruction documents contain the *Purpose* of the document and *Title & metadata*. *Title & metadata* specifies what title the document should have and includes the following information: Responsible department, Tempo designation (e.g., "Turning 1"), Print date, Article designation, Tentik (article marking number), Article number, Machine number, Operation number (Opnr), and ECO. This is followed by guidelines on the main view's content, instructions for detail views, special markings for specific measurements, visual clarity standards, color coding considerations, label display for certain processing tools and how to present measurement tables.

The guidelines for each document was tailored to each document since they differentiate in relevant content. The standard was primarily developed with a focus on turning processes, as this was the main subject of the thesis and pilot process. As a result, guidelines for other machine processes may be insufficient. However, it is intended to serve as a solid foundation and allow for further development.

Concept 2 - State of the Art Solution
The prototype consisted of several pages and was designed to present a simple interface with clear user guidance and reuse of familiar patterns and functions, as emphasized in Section 5.1.2 and the requirement specification in Section 5.4.1. Due to Scania's confidentiality regulations, information such as tool names, article numbers, article names, technical drawings, measurements, process and tempo names, as well as employee names, has been censored in the images illustrating various pages of the prototype in this report.

The initial process flow of the prototype is illustrated in Figure 5.6, where the starting interface includes a login function, addressing *Requirement 8.3* as defined in the specification outlined in Section 5.4.1.

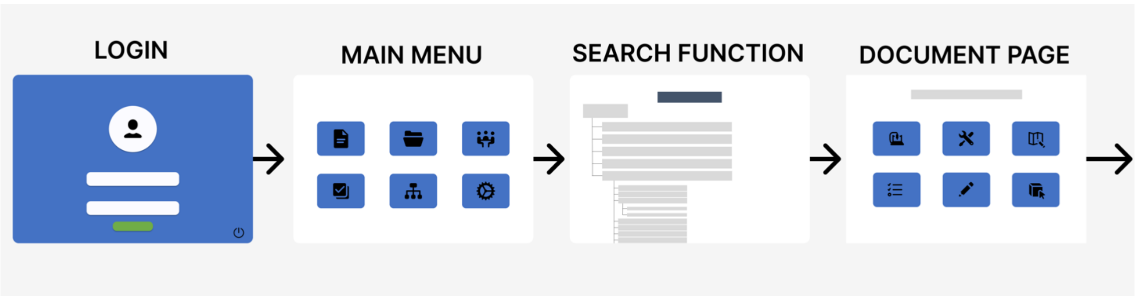


Figure 5.6: The first process flow of the prototype.

Upon successful login, the user is directed to a centralized interface, the Main Menu, where the MES system, team activities (such as UFO), instructions, and other relevant features are consolidated, see Figure 5.7. This design choice reflects best practices identified during benchmarking with other companies, highlighting the importance of having all critical functionalities accessible in one place. The other functionalities were not made interactive in the prototype, as this was beyond the scope of the project. Their inclusion served solely to illustrate the features that a future system should incorporate. Only the instruction system was developed with interactive elements for user testing.

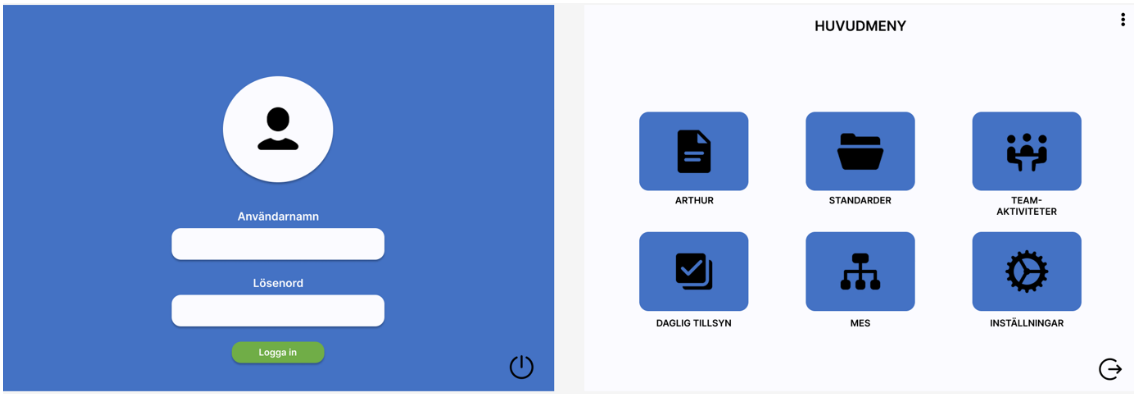


Figure 5.7: Login page and main menu.

When the user selects the instruction system *ArtHur*, they are directed to the search function, see Figure 5.8. An intuitive search bar was included based on feedback from interviews, which emphasized its importance for usability and, connected to *Requirement 1.11*. Additionally, the search tree structure was retained from the current system as a feature for locating parts, as it was highlighted in the interviews as being particularly useful for providing an overview of different articles and components, as well as the production sequence of the components, see Figure 5.9.

Figure 5.8: The search function - Start view.

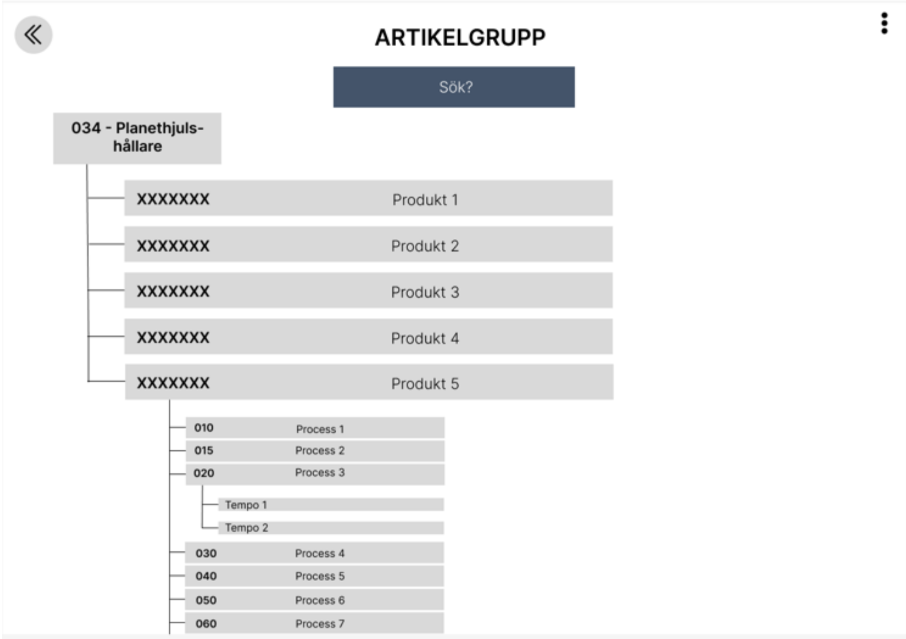


Figure 5.9: The search function - Example of product breakdown.

When choosing a tempo on the search page, the user is directed to a page with an overview of all the relevant documents connected to the specific part, see Figure 5.10. On this page, the user can easily choose which document to view by clicking. The whole procedure of retrieving the right document is emphasized by *Requirement 2.3*.

Figure 5.10: Start page for chosen tempo in ArtHur.

An overview of the second process flow, illustrating the functions specific to each document type as well as those common across all types, is presented in Figure 5.11, and is described in more detail later in this section. The features that are common for all documents are presented along the right-hand side of the figure.

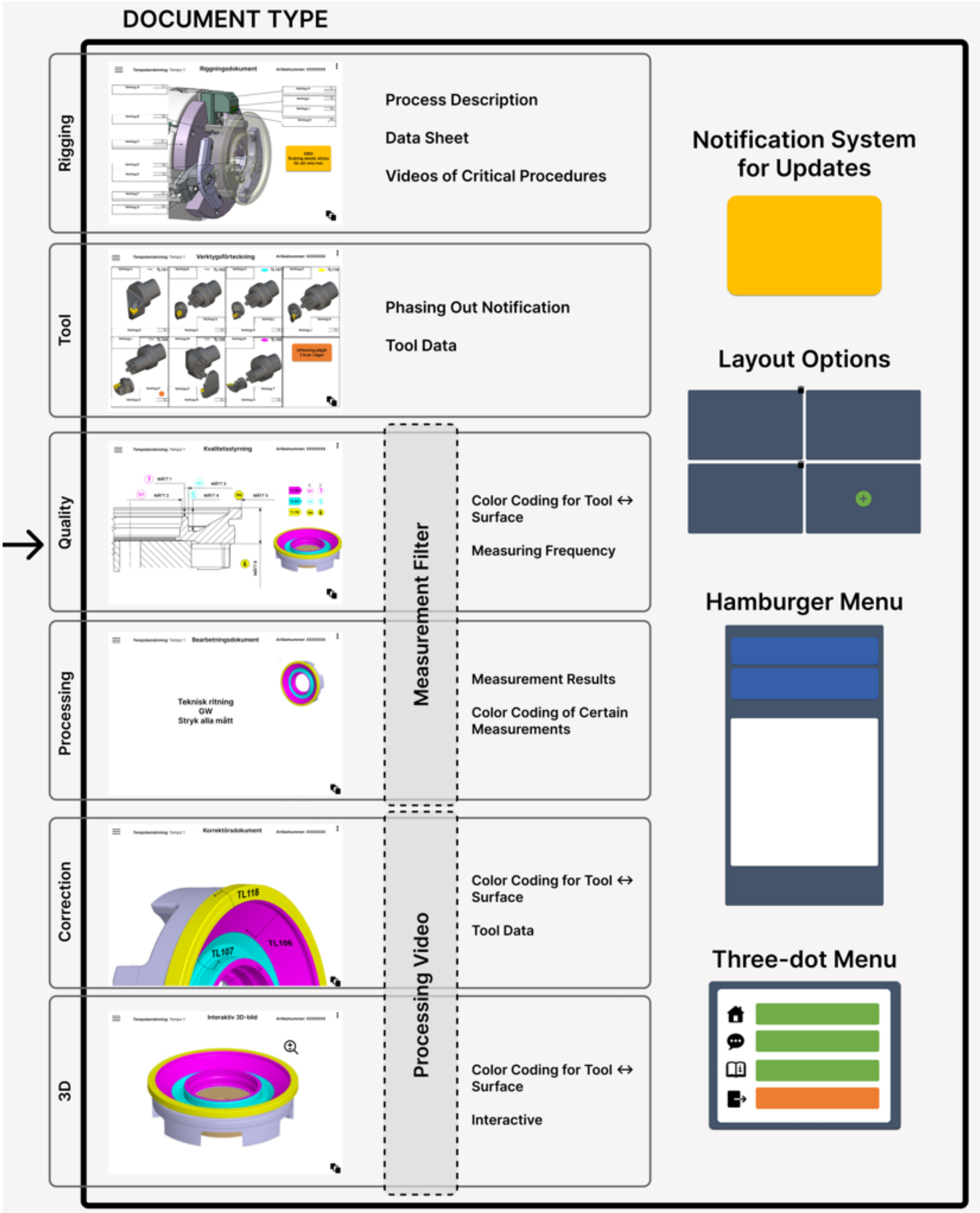


Figure 5.11: The second process flow of the prototype, illustrating the various functions linked to each document type.

In the *Rigging Document*, the feature for notifying the user regarding updates and modifications was showcased using a yellow notification box, see Figure 5.12. This feature aligns with *Requirement 1.5* and was made interactive for demonstration purposes - when the user clicks on the box, a pop-up window displays information about what was modified and why, see Figure 5.13.

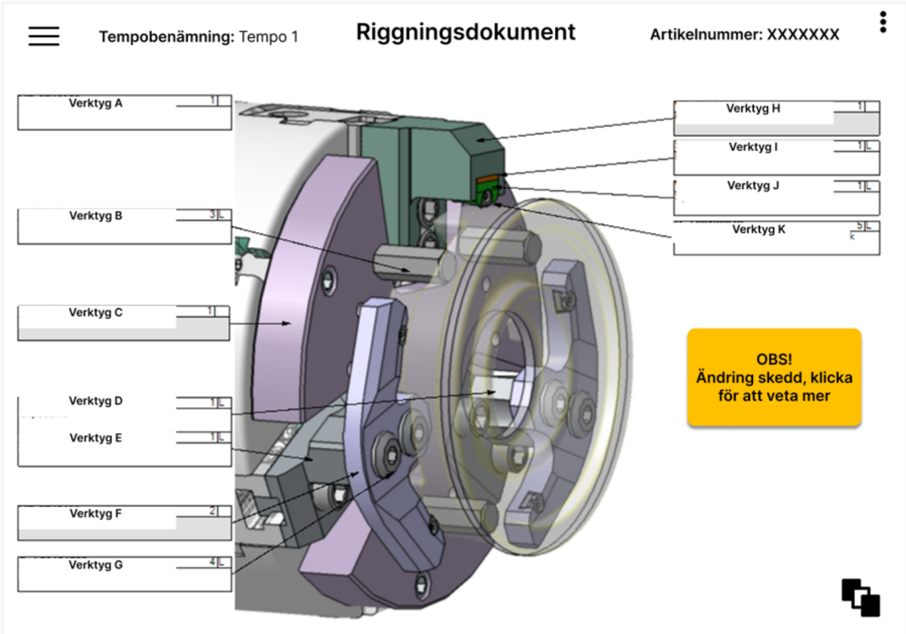


Figure 5.12: Rigging Document main view with update notification.

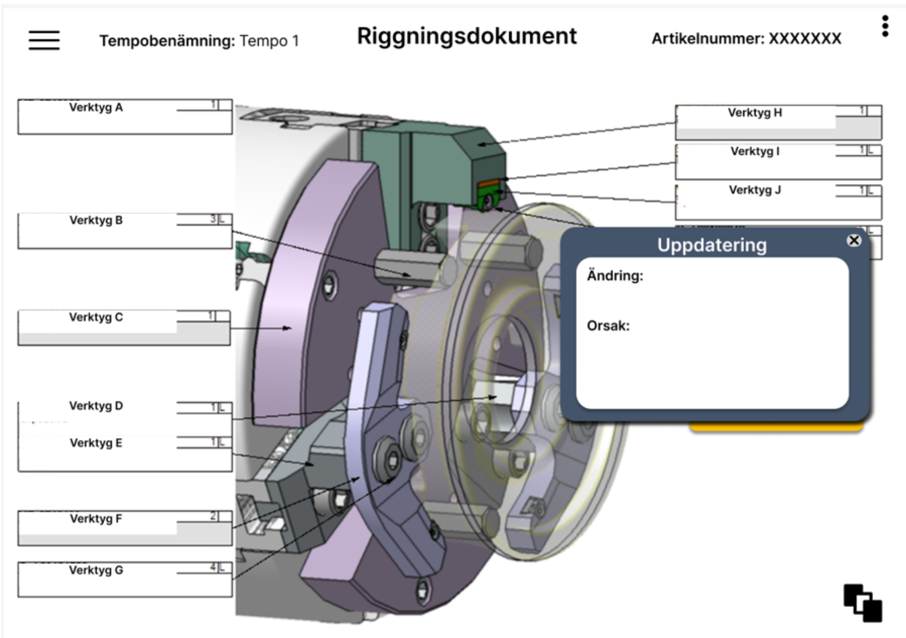


Figure 5.13: Main view of the Rigging Document, showing the pop-up box containing the update description.

A common feature across all pages is the *hamburger menu*, which provides quick access to the start page of *ArtHur*, specific information about the article, and document specific buttons and functions, see Figure 5.14. The decision to hide this information by default was based on *Requirement 4.10* and insights gathered during the workshops, as such details are not relevant during the execution of a work task but still need to be accessible. Another consistent element is the *three-dot menu* located in the top-right corner of each page, presented in Figure 5.15. This menu includes functionalities such as live commenting, a user guide, access to the main menu, and a logout option, aligning with *Requirements 1.4* and *1.6*.

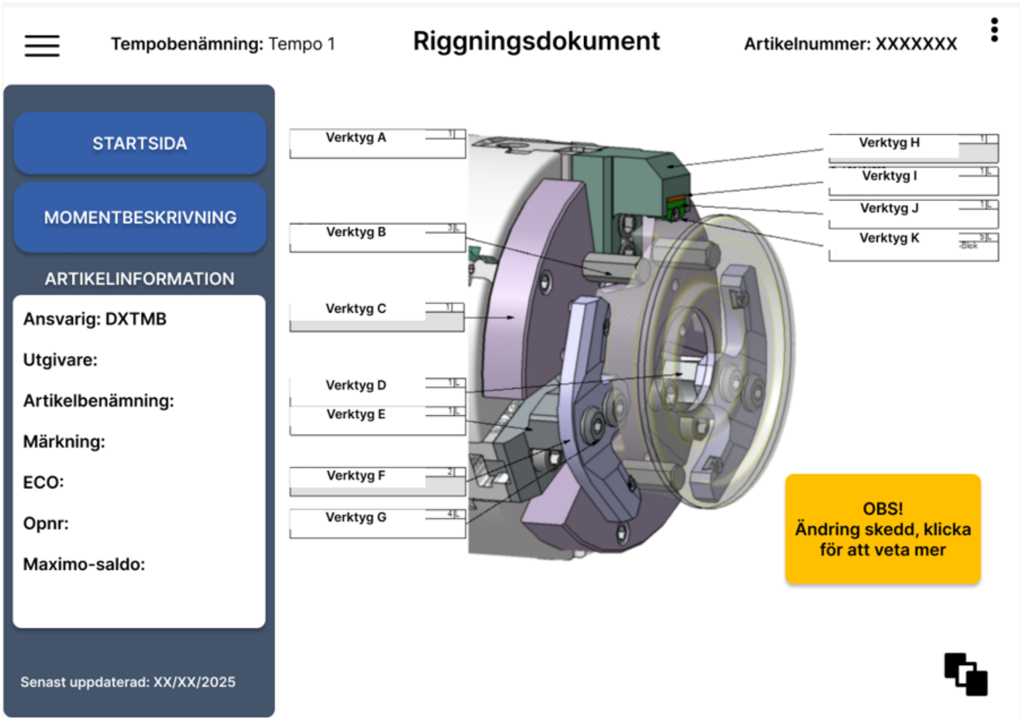


Figure 5.14: Hamburger menu - Showcased in the Rigging Document.

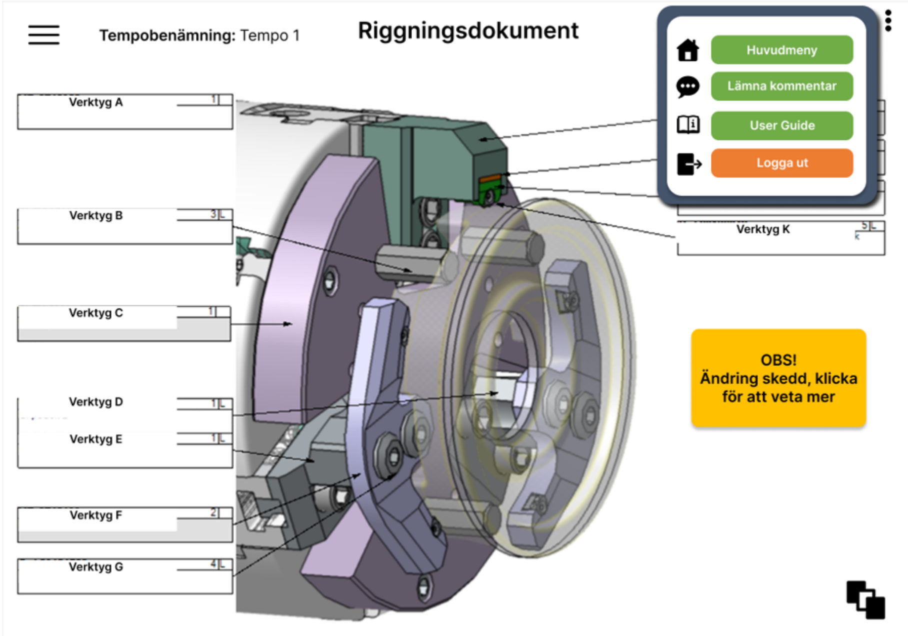


Figure 5.15: Three dot menu - Showcased in the Rigging Document.

To align with best practices for work instructions, as outlined in *Requirement 3.5* and supported by industry insights, benchmarking, and the SLR, a procedure description feature (*Momentbeskrivning*) was added to the rigging document, see Figure 5.16. This section provides users with step-by-step instructions as well as access to a detailed procedure data sheet (*Elementblad*), see Figure 5.17. The steps were not numbered or linked to specific tools in the drawing, as process planners explained that "specific steps for this rigging do not exist, and the order of rigging the parts does not matter". Additionally, the prototype demonstrates that users should have access to instructional videos for critical procedures - an essential feature identified through benchmarking and the SLR, highlighted in *Requirement 3.7* and *3.8*. Since individuals learn in different ways, it is important to support multiple learning styles by integrating visual and auditory content into the instruction system.

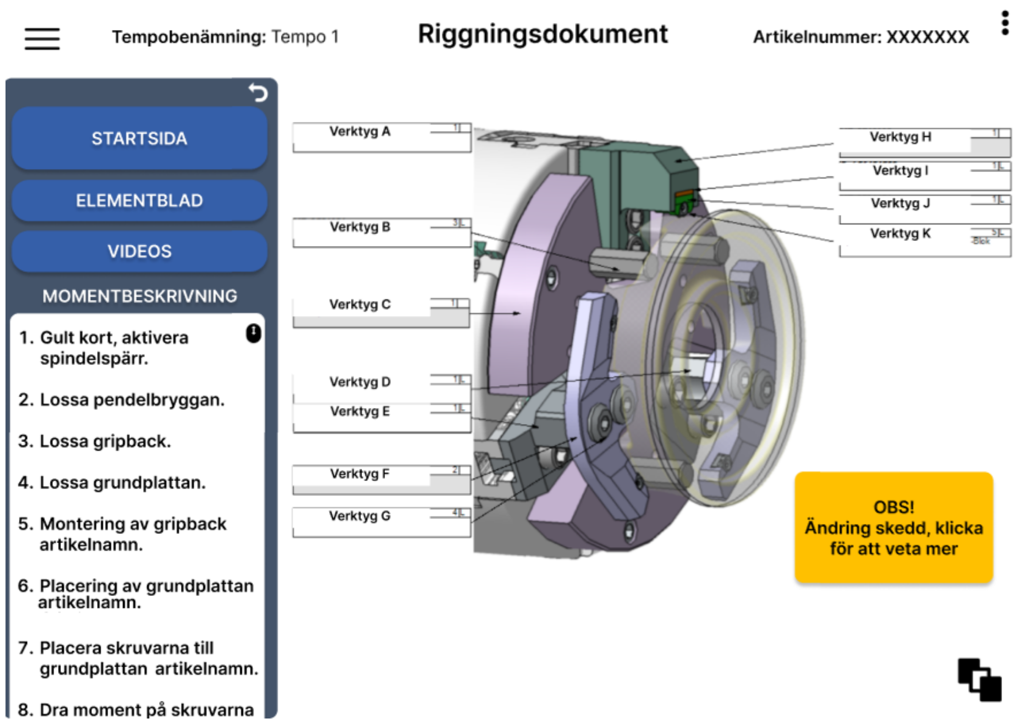


Figure 5.16: Rigging document - Procedure description located in the hamburger menu.

Figure 5.17: Rigging Document - Data sheet view with procedure description displayed in the hamburger menu.

The tool list, referred to as *Verktygsförteckning*, was previously included as a secondary *Rigging Document*. However, based on feedback from internal interviews, it was determined that this information should be presented in a separate document. As a result, a standalone tool list was added to the prototype, see Figure 5.18. In this document, a feature highlighting tools that are being phased out was showcased using an orange notification box, similar in design to the update box in the rigging document. Unlike the update box, this indicator is not interactive; it simply marks which tool is being phased out and indicates how many units remain. Another feature demonstrated in this view is the ability for users to click on a specific tool to access additional information such as inventory levels, tool life, and available spare parts. This functionality was added in response to feedback from operators, who expressed a need for quick and easy access to such details, detailed in *Requirement 3.1*.

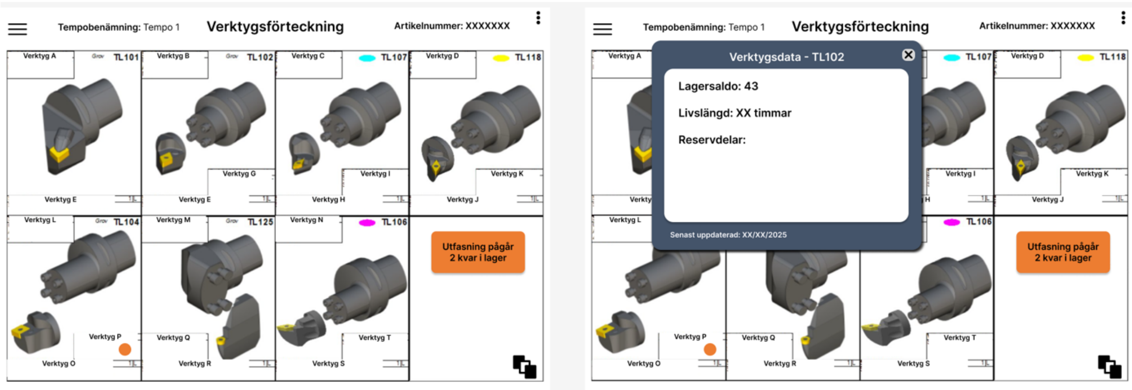


Figure 5.18: Tool list document - Main view and view with pop-up box with tool information.

In the *Quality Control Document*, measurement frequencies were intentionally hidden, as it was mentioned during interviews that this information is not relevant to display at all times. Unlike the other documents, the frequency intervals for measurements were placed on the first page within the hamburger menu, see Figure 5.19, as quick and easy access to this information was considered essential. Article-specific information (*Artikelinformation*) was instead made available through a separate button, allowing the user to access it only when needed.

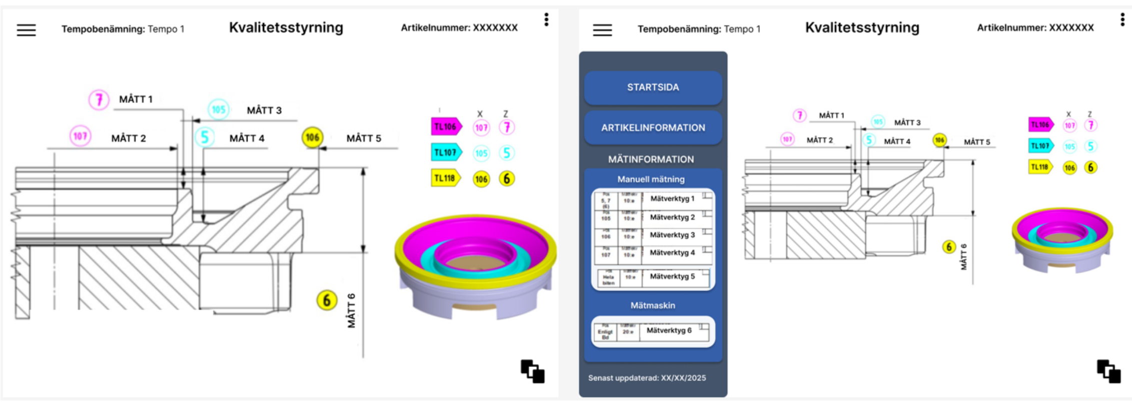


Figure 5.19: Quality Control Document - Main view and view with hamburger menu open.

An additional feature implemented in the *Quality Control Document* allows users to filter measurement data specific to a selected tool by clicking on the measurement tool name. See Figure 5.20 for a demonstration. This functionality was frequently requested by operators during interviews and supports the principle that only relevant information should be displayed to the user, in accordance with *Requirement 4.10*.

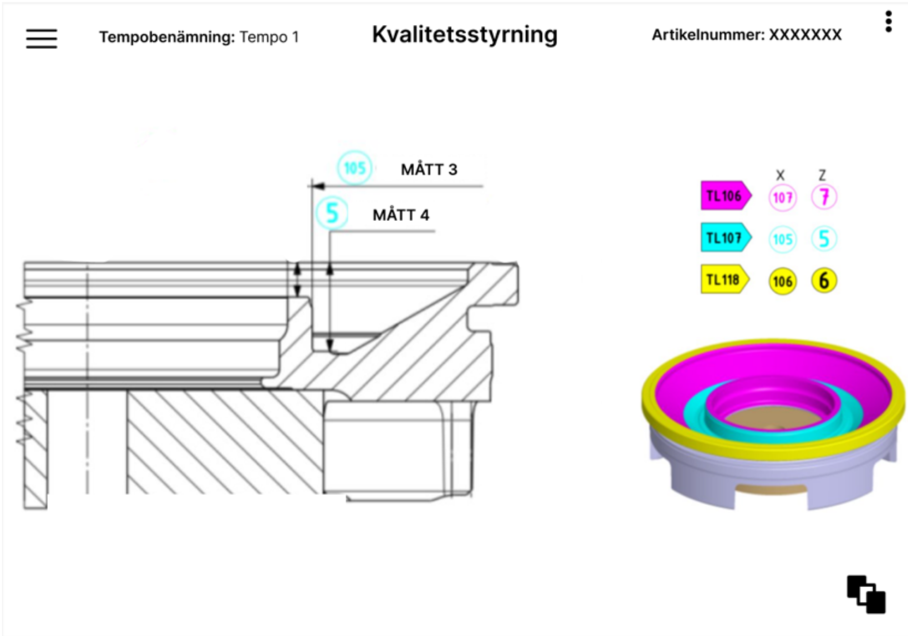


Figure 5.20: Quality Control Document - Shows the view when filtered measurements for the selected tool when the turquoise button is clicked.

For the *Processing Document*, a feature was added to filter measurements (*Filtrera mått*), following the same principle as the *Quality Control Document* - only relevant information for a specific task should be displayed. Additionally, a button (*Mätresultat*) was added to ensure that measurement results are easily retrievable, a feature frequently requested by operators who noted the value of having such information readily available, see Figure 5.21.

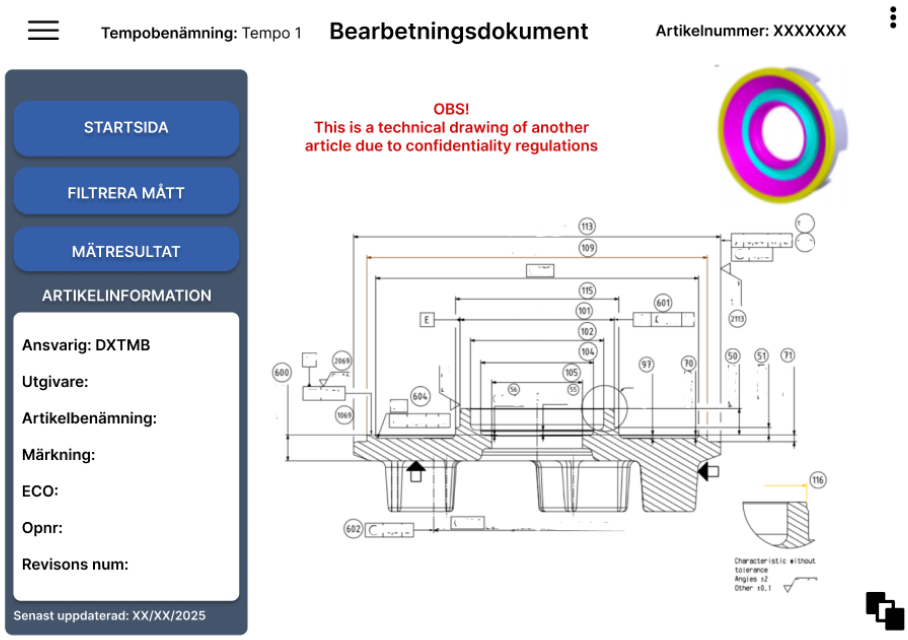


Figure 5.21: Processing Document - Main view with hamburger menu open.

However, due to the larger number of measurements in this document, the feature was designed differently. A marking list was introduced, allowing the user to select which measurements they wish to view, see Figure 5.22. To facilitate quick use, a button was included to clear all selected marks at once, eliminating the need for manual removal of individual selections (*Markera/Avmarkera alla mått*).

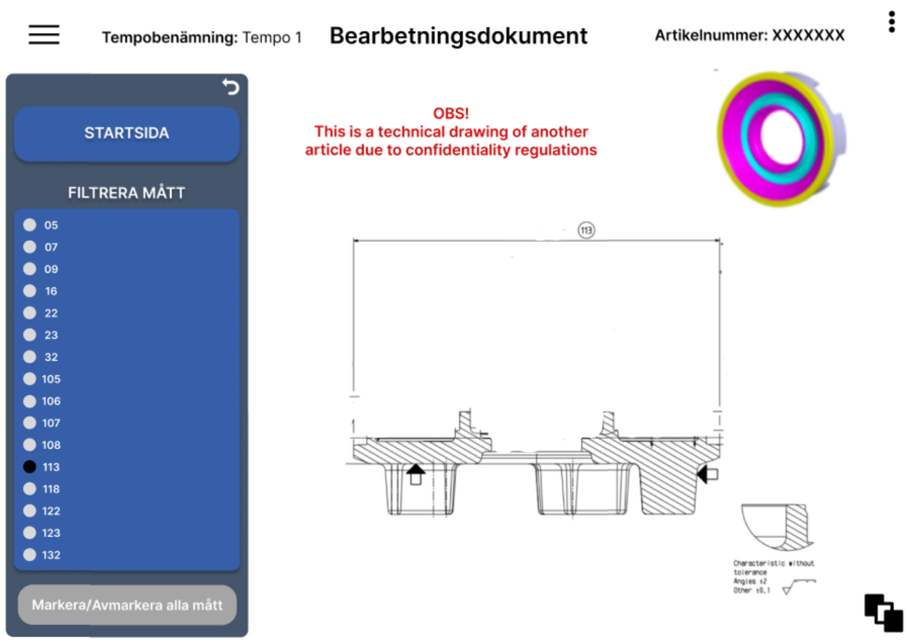


Figure 5.22: Processing Document - Marking list for filtering measruements, with measurement 113 selected.

Based on *Requirement 3.6*, the *Correction Document* includes features that display the direction and start/end of a machining process directly on the part, see Figure 5.23. Additionally, in the hamburger menu, a button was added to provide access to videos of the machining process (*Bearbetningsvideo*). Videos were not directly integrated into the prototype but were presented separately. These videos were generated using EdgeCAM [59], a Computer-Aided Manufacturing (CAM) software used for programming CNC machining operations. This feature aligns with *Requirements 3.7* and *3.8*, and was requested by operators as it enhances process understanding and facilitates easier troubleshooting when quality issues arise. Another feature in the *Correction Document* allows users to click on a surface of the part to view information about the tool used. This functionality was also suggested by operators, who emphasized the need for quick access to such information.

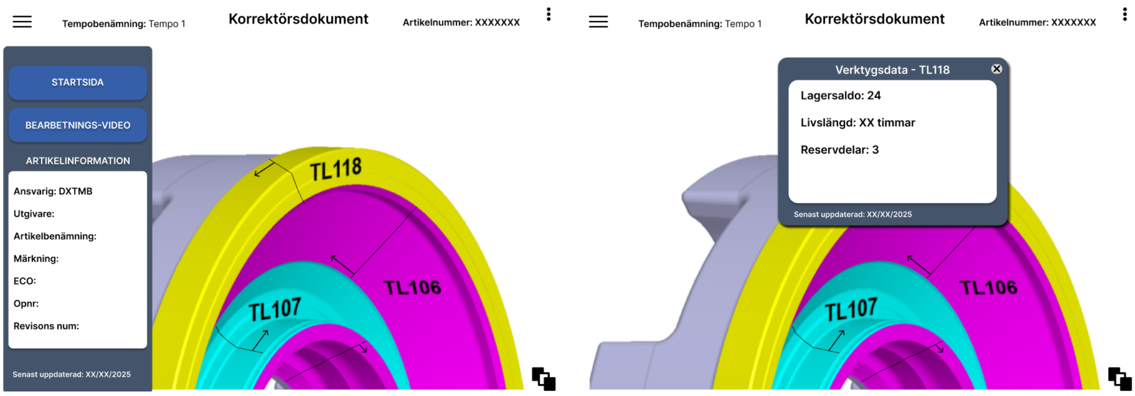


Figure 5.23: Correction Document - Main view with the hamburger menu open, and view with tool information displayed.

The interactive 3D image feature (*Interaktiv 3D-bild*) supports *Requirements 1.10* and *4.17*, and was specifically requested by operators as it improves process understanding and facilitates more efficient troubleshooting in the event of quality issues. Consequently, this feature was included as an additional document. Similar to the *Correction Document*, this document also contains a video animation of the machining process (*Bearbetningsvideo*), see Figure 5.24.

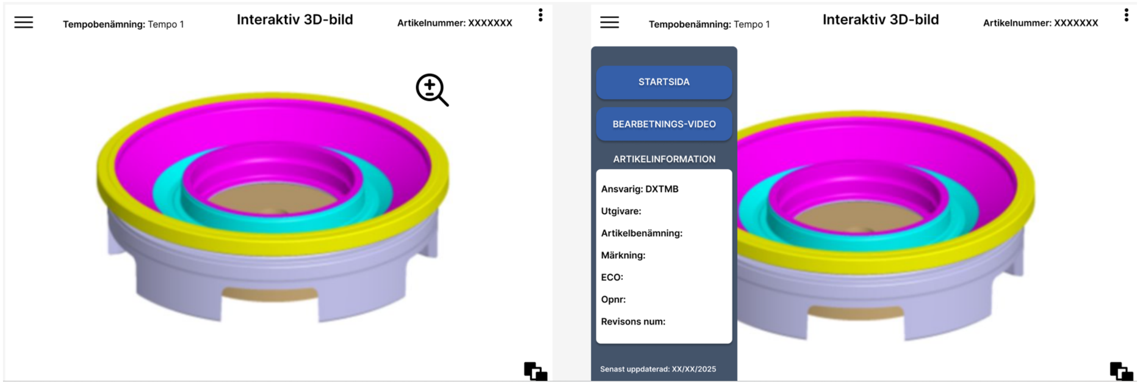


Figure 5.24: Interactive 3D-model document - Main view and view with hamburger menu open.

Finally, since operators currently use several papers displayed on the machines, a layout function was added to allow users to choose if they want multiple documents displayed simultaneously, see Figure 5.25. This function is accessed via the stacked pages icon located at the bottom right of each document page. The user can select how many documents to display at once (up to a maximum of four) and customize the layout. This feature was introduced based on observations made on the production line, although it was not explicitly mentioned by any operators, and is highlighted in *Requirement 1.7*.

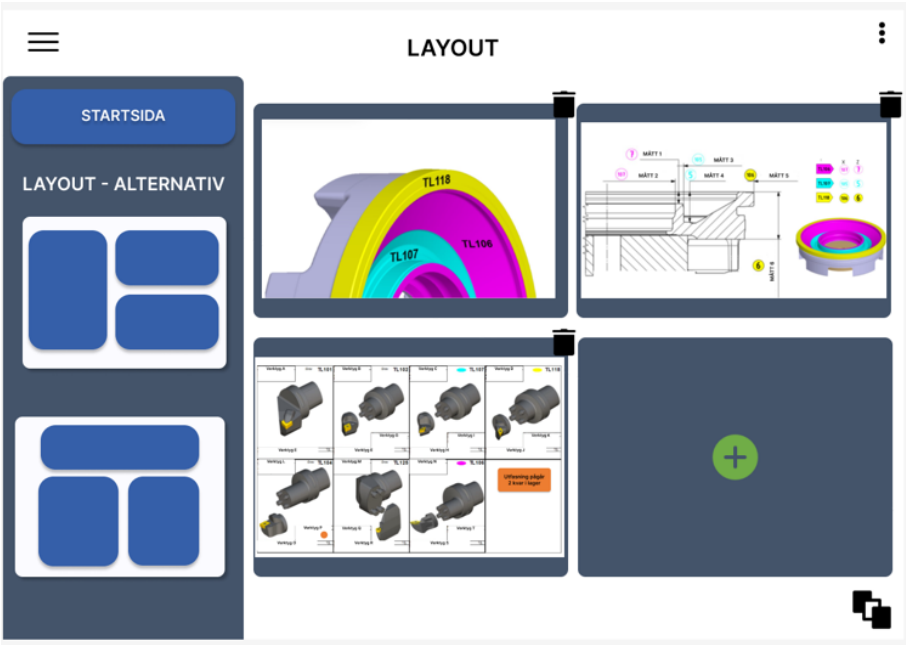


Figure 5.25: Layout page with hamburger menu open.

5.4.3 Outcome of Pilot Project

This section presents the outcome of testing the two concepts in the feedback forum and during the pilot process.

Concept 1

The pilot study for Concept 1 was carried out in collaboration with all process planner team leaders. The primary objective was to review the newly developed standardization framework for structuring *ArtHur* production instruction documents, with the aim of establishing a consistent and unified format across all departments at DX based on identified best practices internally and from earlier research on information presentation.

A key insight from the pilot study was that the conditions and requirements vary significantly between different machining processes, resulting in notable differences in the way production documentation is structured. Some process planners have advanced their documentation considerably, incorporating extensive 3D visualizations to present components and relying less on traditional technical drawings. In contrast, others still depend solely on black-and-white technical drawings, without any 3D visuals. These variations extend to the use of color coding, which also differs from one process planner to another. As a result, the appearance and clarity of production instructions can vary greatly between production lines and processes. While CATIA V5, used to prepare the schematic drawings of parts and articles, supports color coding in drawings and 3D model visuals, such as highlighting different sections of a component by changing line colors, this method is significantly more effective and visually intuitive when applied to 3D models. However, generating and applying color coding to 3D views requires additional effort from process planners. Furthermore, a consistent implementation is hindered by the fact that 3D views are not available for all parts, leading to inconsistencies in the visual presentation of information to operators.

Moreover, participants in the pilot study expressed concerns about how the new standard would be applied across all processes, given the significant differences in how documentation is prepared. They emphasized that a single, uniform standard may not be suitable for all cases. Instead, they suggested that the standard should be developed in a way that allows for process-specific adaptations, for example, by grouping similar processes together and creating tailored guidelines for each group. This approach would make it possible to generalize certain conditions within each group, while still accommodating the unique requirements of other process types. The existing standardization framework that Concept 1 is intended to replace provides only a brief description of what each production instruction document should include. It lacks detailed guidance on how the content should be structured, where specific elements,such as tools and technical drawings, should be placed, and does not define any rules for their presentation.

The initial version of Concept 1 includes general guidelines for naming articles, processes, and operations, as well as instructions on how process planners should structure documents according to the different hierarchy levels within *ArtHur*. For example, the structure begins with article groups at the top level, followed by individual article types within each group, then the various processing operations, and finally the documentation for each specific process. While similar information existed in a previous standard, participants in the pilot study noted that it was outdated and rarely used in practice. As a result, some participants expressed there was a recognized need to incorporate this guidance into Concept

1 in order to create a more comprehensive standard that addresses all key features and functions of the *ArtHur* system. However, feedback on this inclusion was mixed. Some participants welcomed the addition, seeing it as a valuable step toward standardization. Others, however, argued that this structure varies too much between departments to be effectively standardized. A few participants also suggested that such structural guidelines should be separated into a standalone document rather than being part of the main Concept 1 standard.

Additional feedback from the process planners related primarily to technical functionalities in *ArtHur* and CATIA V5, the two programs that are used to prepare the production instruction documents. Currently, In-Process Parts (IPP) are prepared in CATIA V5, where both technical drawings and 3D visualizations are created. These are then intended to be transferred into *ArtHur*, where the production instruction documents are compiled.

However, the way this transfer is handled today varies among process planners. Some take screenshots directly from CATIA V5 and insert them into *ArtHur*, while others export the files as PDFs or Drawing Exchange Format (DXF) files and then attach them to the *ArtHur* documents. This inconsistency was highlighted as a concern during the internal interview phase with process planners as it affects the quality and look of the instructions.

As a result, the newly developed standard clearly states that screenshots are not acceptable. Instead, DXF or PDF files must be used, and they must be named according to the document naming convention (Enovia), together with the date of the downloading from CATIA and also the respective file place in CATIA to ensure traceability. Adhering to this format will help reduce the risk of multiple versions of the same component circulating in the system and improve overall data consistency. Furthermore, efforts are currently underway to automate the transfer process from CATIA V5 to *ArtHur*. For this automation to function reliably, it is critical that all files follow the correct format and naming guidelines from the outset.

Despite these differences, the overall feedback was positive during the pilot study. Participants appreciated the initiative and agreed on the importance of moving toward a shared standard. The pilot study helped raise awareness among process planners about current documentation practices and encouraged reflection on how instructions are created and used. Many expressed that the initiative was long overdue and would contribute to improving both clarity and efficiency in production support documentation.

Results of the Standardization Framework Questionnaire
Despite the limited number of responses (three completed questionnaires), the feedback provides insights into how the standardization framework is perceived in terms of clarity, usability, and implementation potential. See Appendix D for the full questionnaire.

The responses reveal a carefully optimistic view of the new standard. Participants generally acknowledged its value in improving workflow consistency and reducing the risk of errors. For example, the questions related to ease of use (mean score: 8.3), overall efficiency (8.3), and error reduction (8.7) received the highest ratings, indicating that the respondents believe the framework could support more structured and reliable production instruction processes.

However, other aspects of the standardization framework were met with more varied opinions. Clarity (mean: 5.7) and alignment with existing planning processes (mean: 4.7) were scored moderately, suggesting that while the framework introduces improvements, it may not yet be fully aligned with the realities of all departments. Similarly, the user-friendliness (mean: 6.3) and flexibility (6.3) of the structure were seen as areas where further development is needed, particularly to ensure adaptability across different production contexts and operator needs.

Perceptions around time savings (mean: 6.7) were more neutral, implying that although some efficiency gains are expected, they are not yet seen as substantial. In addition, the feedback on training needs (mean: 4.7) revealed varying levels of confidence in the ability to adopt the new standard without additional support. This points to the importance of providing introductory materials or training sessions when rolling out the framework more broadly.

Finally, overall satisfaction with the content and structure of the standard was moderate (mean: 5.7), but participants expressed strong support for further refinement before full implementation, as indicated by a relatively high mean score (7.3) for suggested revisions. The open-ended responses reinforced this sentiment, highlighting the need for clearer definitions of what content belongs in each document type, better alignment with non-turning processes, and suggestions for integrating the standard with other systems or tools.

While the standardization framework was generally viewed as a step in the right direction, the feedback highlights the need for continued iteration and refinement. The responses underscore the importance of clarity, process adaptability, and user-centered implementation strategies. The insights gained from this evaluation serve as valuable input for improving Concept 1 and provide a stronger foundation for scaling it across departments as part of Scania's broader digital transformation efforts.

Concept 2
The users, primarily operators and technicians, expressed appreciation for the idea of having all relevant tools, functionalities and documents, such as *ArtHur*, daily activities and checks, MES, standards, and others, gathered in one centralized and easily accessible location. They also suggested including shift handover notes within this platform, within team activities, to enhance continuity between shifts. This would support better tracking of recurring issues and provide a shared space where important information is readily available to both incoming shift personnel and team leaders. Additionally, it would enable line managers to monitor production status and review events from previous shifts. The study also confirmed that the current navigation tree structure in *ArtHur* remains a valuable tool for efficiently locating documentation. Users expressed a preference for keeping it unchanged, as it not only aids navigation but also reflects the production sequence. At the same time, the integrated search bar was highly appreciated for providing a quicker and more flexible way to find specific content.

When it comes to the presentation of various types of production documentation and the new features introduced in the concept for retrieving and visualizing operator support, the overall impression from operators, technicians, team leaders, and line managers was positive.

The common feature of hiding specific article information behind a hamburger menu, information that was previously visible in every production instruction, was initially met with some hesitation by the pilot study participants. This reaction may stem from established habits and the perceived importance of immediately seeing key details, such as the document's last update date, to ensure the information is current and complete. However, after demonstrating how this information is still included and easily accessible, the audience responded positively. They felt the feature contributed to a cleaner and more organized presentation of the content.

The three-dot menu was also highly appreciated by the operators, as it addressed a previously expressed need for an easy way to request updates or changes to documentation. This is made possible through the live commenting function accessible via the menu. However, the participants raised some suggestions and requirements for this feature. They questioned how the comments would be communicated to the responsible process planners, whether it would be possible to view historical comments to avoid duplicate feedback, and whether notifications could be sent to process planners. Additionally, they suggested that line managers should also receive these notifications to stay informed. The other functions within the menu were also well received. Participants highlighted the value of including a user guide that explains how the system works, as well as clarifying the purpose and content of the various production documents. This was an expressed need during the internal interview phase of the thesis. The log-out option and the button for returning to the main menu were also seen as valuable features of the three-dot menu. They were considered sufficient for simplifying navigation within the digital concept, eliminating the need to press multiple "back" buttons to return to the starting point.

The layout function, which allows operators to view multiple documents simultaneously, was considered a fundamental requirement in the design of Concept 2. This need was initially highlighted during the interview phase, as operators explained that they currently rely on having several documents physically displayed beside the machines. This setup reflects how they manage production tasks today. During the pilot study, the importance of this feature was reaffirmed. While participants did not express strong opinions about specific changes to the layout function, they emphasized the value of being able to choose which documents to display side by side and to easily switch between different views. This flexibility was seen as beneficial for adapting to varying tasks and workflows.

Rigging Documentation (Riggningsdokument)
In Concept 2, the rigging documentation featured a yellow text box to indicate when a change or update had been made. By clicking on the box, users could see what was changed and why. This function was highly appreciated by the pilot study participants, who expressed a desire to see it included in all types of production instruction documents.

The clearly defined order for performing rigging steps was also well received. However, it was noted that not all rigging operations follow a fixed sequence - some cases allow for flexibility in the order of tasks.

Additionally, a "Momentbeskrivning" (step-by-step instruction) button was included in the rigging documentation via the hamburger menu. This button displays the individual steps in the correct sequence for performing the rigging process. Participants responded positively to this feature, as this information already exists today but is currently stored separately from the *ArtHur* system. These step-by-step instructions, known as elementblad, are prepared by the Transmission Factory Manufacturing Organization (DXM) in Excel format.

Access to the procedure data sheet was also integrated into the hamburger menu through a button called "Elementblad", along with a button for video recordings of critical tasks. While this was a new concept for many participants, it was seen as highly valuable - especially for individuals who may struggle with text-based instructions. Videos and images were viewed as effective tools to enhance understanding and visualize procedures more clearly. One suggestion from the participants was to link each step in the momentbeskrivning directly to the corresponding section of the "Elementblad". This would allow users to simply click on, for example, Step 1 in the momentbeskrivning and be taken directly to the relevant part of the elementblad, eliminating the need to open the elementblad separately and manually search for the correct step.

Tool list (Verktygsförteckning)
One usability improvement introduced in the tool list document was the inclusion of an orange text box to indicate when a tool is being phased out and replaced. This box is visually connected to the relevant tool by using the same color coding, allowing users to easily identify which items are affected. The text box is labeled "Phase Out" and also displays the number of items remaining in stock.

This feature was developed in response to feedback collected during the internal interview phase, where both operators and technicians emphasized that this type of forward-looking stock information is often missing in their current systems. The visual cue was well received in the pilot study and seen as a helpful enhancement for planning and decision-making on the shop floor.

However, a recurring concern raised by users involved the accuracy of stock levels. Although the concept of highlighting phase-outs was positively evaluated, participants noted that existing stock data is frequently unreliable. Addressing the root of this issue, such as improving data integration or stock management processes, was deemed outside the scope of this thesis but remains an important area for future development.

Another feature integrated into the tool list was the ability to view detailed tool data for each individual tool. By clicking on a tool image, a larger panel appears displaying key information such as stock balance (lagersaldo), expected lifespan (livslängd), and available spare parts. The panel also includes a timestamp indicating when the information was last updated.

Participants appreciated this feature, recognizing it as a useful step toward improving access to tool-related information. However, they also suggested enhancements to make it more effective. Rather than presenting the data in a temporary pop-up that partially covers the screen, users recommended displaying this information on a dedicated page. This would allow for a more comprehensive and user-friendly layout.

Their proposed improvements included the integration of a visual representation, such as a photo or 3D model, of the complete tool and its components. They also suggested a structured breakdown of the tool, similar to the rigging document layout, with individually clickable parts that display associated spare parts, stock levels, storage location, and tool lifespan. This expanded view would provide a clearer overview and support more efficient maintenance and planning.

One participant also suggested incorporating assembled 3D models of the tools to improve visualization. For new employees in particular, it can be difficult to understand what a fully assembled tool looks like when it is only shown as separate components. Providing a complete 3D view would help bridge this gap and support faster understanding and learning.

Processing Document (Bearbetningsdokument)
Participants gave positive feedback on the ability to filter measurements directly within the drawings. They also appreciated the option to access qs-STAT measuring protocols via the "Mätresultat" button in the hamburger menu. qs-STAT is a quality management system used to register, categorize, and track quality deviations in production. This feature was seen as a step toward digitalizing the current process, where measurement protocols are printed, temporarily attached to machines using magnets during production, and then discarded after a limited period.

Additionally, participants suggested that dimensions falling outside specified tolerances should be automatically highlighted in red within the processing documents, based on data retrieved from automated measurement systems. This visual indicator would enable operators to quickly identify deviations and enhance quality control during production. However, implementing such a feature is considered highly forward-looking, as no existing system currently supports this level of integration.

Quality Control Document (Kvalitetstyrningsdokument)
As outlined in Section 5.4.2, in Concept 2, measurement data, including measuring frequency, measurement tools, and the specific positions to be measured, was placed behind the hamburger menu to reduce visual clutter. Feedback on this approach was mixed. Some participants felt that measurement frequency should remain constantly visible to support memorization and routine adherence. Others preferred that manual measurement data be presented on a dedicated page for clearer access and separation from other content.

Participants responded positively to the feature allowing filtering of dimensions based on the tool used for processing. This was seen as beneficial both for understanding the production process and for grouping related measurements, making it easier to interpret and manage the data, according to the participants.

Correction Document (Korrektörsdokument)
The feature that visualizes the starting point and direction of the tool paths during processing was appreciated by participants, as it enhanced their understanding of the machining sequence. However, there was some uncertainty regarding the potential increase in workload for process planners responsible for creating this documentation.

Additionally, participants found videos demonstrating the processing (*Bearbetnings-video*), such as those generated from EdgeCAM [59], both helpful and desirable. These videos were seen as valuable tools for understanding how different tools interact during the machining process, as well as for troubleshooting when issues occur.

Interactive 3D Visuals (Interaktiv 3D Bild)
The interactive 3D visuals received positive feedback from participants in the pilot study. While a fully interactive model could not be implemented for testing in Concept 2, the feature was represented by a large 3D model of the component, with color coding used to indicate different processing areas. The model depicted the component in its final, post-turning state.

Participants noted that additional value could be gained by also visualizing the raw material at the start of the process, alongside the finished product. This would help users better understand the transformation that occurs during machining. However, it was also pointed out that this approach may not be applicable to all processes. In some cases, particularly where only minor or less visible modifications are made, such visual comparisons may offer limited insight - unlike in turning processes, where large volumes of material are removed and the changes are more apparent.

Results of Concept 2 Questionnaire
To assess user perceptions of Concept 2, a digital questionnaire was distributed to participants involved in the pilot study, see Appendix E. Three complete responses were collected from operators and one technician who had tested the interactive prototype based on their current process. Although the sample size was small, the results provide a strong indication of the perceived strengths and usability of the concept.

Overall, the responses reflect a highly positive reception of the digital platform. The participants rated the prototype very favorably across all key usability dimensions. The user interface was considered easy to navigate (mean score: 9.3), and respondents indicated a high level of confidence in using the tool without external help (mean: 8.3). Furthermore, the estimated learning curve was perceived as short (mean score: 9.7), suggesting that operators felt the system would be easy to adopt with minimal training.

Several other criteria received equally positive evaluations. Clarity of the instructions and readability of text and images both averaged 9.7, indicating that the platform successfully presented information in a clear and intuitive format. Design and layout were rated a perfect 10.0 by all respondents, underscoring that users found the overall structure and visual presentation of the platform to be well-designed and appropriate for the production environment.

Qualitative comments echoed these sentiments. Respondents noted that the digital instructions were "easy to access" and "helpful for simplifying the process." One participant emphasized that the system made it easier to avoid having to "run around" looking for information, as everything was accessible in one place. Another highlighted that it would be particularly beneficial for operators who struggle with paper-based instructions or prefer visual guidance.

Only minor concerns were noted, such as the challenge of getting used to a new tool in the beginning - something expected with any technological change. One user also suggested that having the option to print paper copies could be beneficial in some situations, indicating a need for hybrid functionality during transition phases.

In summary, the questionnaire responses confirm that Concept 2 is perceived as highly usable, intuitive, and well-aligned with operator needs. These findings are consistent with the positive verbal feedback collected during the pilot study and suggest strong potential for further development and broader implementation. While the sample size limits the generalizability of the results, the consistently high ratings and enthusiastic comments point to a clear interest in moving toward more digital, integrated operator support systems.

5.4.4 Evaluation of Results

The evaluation of the pilot study was structured around KPIs to assess the usability, feasibility, and improvement potential of both Concept 1 (standardization framework) and Concept 2 (interactive prototype for digital work instructions). The feedback was collected through workshops, forums, and structured surveys among key stakeholders, including process planners, operators, technicians, team leaders, and line managers.

Evaluation of Concept 1
The evaluation of Concept 1, based on KPIs, is presented below.

KPI 1: User satisfaction with clarity and structure
The majority of process planners welcomed the initiative to define a common standard. Participants emphasized the importance of a unified structure to reduce ambiguity and inconsistencies across documentation. The introduction of naming conventions, layout guidelines, and defined content structure was seen as a necessary step forward. However, concerns were raised regarding the adaptability of the standard across different departments and machining processes. Some participants expressed a preference for having tailored standards per process group rather than a single unified one.

KPI 2: Alignment with existing workflows
Feedback highlighted that while the standard aligned well with current practices in turning processes (the focus of the pilot), its applicability to other machining areas remains limited. Planners noted that differences in process maturity, visual material availability (e.g., 3D models), and tooling documentation make it difficult to implement a one-size-fits-all solution. Nonetheless, it was acknowledged that the proposed standard provides a solid base for further refinement and adaptation.

Opinions on time efficiency were mixed. While some process planners believed the standard could streamline documentation in the long term, others raised concerns about the initial time investment needed to align with the new structure and format. Overall, the evaluation suggested that the standard could improve long-term efficiency once fully adopted and integrated with automation tools for transferring content between CATIA V5 and *ArtHur*.

KPI 3: Reduction of errors and inconsistencies
A significant benefit identified was the potential to reduce redundant versions of documents by enforcing consistent naming conventions and the exclusion of manual screenshots. The shift to be consistent with DXF or PDF files, properly labeled and dated, improves traceability and minimizes document duplication - addressing an issue that previously led to confusion and inefficiencies.

Evaluation of Concept 2
The pilot study for Concept 2 was conducted with operators and technicians at DX, and the feedback was overwhelmingly positive. A structured questionnaire supported the pilot evaluation, with participants rating aspects such as ease of use, clarity of information, layout, and relevance to daily work.

KPI 1: Presentation of information in a digital format
All participants confirmed that the digital format effectively replaced paper-based work instructions and provided better structure, clarity, and interactive capabilities. The ability to integrate videos, 3D models, and visual highlights (e.g., colored update notifications and phase-out warnings) was viewed as a substantial improvement.

When asked how long it would take to learn the system with proper training, participants gave the maximum score (10/10), indicating that the system is perceived as easy to adopt. Confidence in using the tool without assistance was also high (ratings of 7 and 9), reflecting that the design supports user autonomy and efficient task completion.

The participants saw significant value in the system's digital format. Benefits mentioned include:

- Time savings and easier access to information
- Reduced need to physically move around the workspace
- Centralized location of all tools and documents
- Flexibility to still access paper versions if needed

All users said they would recommend the tool to colleagues and expressed willingness to use it in their daily work, reinforcing the concept's practical relevance.

KPI 2: Ease of navigation
Users responded positively to the simplified navigation enabled by the centralized main menu, the inclusion of a search bar, and the retention of the familiar *ArtHur* tree structure. The addition of the hamburger and three-dot menus further streamlined access to essential features without cluttering the interface. These features contributed to a more intuitive and ergonomic user experience.

Participants rated the interface as intuitive and easy to navigate (scores of 9 and 10 out of 10). This validates the design decisions to incorporate a familiar layout, centralized main menu, and consistent elements like the hamburger and three-dot menus. Users appreciated how these features minimized screen clutter while still making key functions accessible when needed.

KPI 3: Preference for the new presentation of instructions
Participants expressed strong support for the new way of presenting instructions. Features such as interactive step-by-step guides (*Momentbeskrivning*), linked documents (*Elementblad*), and integrated video instructions were well received. Visual clarity and modular content layout were seen as crucial for accommodating different learning preferences. The

layout function, allowing multiple documents to be viewed side by side, was considered essential for aligning with how paper documents are currently used in production.

Text and images were considered easy to read and understand (both users rated this aspect 10/10), and the layout was described as visually pleasing and functional. One participant specifically mentioned that the digital work instructions were "easy to access", while another noted they were “simple and clear”.

Overall Takeaways
Both concepts were positively received, though from different perspectives. Concept 1 laid the foundation for standardization and long-term process alignment, while Concept 2 showcased the tangible benefits of a user-centered digital interface. Participants acknowledged the need for further development, especially in ensuring system integration and adapting standards to the diversity of Scania’s manufacturing processes.

The evaluation of Concept 2 demonstrates that the prototype aligns well with operator needs and expectations. The high usability ratings, combined with specific functional feedback, suggest that the prototype successfully improves accessibility, supports visual learning, and mimics current paper-based practices in a digital format. The findings also confirm that operators see clear advantages in using the tool and are open to adopting it in their daily routines.

While future iterations may require adjustments for specific workflows or additional integrations, the pilot study confirms that Concept 2 is a strong foundation for digitalizing work instructions in a user-centered and scalable way.

Collectively, the results highlight the potential of a hybrid approach, combining structured standards with interactive digital support, to improve cognitive ergonomics, information accessibility, and process quality in production environments.

6
Discussion

This chapter discusses key findings related to the design and use of digital work instructions, the importance of education and onboarding, pilot evaluation and stakeholder engagement, and the feasibility of scaling the solution. It also covers benchmarking insights, human factors, standardization, ethical considerations, and future implementation recommendations.

6.1 Instructions & Cognitive Support

The effectiveness of the digital prototype (Concept 2) in supporting operator cognition was evaluated based on feedback from participants during the pilot study. Overall, the results indicate that the proposed solution successfully reduced cognitive load by presenting information in a more accessible and user-friendly format.

Operators expressed a clear preference for the instruction format in Concept 2, noting that the amount of information displayed at once was appropriate and well-structured. They reported that the new layout made it easier to understand the content, locate relevant information quickly, and perform their tasks more efficiently. Several participants stated that the interface would likely reduce the number of errors due to the improved clarity and navigation. No elements of the instruction presentation were reported as confusing or difficult to interpret, indicating a high level of usability. These findings suggest that the prototype effectively supports cognitive ergonomics by minimizing unnecessary mental effort and streamlining access to critical information. For future evaluations, however, it would be beneficial to incorporate time-based testing in order to quantitatively assess the system's impact on operational efficiency.

Although the SLR highlighted the benefits of visual, auditory, and haptic elements for enhancing cognitive support, such features were not incorporated into the current version of Concept 2. The prototype focused solely on visual interface improvements. Future iterations could be significantly strengthened by integrating auditory cues (e.g., alerts or confirmations) and haptic feedback (e.g., vibrations to signal errors or next steps), which would align more closely with best practices in cognitive ergonomics and support operators in complex or distracting work environments.

All participants in the pilot test fell within a similar age range, generally classified as middle-aged, and had substantial experience in their roles. Despite varying familiarity with digital tools, all participants found the system straightforward, intuitive, and easy to use. No significant difficulties were reported in adapting to the prototype, suggesting that the interface design is accessible and does not pose a barrier to users based on age or prior digital experience. However, further testing with a broader age and experience demographic, particularly including younger and older operators, would be valuable in evaluating the inclusiveness and generalizability of the system.

6.2 Evaluation of the Pilot & Stakeholder Engagement

This section reflects on the broader engagement with stakeholders throughout the project, from early interviews and requirement gathering to the pilot studies for Concept 1 and Concept 2. The goal was to involve a wide range of roles, including process planners, operators, team leaders, and line managers, in order to understand needs, validate ideas, and evaluate feasibility.

6.2.1 Preperations and Interview Reflections

One key learning from this project was the importance of properly preparing stakeholders ahead of interviews and pilot sessions. This became especially evident during the internal interview phase. In this case, the interview scheduling was coordinated through group managers, who were given an initial introduction to the thesis project's scope and the purpose of the interviews. These managers were then asked to select operators and technicians to participate.

However, in many instances, the group managers had not passed on this context to the selected participants. As a result, several of the interviewees were unfamiliar with the topic or unaware of why they had been invited. Although no prior preparation was required from participants, the lack of awareness led to some individuals feeling unprepared or unsure of what to contribute. A few even stated that they hadn't thought about the subject before and therefore didn't have anything specific to say.

This situation resulted in a greater need for guided questioning by the interviewers, often requiring more time to help participants reflect and formulate meaningful input. While this approach was still productive, it is likely that more thoughtful or varied insights may have emerged had the interviewees received background information in advance. In future projects, providing participants with a short pre-read, scope summary, or sample questions beforehand would likely enhance engagement, reduce initial confusion, and improve the depth and relevance of the feedback collected.

Despite this, the interviews helped to uncover critical pain points and expectations. Many stakeholders had not previously reflected on how inconsistent documentation practices are across departments. Simply initiating the conversation on standardization was valuable in itself.

6.2.2 Pilot Study Reflection

For the pilot study, these earlier challenges were taken into consideration. A presentation was prepared and delivered during an initial meeting with the participants involved in the Concept 1 pilot. This session served to introduce the scope and objectives of the thesis, ensuring that all participants had a shared understanding of the context before the evaluation began.

During the second meeting, the participants were already familiar with the project, which allowed the focus to shift toward a detailed walkthrough of the proposed standardization framework. Feedback was gathered during this session, and the material was subsequently shared with participants to review further with their respective teams. They were encouraged to submit additional comments on the framework and complete a questionnaire specifically designed to gather insights on Concept 1.

Four sets of written feedback on the standard were received from various process planner teams. The comments were largely consistent across teams and highlighted several points and process-specific insights that the master thesis students had not previously been aware of. These inputs were validated in consultation with the Scania supervisor, and relevant updates were subsequently made to the standard. However, the questionnaire distribution was less successful. Despite being shared with 12 team leaders, who were also encouraged to forward it to their colleagues, only three responses were submitted. This limited response rate resulted in a limited sample size and reduced ability to generalize findings.

The low response rate to the questionnaire highlights challenges in engaging stakeholders in structured feedback. Several factors may have contributed, including time constraints, unclear prioritization, and the fact that the request came from thesis students rather than internal leadership. It is also possible that some respondents found the questions difficult to interpret or too abstract, which could have discouraged participation or completion. Moreover, based on informal feedback, the combination of attending the pilot study meeting, reviewing the standard, submitting comments, and then completing the questionnaire may have been perceived as too demanding within existing workloads. Additionally, the reliance on team leaders to forward the questionnaire may have reduced visibility or context for potential respondents.

For the pilot study of Concept 2, a similar approach was taken. A selected group of operators and one technician were contacted through the master thesis supervisor at Scania at the pilot process. The participants were first introduced to the thesis through an initial presentation and a baseline interview, during which they were informed about the scope of the pilot study and their role in it. They were also notified that a follow-up session would be held to test the developed concept.

As previously mentioned, the feedback from this pilot study was highly positive. Participants expressed enthusiasm about the concept and also provided constructive suggestions for how it could be further improved to increase usability and functionality. Following the pilot, participants were invited to complete a questionnaire. Out of the four individuals involved, three responded.

The questionnaire results for Concept 2 reflected the same positive feedback received during the pilot study. Although the sample size was small, the responses supported the findings that the concept was intuitive, well-received, and aligned with operator needs. However, it would have been highly valuable to test Concept 2 with a broader group of users and across multiple production processes. A larger and more extensive pilot study could have provided more representative feedback by capturing a wider range of workflows, user experiences, and process-specific requirements. It would also have helped identify edge cases or integration challenges that may not arise in a single-process setting. Involving more operators would have allowed for deeper validation of usability, increased the reliability of feedback data, and strengthened user buy-in by fostering a sense of ownership in the development process.

Ideally, such testing would have taken place in a live production environment, allowing observations of how operators use the digital interface in real time to access information and guide their tasks. However, this was beyond the scope of the master thesis due to the extensive safety and quality assurance measures required to ensure that neither the product nor the production process would be negatively affected during testing. Nevertheless, the pilot and questionnaire together provide a strong indication that the concept has significant potential for further development and broader implementation

One notable observation from the pilot phase is that Concept 1 received more critical feedback than Concept 2. This was largely due to the composition of the pilot group: Concept 1 was evaluated by process planner team leaders from multiple departments, each with differing structures and process needs. As a result, the feedback reflected broader challenges in applying a single standard across all of DX. The framework itself was developed primarily around a turning process, common but not universally applicable for all existing processes within the organization. Given the time constraints of the thesis, it was not feasible to create a fully inclusive standard that accounted for all manufacturing process types.

In contrast, Concept 2 was evaluated by stakeholders directly tied to the pilot process, and its development was tailored to address the specific challenges of that workflow. As a result, it resonated more strongly with users. However, had the prototype been tested across a broader audience with experience from other process types, more diverse and critical feedback would likely have emerged.

6.3 Feasibility & Scalability

This section evaluates the feasibility and scalability of the two proposed concepts developed during the thesis. Concept 1 is examined in terms of its practical applicability, organizational impact, and role as a foundational element for future digital initiatives. Concept 2, a prototype for a centralized digital platform, is assessed for its potential to scale within Scania's production environment, including technical integration challenges, investment requirements, and adaptability to real-world constraints. The section also discusses broader organizational and technical prerequisites for successful implementation, and outlines key challenges and considerations related to expanding these concepts across departments and production lines within DX.

6.3.1 Feasibility of Concepts

The goal of Concept 1 was to establish a standardization framework that could serve as a foundation for preparing and structuring operator support-production instructions-in a more unified and consistent way across DX. Today, there are significant variations in how process planners prepare and structure instruction documentation between production lines and departments. While some areas have developed advanced, more cognitive intuitive instructions, others still rely on simpler formats that are harder to interpret and less supportive for operators. Defining a baseline for how operator instructions should be structured is essential to ensuring fairness, clarity, and quality in the support material used daily on the production.

Beyond harmonizing existing documentation, Concept 1 also aimed to lay the groundwork for scaling future digital solutions, such as Concept 2. If operator support follows a common format and structure, implementation of new systems can occur more seamlessly and consistently across departments, without requiring substantial local adaptation. Although the standardization framework developed in Concept 1 may not yet be fully applicable to every process or department, the pilot sparked important discussions among process planners. It prompted reflection on current practices and initiated a shift toward long-term alignment. Even if full consensus was not reached, the work has planted a seed for more unified thinking and marks a critical first step toward broader digital transformation.

However, the feasibility of scaling both concepts beyond the pilot environment presents several challenges. The pilot was limited in scope, making it difficult to predict how well the concepts would perform in more complex or diverse areas of the factory. Differences in process types, layouts, documentation maturity, and access to foundational resources, such as updated drawings and 3D models, may all impact the replicability and success of both concepts. Furthermore, Concept 2 demands greater involvement from the manufacturing organization, particularly in content creation. This includes the development of element sheets that define the what, how, and why of a task, as well as videos for critical, unsafe or complex operations.

Additionally, the development and implementation of Concept 2 would require a substantial upfront investment, both financially and organizationally. The system must also be capable of integrating with existing legacy systems at Scania, including *ArtHur*, *Maximo*, and any other tools the company wishes to incorporate into the platform, such as the MES. The broader scope of Concept 2, beyond what *ArtHur* currently supports, is based on insights gathered from benchmarking and internal interviews. It represents a vision for a more holistic and centralized operator support system - one where manufacturing personnel can, for example, digitally log team activities, update the next shift on process developments or failures, access relevant standards, and record daily machine check-ups in one unified platform. Currently, this type of information is either paper-based or written on large whiteboards, meaning that no records are retained over time. By digitalizing these activities, valuable data, such as machine failures and how they were resolved, could be systematically captured and stored. In the future, this historical data could serve as input for machine learning algorithms or AI models, similar to the data-driven approaches observed at the factory visited during the benchmarking phase.

While Concept 2 remains a prototype, it can together with the accompanying requirement specification function as a process blueprint and strategic foundation for future platform development. It outlines key system features, integration points, and user needs, offering a structured starting point for further development and cross-functional collaboration.

6.3.2 Challanges of Scaling Across DX

A key barrier to scaling either concept is the absence of a unified way of working. Without consistent practices across departments, the implementation of new systems becomes far more complex. Although Concept 1 may not yet offer a fully comprehensive standard for all of DX, it successfully initiated discussions around documentation practices and process alignment. These conversations are essential preconditions for building a scalable and sustainable digital infrastructure.

Introducing new standards also exposes a deeper organizational challenge, resistance to change. This is particularly evident when current systems, such as *ArtHur*, are seen as rigid and outdated. Several stakeholders expressed frustration at being expected to adopt new workflows using tools that do not support flexibility or efficiency. This resistance is understandable and highlights the importance of not only updating processes but also modernizing the tools that support them. In its current state, *ArtHur* imposes limitations on usability, automation, and content management. As one participant remarked, "*ArtHur* limits how much you can dream".

The feasibility of Concept 2 also hinges on its ability to integrate with existing systems, accommodate varying process types, and meet the real-world needs of operators. While Concept 2 received positive feedback for being intuitive and useful, this was within a relatively narrow testing context. Broader implementation would require significant customization, operator training, and technical support, particularly in areas where digital tools are less familiar or practical due to environmental factors (e.g., dirt, machine access, or screen usability).

Technical and Organizational Preconditions
Scalability of both concepts is dependent on several critical enablers:

- System Integration: The future platform must interface seamlessly with legacy systems like *ArtHur* and *Maximo*. Without integration, siloed data and redundant work may persist.
- Digital Infrastructure: There must be reliable access to updated digital assets (e.g., 3D models, version-controlled drawings) to enable standardized and visual instruction.
- Change Management: Process planners, team leaders, and operators must be engaged through ongoing communication and training. Buy-in from leadership is essential to reduce friction.
- Role Adaptability: As observed in benchmarking, operator roles are evolving toward more technical and supervisory tasks. The system must support different experience levels and learning styles.
- Cost-Benefit Alignment: A realistic evaluation of the return on investment must be made, especially when comparing centralized platforms to smaller-scale, leaner alternatives.

While both Concept 1 and Concept 2 are technically feasible and aligned with stakeholder needs, their successful scaling across DX will depend on strategic investment, cultural alignment, and modernization of existing systems. Concept 1 lays the foundation for standardization, while Concept 2 demonstrates what a future operator support platform could look like. To move forward, Scania must balance the desire for innovation with the realities of existing workflows, system constraints, and the people who ultimately rely on these tools in their daily work.

6.4 Benchmarking Evaluation & Reflection

The benchmarking conducted in this thesis served as a critical input for identifying best practices and exposing gaps in Scania's current approach to production instructions. Interviews were held with several peer companies and industry experts, complemented by a site visit to a Global Lighthouse Network facility. These activities collectively enabled a comparative analysis between Scania and industry-leading practices.

6.4.1 Key Differences Between Scania and Benchmarking Peers

The benchmarking conducted in this study revealed clear differences in how production instructions are structured and presented at Scania compared to peer companies. One key observation was that many peer OEMs have adopted significantly more mature and standardized digital instruction systems. While Scania continues to rely heavily on printed instructions through the *ArtHur* system, several peers have transitioned to centralized digital platforms, often fully integrated with their MES. For instance, one benchmarked company employed a structured "Define Work" methodology, supported by interactive tablets on the shop floor, job breakdown sheets, and embedded instructional videos for critical tasks. This approach integrates operator training, standardization, and process understanding directly into daily work. Another OEM had adopted a hybrid approach similar to Concept 2, where a digital platform had been developed to provide centralized access to work instructions and other production-related activities directly at the line via a larger screen. However, paper-based materials were still used when necessary, for example, technical drawings for machine rigging were often printed and kept at the workstation for practical use.

Another company employed barcode-based instruction systems, enabling operators to scan and receive up-to-date information about tools, material, and work orders directly on digital displays. This approach not only reduced paper usage but also improved real-time accuracy and reduced human error. Scania's current infrastructure, particularly *ArtHur*, lacks this level of integration and adaptability, and often presents usability barriers that were highlighted by several internal stakeholders.

Another clear contrast was found in how instructions are visually presented. At the benchmarked Lighthouse factory, digital twins, 3D visualizations, and AI-assisted inspection tools were used extensively to support operator tasks and decision-making. This contrasts with Scania's current heavy reliance on static technical drawings, where visual support is more limited and often outdated or inconsistent across departments.

The company visit also highlighted the importance of user role adaptation. Operators in advanced factories were transitioning into more technical and supervisory roles, supported by streamlined systems and real-time feedback mechanisms, an evolution that requires matching digital tools and flexible systems, which Scania has not yet fully embraced.

While the larger OEMs provided examples of advanced, integrated digital instruction systems, the smaller benchmarked companies, those not operating as OEMs, offered a different, but equally valuable, perspective. These companies often had more limited resources, smaller production volumes, and less complex product portfolios, which influenced how they approached digitalization and work instructions.

In several cases, the smaller companies had implemented leaner and more pragmatic solutions, often demonstrating greater flexibility and responsiveness to their specific operational needs. While their systems were not as technologically advanced as those of the larger OEMs, they placed a strong emphasis on clear, concise instructions tailored to the tasks at hand. These companies frequently relied on simple digital tools, such as PDFs, Microsoft Word, or Excel files stored on shared drives, and prioritized ease of access and rapid updating over advanced system integration.

Many of the smaller suppliers also noted that their operators were highly experienced and comfortable working with complex schematic drawings. Interestingly, unlike Scania, where in-process part (IPP) drawings are often used to guide operations for each process, these suppliers typically based their work on final product drawings, which are even more detailed and technically dense. Despite this, their experienced workforce had no significant difficulty navigating such documentation.

Some of the smaller companies had previously experimented with introducing tablets on the shop floor, aiming to digitalize instruction access. However, several of these initiatives were ultimately discontinued. Feedback suggested that the tablets were not widely adopted by operators, partly due to challenges in using the devices in typical manufacturing environments, where dirt, oil, and the need to physically enter machines made such tools impractical. This underscores the importance of context-specific implementation and the need to ensure that any digital solution is well-adapted to the realities of the production setting.

6.4.2 Lessons Learned

In contrast to the benchmarked OEMs, Scania's current approach, primarily built around the *ArtHur* system, relies heavily on printed instructions, has limited use of supportive elements, and lacks standardized processes for how instructions are created, maintained, and accessed. While some departments have taken steps toward more advanced and user-friendly documentation,using color-coding and more 3D visuals, others continue to use simpler and more outdated formats. This results in an inconsistent and, at times, inefficient user experience for operators.

These disparities point to a broader challenge: Scania is currently positioned at an earlier stage of digital maturity compared to several of its industry peers. The benchmarking activities clearly highlighted an opportunity to modernize the operator support system, particularly in how information is visualized, retrieved, and updated. They also underscored the relevance of the standardization framework developed in Concept 1, which serves as a foundational step toward enabling scalable, consistent, and user-centered digital solutions such as Concept 2.

The insights gained from benchmarking significantly influenced the design of Concept 2. The prototype incorporates several features inspired by observed best practices, including centralized access to information, video-based instructions for critical tasks, layered content navigation via hamburger menus, and a modular layout designed for scalability and future integration with systems like MES. These elements reflect not only technical capabilities but also a deeper understanding of the operational needs within modern production environments.

Importantly, the benchmarking also validated the necessity of creating systems that balance standardization with adaptability. With varying operator skill levels, learning preferences, and process complexities across departments, flexibility in how instructions are delivered is not just a convenience, it is essential. Supporting diverse user needs through multiple formats and entry points ensures that a digital solution remains usable and effective at scale. These lessons serve as guiding principles for future development and implementation of digital support systems at Scania.

Finally, in light of Industry 4.0 advancements, methods need to be modernized to better support operators, enhance efficiency, and unlock opportunities for future innovations within the system. Future advancements could include integrating capabilities such as smart quality control, improved tool wear predictions, and enhanced machine failure forecasting, each of which has the potential to further optimize operations. This modernization must also align with the principles of *the Scania Way*, fostering a more streamlined, agile, and forward-thinking approach to production.

6.4.3 Reflections on Benchmarking Method

While the benchmarking approach used in the thesis, based on interviews and a single site visit, yielded valuable insights, the method could be expanded in future studies. Including more diverse companies, cross-industry comparisons, and direct observations of operator workflows over time would allow for a deeper understanding of best practices. Additionally, collecting measurable performance data (e.g., error rates, time to train new operators) could provide objective support for the benefits of different instruction models. In contexts where site visits are not possible, video walk-throughss or remote demonstrations could also serve as an effective complement.

In summary, the benchmarking process served as a useful diagnostic tool to assess Scania's current state and to identify realistic opportunities for improvement. It also emphasized that successful digital transformation requires not just new tools, but a shift in mindset and structure, starting with consistent standards and growing into integrated, user-friendly systems aligned with operator needs.

6.5 Human Factors & Standardization

A key challenge in developing instruction systems for complex manufacturing environments lies in balancing standardization with personalization and adaptability. Standardization is essential for consistency, safety, and quality assurance, ensuring that all operators follow a unified method of work. However, rigid standardization can sometimes limit flexibility in addressing the nuances of different processes, parts, or work environments.

In practice, it can be difficult to enforce a single, fixed standard that applies universally across all events, components, or machine operations, which have been noted in the feedback from process planners regarding Concept 1. There may be cases where deviating from the standard leads to a more efficient or cognitively supportive solution, such as a better visual layout or clearer sequence of actions for a particular part. In such situations, it is important that the standard is not disregarded or bypassed informally. Instead, a robust standardization system should include mechanisms for continuous feedback and improvement, allowing suggested changes to be evaluated, validated, and, when appropriate, integrated into the standard. This fosters alignment and collaboration while still enabling innovation and practical improvements.

To a certain extent, standardization and cognitive ergonomics can coexist, as demonstrated in the development of Concept 2. Cognitive ergonomics focuses on minimizing mental workload and enhancing clarity, which can be supported through standardized formatting, layout, and structure. However, complete uniformity in visual or instructional elements, such as specific color, coding for part surfacesm, may not always be effective across all contexts. For example, assigning the same color to a certain surface type across all parts may result in confusion or misinterpretation due to design or geometric variations. Instead, the standard could define a set of approved colors or principles for color usage, offering enough flexibility for adaptation while maintaining consistency in intent.

Additionally, cognitive support depends on autonomy and situational awareness, particularly for experienced process planners who often have deep domain knowledge. Allowing limited scope for individual judgment within the standardized framework can help preserve both quality and usability.

Emerging technologies such as Adaptive User Interfaces (AUIs), as described in the SLR, offer promising potential for personalizing instruction delivery. These systems can dynamically adjust the level of detail and guidance based on factors such as the operator's experience, prior mistakes, or the complexity of the task at hand. This tailored approach improves both performance and learning by ensuring that each user receives the appropriate level of support.

However, such personalization also presents practical challenges. For instance, if multiple operators share the same device, such as a tablet, and the system is personalized based on login credentials, issues can arise when users forget to switch accounts or when devices are used without individual authentication. In such cases, adaptive settings may not align with the current user's needs, potentially causing confusion or inefficiency. These challenges highlight a limitation in how deeply instruction systems can be tailored in shared work environments, and point to the need for smart yet practical design solutions - such as quick-switch profiles or role-based default settings.

To summarize, while personalization and standardization may seem conflicting, they can be made to complement each other through thoughtful design. A flexible standard, informed by user feedback and enabled by intelligent technologies, can promote both operational consistency and user-centered support.

6.6 Societal, Ethical & Environmental Considerations

This section discusses the broader societal, ethical, and environmental implications of the proposed digital instruction system, highlighting both the opportunities and limitations associated with implementing such technologies in an industrial context.

6.6.1 Societal Considerations

During the interviews conducted both at the pilot process and across the plant, no female operators were included. This was due to the significant gender imbalance within the factory, where the operator workforce is predominantly male, as well as the fact that interview participants were pre-selected, despite a request for as diverse a group as possible. A similar imbalance was observed among the process planners at DX, resulting in a lack of female perspectives in this part of the study. Since men and women may differ in, for instance, communication preferences, and physical needs in the workplace, this constitutes a notable limitation. These perspectives are crucial to consider when designing inclusive production systems, and future work should address this gap by intentionally incorporating more diverse voices.

Moreover, no individuals with disabilities or special needs were included in our interviews, meaning that accessibility-related insights are also missing from this study. In the benchmarking activities, some female participants were interviewed, although they still represented a small minority. This reflects a broader trend in the manufacturing industry today, where gender imbalance and underrepresentation of minority groups remain prevalent. These industry realities may both influence and be influenced by wider societal structures, underscoring the importance of considering diversity and inclusion in future development and implementation of digital instruction systems.

The positive feedback received from operators indicates that improved instruction systems, such as Concept 2, have strong potential to enhance job satisfaction. Comments such as “would save time and make it easier” and “everything is close at hand” suggest that the new system contributes to a more efficient and user-friendly work experience. Furthermore, operators noted that the system could help reduce errors, which implies a potential for lowering stress levels on the production floor.

6.6.2 Ethical Considerations

The results pointed to the importance of initial learning and training. Concept 2 assumes a certain level of digital literacy, including comfort with navigating applications and understanding software interfaces. For operators unfamiliar with such tools, particularly those with limited prior exposure to digital technologies, this could present a barrier. This highlights a broader societal challenge - not all individuals, especially older employees or those from non-digital backgrounds, may feel equipped to use such systems without substantial support.

Moreover, educational backgrounds and baseline technical knowledge vary significantly across different regions of the world. While a digital solution like Concept 2 may be effective in a highly industrialized context with well-developed infrastructure and digital literacy, its applicability may be limited in regions where access to education, digital tools, or training is constrained. These global disparities must be taken into account when considering broader implementation, especially for multinational companies or suppliers operating in diverse environments.

6.6.3 Environmental Considerations

This thesis did not assess the environmental impact of the proposed digital solution, as doing so would require a comprehensive analysis involving factors such as the lifespan of digital devices in a production environment, the total number of screens needed, and their overall energy consumption. As a result, it remains unclear whether Concept 2 would constitute a more environmentally sustainable alternative to the current paper-based system.

However, the evaluation indicates that Concept 2 has the potential to reduce production errors through improved instructions and troubleshooting support. These improvements may lead to fewer defective products and less rework, which could, in turn, have positive environmental implications by minimizing material waste and energy use. Additionally, a digital system enables better logging of activities and opens possibilities for integration with AI technologies, which could support predictive maintenance, enhanced analytics, and more efficient production planning.

Digitalization is also a key driver of future industrial development and plays a central role in building more sustainable and intelligent production systems. Nevertheless, there is a delicate balance between promoting technological advancement and maintaining environmental responsibility. Determining where to draw the line between pushing digital transformation and minimizing environmental impact remains a complex but important consideration, one that would benefit from further dedicated study.

6.7 Future Work & Implementations

While this thesis provides a foundational exploration of digitalizing production instruction systems, several important steps remain for broader implementation and further development. Future work should focus both on practical deployment and continued technological advancement to realize the full potential of systems such as Concept 1 and Concept 2.

6.7.1 Further Development of Standardization (Concept 1)

An important next step is to continue developing the standardized instruction format proposed in Concept 1, with the goal of making it applicable across all production lines and machining processes within the factory. This would ensure consistency in how instructions are structured, interpreted, and updated, regardless of department or process type. Concept 1 serves as a critical foundation for unifying documentation practices and supporting cognitive clarity for operators. For full implementation, additional refinement of both content and format is required, along with the integration of this standard into existing workflows and systems used by process planners.

6.7.2 Bridging Concept 2 and Process Planning

While Concept 1 addresses standardization in a paper-based or semi-digital format, Concept 2 offers a vision for a fully digital instruction environment. Future work should explore how Concept 2 can function not only as a user interface prototype but also as a process model for how instructions should be created and managed. This includes defining the required tools, systems, and methods for instruction generation that align with the structure and user experience of Concept 2. Establishing this link is essential for turning the concept into a scalable and sustainable digital solution.

6.7.3 Expanded Pilot Testing

To better understand the long-term usability and practical effects of the digital solution, a larger-scale pilot study should be conducted. This could involve testing the system over the course of a full workday or week, enabling comprehensive evaluation of operator performance, error rates, usability, and overall process efficiency. Such a study would provide critical data for refining the system prior to broader rollout.

6.7.4 Future Advancements Through Emerging Technologies

As identified in the SLR, the long-term potential of digital work instruction systems lies not only in digitizing existing practices but also in leveraging emerging technologies to enhance cognitive support and overall system intelligence. Once a robust digital infrastructure is in place, additional technologies can be integrated to further improve operator guidance, reduce errors, and enhance efficiency across manufacturing environments.

One such advancement is the implementation of poka-yoke systems, which are designed to prevent mistakes by making incorrect actions either impossible or immediately detectable. These systems can play a crucial role in supporting operators, especially in high-variation or high-precision tasks, by minimizing the likelihood of human error and ensuring process consistency.

Another promising technology is pick-by-light, which uses visual indicators, typically LEDs positioned on shelves, machines, or workstations, to guide operators in selecting the correct components or tools. Similarly, pick-by-voice provides audio instructions through headsets, allowing operators to keep their hands and eyes free while performing tasks. Both technologies enhance efficiency and accuracy by reducing confusion and cognitive load, particularly in environments where many parts or instructions must be handled simultaneously.

Furthermore, haptic feedback technologies offer an additional sensory layer of communication, providing tactile signals, such as vibrations or pulses, to convey information to the operator. This can be especially useful in noisy or visually demanding environments where traditional visual or auditory cues may be less effective. By engaging multiple senses, haptic feedback can enhance focus, reduce response time, and increase the robustness of operator support systems.

In parallel, the integration of AI and Machine Learning (ML) presents transformative opportunities for production instruction systems. These technologies can enable dynamic, data-driven support that adapts to real-time conditions and individual user needs. For instance, as observed at the company visit at the lighthouse factory, AI systems can analyze historical maintenance data, such as tickets submitted to systems like *Maximo*, and provide operators with real-time troubleshooting suggestions. This not only accelerates problem-solving but also reduces dependency on support functions and documentation searches.

Beyond troubleshooting, AI and ML can be utilized to continuously optimize instruction content based on user interactions. By tracking which parts of the instructions are accessed most frequently, where users tend to slow down, or which steps correlate with errors, the system can evolve to better meet operator needs over time.

Together, these technologies present a vision for the future of production instruction systems: one that is intelligent, responsive, and inclusive. By combining automation, sensory augmentation, and AI-driven insights, manufacturing environments can become not only more efficient but also better aligned with the cognitive capabilities and needs of their workforce, ultimately supporting safer, smarter, and more sustainable production processes.

7
Conclusion

This thesis aimed to improve the presentation of information within Scania's Transmission Factory to better support operators in machining processes. By combining a thorough systematic literature review, benchmarking with industry peers, and iterative development involving key stakeholders, two concepts for an enhanced Production Instruction System were created and evaluated.

The first concept aligns with existing Scania standards, enabling relatively quick implementation. The second concept offers a more advanced, digital solution, incorporating features such as integrated "what," "how," and "why" instructions, interactive 3D models, embedded media, and improved navigation. This concept was tested in a pilot study and received positive feedback from operators, who found it beneficial for improving clarity and usability. Findings emphasize the importance of user-centered design and active stakeholder involvement in developing systems that are both functional and intuitive. Additionally, while digitalization presents clear advantages, its success depends on careful integration with current workflows and infrastructure to ensure user acceptance and long-term effectiveness.

Overall, this study provides valuable insights and practical recommendations for advancing production instruction systems that enhance cognitive assistance, operational efficiency, and user experience in manufacturing environments.

However, the scope of this thesis was limited to one pilot process, and real-time testing in a live production environment was not feasible due to safety and quality assurance constraints. The small sample sizes in both pilot studies and questionnaires also limit the generalization of the results, although they still provide strong directional insights.

This study highlights a significant gap in current academic research; while there is extensive literature on digital operator support in assembly environments, far less attention has been given to machining and manufacturing contexts. The cognitive demands and workflow structures differ notably between these domains, suggesting that solutions effective in assembly may not directly translate to machining. More focused research is therefore needed to address this disparity.

Future studies should investigate how digital instruction platforms function across a broader variety of machining processes and operator profiles. Long-term studies would be valuable in assessing impacts on performance, error rates, and knowledge retention over time. Additionally, with increasing digital maturity, there is growing potential to explore how logged data from operator interactions can inform adaptive systems - potentially integrating AI or machine learning to optimize instruction formats and predictive maintenance support.

As Scania continues its journey toward greater digitalization, the concepts and findings from this thesis can serve as a foundation for larger-scale implementations. Moving forward, it is essential that both technological advancement and user experience remain central to these efforts.

Bibliography

[1] Scania Group, *About scania*, Accessed: 2025-02-04, 2025. [Online]. Available: https://www.scania.com/group/en/home/about-scania.html.

[2] T. Pfeifroth, M. Dietsch, and R. Mahlandt, "Werkerassistenz in der manuellen montage/analysis of the impact of informational assistance systems on manual assembly – operator assistance in manual assembly," *Wt Werkstattstechnik Online*, vol. 111, no. 03, pp. 102–106, 2021. DOI: 10.37544/1436-4980-2021-03-10. [Online]. Available: https://doi.org/10.37544/1436-4980-2021-03-10.

[3] A. Palmqvist, E. Vikingsson, D. Li, Å. Fast-Berglund, and N. Lund, "Concepts for digitalisation of assembly instructions for short takt times," *Procedia CIRP*, vol. 97, pp. 154–159, 2021, 8th CIRP Conference of Assembly Technology and Systems, ISSN: 2212-8271. DOI: https://doi.org/10.1016/j.procir.2020.05.218. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2212827120314396.

[4] B. Rupprecht, E. Trunzer, J. Kovac, and B. Vogel-Heuser, "Conception and development of a support system for assembly technology," in *Human-Computer Interaction. Human Values and Quality of Life*, M. Kurosu, Ed., Cham: Springer International Publishing, 2020, pp. 639–657, ISBN: 978-3-030-49065-2.

[5] G. Urbikain and L. López de Lacalle, "Monithor: A complete monitoring tool for machining data acquisition based on fpga programming," *SoftwareX*, vol. 11, p. 100 387, 2020, ISSN: 2352-7110. DOI: https://doi.org/10.1016/j.softx.2019.100387. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352711018300645.

[6] P. E. Johansson, F. Delin, S. Jansson, L. Moestam, and Å. Fast-Berglund, "Global truck production – the importance of having a robust manufacturing preparation process," *Procedia CIRP*, vol. 57, pp. 631–636, 2016, Factories of the Future in the digital environment - Proceedings of the 49th CIRP Conference on Manufacturing Systems, ISSN: 2212-8271. DOI: https://doi.org/10.1016/j.procir.2016.11.109. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S221282711631263X.

[7] S. De Treville, J. Antonakis, and N. M. Edelson, "Can standard operating procedures be motivating? reconciling process variability issues and behavioural outcomes1," en, *Total Qual. Manage. Bus. Excel.*, vol. 16, no. 2, pp. 231–241, Mar. 2005.

[8] A. Haug, "Work instruction quality in industrial management," *International Journal of Industrial Ergonomics*, vol. 50, pp. 170–177, 2015, ISSN: 0169-8141. DOI: https://doi.org/10.1016/j.ergon.2015.09.015. [On-

line]. Available: https://www.sciencedirect.com/science/article/pii/S0169814115300330.

[9] D. Li, S. Mattsson, O. Salunkhe, A. Fast-Berglund, A. Skoogh, and J. Broberg, “Effects of information content in work instructions for operator performance,” Cited by: 29; All Open Access, Gold Open Access, Green Open Access, vol. 25, 2018, pp. 628–635. DOI: 10.1016/j.promfg.2018.06.092. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85065659290&doi=10.1016%2fj.promfg.2018.06.092&partnerID=40&md5=f39009021e14ae35fc45a550b32c21aa.

[10] Dassault Systèmes, *Catia v5*, https://www.3ds.com/products/catia/catia-v5, Accessed: 2025-06-16, Dassault Systèmes, 2025.

[11] IBM, *IBM Maximo: Enterprise Asset Management*, Accessed: 2025-04-01, 2025. [Online]. Available: https://www.ibm.com/products/maximo.

[12] O. Zawacki-Richter, M. Kerres, S. Bedenlier, M. Bond, and K. Buntins, Eds., *Systematic Reviews in Educational Research: Methodology, Perspectives and Application*, English, Kindle Edition. Springer VS, Nov. 21, 2019, p. 186. [Online]. Available: https://lead.to/amazon/com/?op=bt&la=en&cu=usd&key=B081W4MSMB.

[13] M. Visic, “Connecting puzzle pieces: Systematic literature review method in the social sciences,” *Sociologija*, vol. 64, no. 4, pp. 543–562, 2022, ISSN: 2406-0712. DOI: 10.2298/soc2204543v. [Online]. Available: http://dx.doi.org/10.2298/SOC2204543V.

[14] Elsevier, *Scopus ai: Trusted content. powered by responsible ai.* Accessed: 2025-05-18, 2025. [Online]. Available: https://www.elsevier.com/products/scopus/scopus-ai#0-about-scopus-ai.

[15] Cabells, *About us*, Accessed: 2025-04-11, 2025. [Online]. Available: https://cabells.com/about-us.

[16] M. Figura, M. Fraire, A. Durante, *et al.*, “New frontiers for qualitative textual data analysis: A multimethod statistical approach,” *European Journal of Cardiovascular Nursing*, vol. 22, no. 5, pp. 547–551, Feb. 2023, ISSN: 1474-5151. DOI: 10.1093/eurjcn/zvad021. eprint: https://academic.oup.com/eurjcn/article-pdf/22/5/547/50877509/zvad021.pdf. [Online]. Available: https://doi.org/10.1093/eurjcn/zvad021.

[17] D. Romero, P. Gaiardelli, T. Wuest, D. Powell, and M. Thürer, “New forms of gemba walks and their digital tools in the digital lean manufacturing world,” in *Advances in Production Management Systems. Towards Smart and Digital Manufacturing*, B. Lalic, V. Majstorovic, U. Marjanovic, G. von Cieminski, and D. Romero, Eds., Cham: Springer International Publishing, 2020, pp. 432–440, ISBN: 978-3-030-57997-5.

[18] O. A. Adeoye-Olatunde and N. L. Olenik, “Research and scholarly methods: Semi-structured interviews,” *JACCP: JOURNAL OF THE AMERICAN COLLEGE OF CLINICAL PHARMACY*, vol. 4, no. 10, pp. 1358–1367, May 2021, ISSN: 2574-9870. DOI: 10.1002/jac5.1441. [Online]. Available: http://dx.doi.org/10.1002/jac5.1441.

[19] P. Storvang, B. Mortensen, and A. H. Clarke, *Using workshops in business research: A framework to diagnose, plan, facilitate and analyze workshops.*

2017, pp. 155–174, Cited by: 24. DOI: 10.1007/978-981-10-5008-4_7. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85055626181&doi=10.1007%2f978-981-10-5008-4_7&partnerID=40&md5=f9a3f84750362d26f95e6dc65953ca87.

[20] C. Eden and F. Ackermann, "Journey making group workshops as a research tool," *The Journal of the Operational Research Society*, vol. 52, no. 5, pp. 556–569, 2001. DOI: 10.2307/4102271. [Online]. Available: https://www.jstor.org/stable/4102271.

[21] M. A. Caretta and E. Vacchelli, "Re-thinking the boundaries of the focus group: A reflexive analysis on the use and legitimacy of group methodologies in qualitative research," *Sociological Research Online*, vol. 20, no. 4, 2015, Cited by: 31; All Open Access, Green Open Access. DOI: 10.5153/sro.3812. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84949205050&doi=10.5153%2fsro.3812&partnerID=40&md5=adc05d4eac43c0f93087f76f5c0d15b1.

[22] J. A. Teresi, X. Yu, A. L. Stewart, and R. D. Hays, "Guidelines for designing and evaluating feasibility pilot studies," *Medical Care*, vol. 60, no. 1, pp. 95–103, 2022, Cited by: 200; All Open Access, Green Open Access. DOI: 10.1097/MLR.0000000000001664. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85120716358&doi=10.1097%2fMLR.0000000000001664&partnerID=40&md5=12b596a2b424b184ccd708c96944acff.

[23] T. Javdani Gandomani, H. Zulzalil, A. A. Abd Ghani, A. B. M. Sultan, and K. Y. Sharif, "Exploring key factors of pilot projects in agile transformation process using a grounded theory study," *Communications in Computer and Information Science*, vol. 403, pp. 146–158, 2013, Cited by: 8. DOI: 10.1007/978-3-642-41947-8_14. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84885701300&doi=10.1007%2f978-3-642-41947-8_14&partnerID=40&md5=af041bec0b8e02e12c34c200f32cad34.

[24] J. Frey, C. Bird, and C. Willoughby, "Human aspects of smart spaces for knowledge transfer," in *Innovation through Knowledge Transfer 2012*, R. J. Howlett, B. Gabrys, K. Musial-Gabrys, and J. Roach, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 19–29, ISBN: 978-3-642-34219-6. DOI: 10.1007/978-3-642-34219-6_3. [Online]. Available: https://doi.org/10.1007/978-3-642-34219-6_3.

[25] W. E. Forum and M.
bibinitperiod Company, "Global lighthouse network: Four durable shifts for a great reset in manufacturing," World Economic Forum in collaboration with McKinsey & Company, Tech. Rep., Sep. 2020, White Paper. [Online]. Available: https://www.weforum.org/reports/global-lighthouse-network-four-durable-shifts-for-a-great-reset-in-manufacturing.

[26] *General Data Protection Regulation (GDPR) – Article 4: Definitions*, https://gdpr-info.eu/art-4-gdpr/, Accessed: 2025-05-15, European Union, 2016.

[27] Microsoft, *Powerpoint | microsoft 365*, Accessed: 2025-04-01, 2025. [Online]. Available: https://www.microsoft.com/en-us/microsoft-365/powerpoint?ocid=ORSEARCH_Bing&msockid=2c836838ad3a6b023bf67dbcacb56a5b.

[28] S. P. Dow and S. R. Klemmer, "The efficacy of prototyping under time constraints," in *Design Thinking: Understand – Improve – Apply*, C. Meinel, L. Leifer, and H. Plattner, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 111–128, ISBN: 978-3-642-13757-0. DOI: 10.1007/978-3-642-13757-0_7. [Online]. Available: https://doi.org/10.1007/978-3-642-13757-0_7.

[29] D. C. Wynn and C. M. Eckert, "Perspectives on iteration in design and development," *Research in Engineering Design*, vol. 28, no. 2, pp. 153–184, Apr. 2016, ISSN: 1435-6066. DOI: 10.1007/s00163-016-0226-3. [Online]. Available: http://dx.doi.org/10.1007/s00163-016-0226-3.

[30] Microsoft, *Microsoft 365 kostnadsfritt online | Word, Excel, PowerPoint — microsoft.com*, https://www.microsoft.com/sv-se/microsoft-365/free-office-online-for-the-web, [Accessed 08-05-2025].

[31] Figma, *What is figma?* Accessed: 2025-04-08, 2025. [Online]. Available: https://help.figma.com/hc/en-us/articles/14563969806359-What-is-Figma.

[32] Encyclopaedia Britannica Editors, *Cognition: Thought Process*, Accessed: 2025-02-20, 2025. [Online]. Available: https://www.britannica.com/topic/cognition-thought-process.

[33] C. Adams and C. Berlin, *Production Ergonomics, Designing Work Systems to Support Optimal Human Performance*. London: Ubiquity Press, Jun. 2017, p. 296, ISBN: 978-1-911529-12-5 , 978-1-911529-13-2, 978-1-911529-14-9, 978-1-911529-15-6. DOI: 10.5334/bbe.

[34] D. Li, "Effective sharing of information and knowledge in production systems," Accessed: 2025-02-20, Ph.D. dissertation, Chalmers University of Technology, Gothenburg, Sweden, 2019. [Online]. Available: https://research.chalmers.se/publication/509786/file/509786_Fulltext.pdf.

[35] S. Mattsson, M. Tarrar, and Å. Fast-Berglund, "Perceived production complexity – understanding more than parts of a system," *International Journal of Production Research*, vol. 54, no. 20, pp. 6008–6016, 2016, Received: 21 January 2015; Accepted: 9 February 2016. DOI: 10.1080/00207543.2016.115421. [Online]. Available: http://dx.doi.org/10.1080/00207543.2016.115421.

[36] S. Mattsson, M. Tarrar, and N. S. Harari, "Using the complexity index for improvement work: Investigating utilisation in an automotive company," *International Journal of Manufacturing Research*, vol. 15, no. 1, 3–End Page, 2020, Accessed: 2025-02-20. DOI: 10.1504/IJMR.2020.105503. [Online]. Available: https://www.inderscienceonline.com/doi/pdf/10.1504/IJMR.2020.105503.

[37] E. M. Alkhalifa, "Exhibiting the effects of the episodic buffer on learning with serial and parallel presentations of materials," *Informing Science: The International Journal of an Emerging Transdiscipline*, vol. 12, pp. 57–71, 2009, Accessed: 2025-02-20. [Online]. Available: https://inform.nu/Articles/Vol12/ISJv12p057-071Alkhalifa228.pdf.

[38] J. Jun, E. Han, J. Min, and Y. Park, "Color coding strategy utilizing stripe patterns for hierarchical environmental information design," Korean, *Archives of Design Research*, vol. 34, no. 3, pp. 229–241, 2021, ISSN: 1226-8046. DOI:

10.15187/adr.2021.08.34.3.229. [Online]. Available: https://aodr.org/_common/do.php?a=full&bidx=2659&aidx=30119.

[39] D Li, A Landström, S Mattsson, and M Karlsson, "How changes in cognitive automation can affect operator performance and productivity," en, 2014. DOI: 10.13140/2.1.5110.9128. [Online]. Available: http://rgdoi.net/10.13140/2.1.5110.9128.

[40] A. Haug, "Work instruction quality in industrial management," *International Journal of Industrial Ergonomics*, vol. 50, pp. 170–177, 2015, ISSN: 0169-8141. DOI: https://doi.org/10.1016/j.ergon.2015.09.015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0169814115300330.

[41] S. Mattsson, Å. Fast-Berglund, and D. Li, "Evaluation of guidelines for assembly instructions," *IFAC-PapersOnLine*, vol. 49, no. 12, pp. 209–214, 2016, 8th IFAC Conference on Manufacturing Modelling, Management and Control MIM 2016, ISSN: 2405-8963. DOI: https://doi.org/10.1016/j.ifacol.2016.07.598. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2405896316308588.

[42] A. Claeys, S. Hoedt, N. Soete, H. Van Landeghem, and J. Cottyn, "Framework for evaluating cognitive support in mixed model assembly systems," *IFAC-PapersOnLine*, vol. 48, no. 3, pp. 924–929, 2015, 15th IFAC Symposium onInformation Control Problems inManufacturing, ISSN: 2405-8963. DOI: https://doi.org/10.1016/j.ifacol.2015.06.201. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2405896315004401.

[43] A. Darejeh and D. Singh, "A review on user interface design principles to increase software usability for users with less computer literacy," *Journal of Computer Science*, vol. 9, no. 11, pp. 1443–1450, Sep. 2013. DOI: 10.3844/jcssp.2013.1443.1450. [Online]. Available: https://thescipub.com/abstract/jcssp.2013.1443.1450.

[44] A. Palmqvist, E. Vikingsson, D. Li, Å. Fast-Berglund, and N. Lund, "Concepts for digitalisation of assembly instructions for short takt times," *Procedia CIRP*, vol. 97, pp. 154–159, 2021, 8th CIRP Conference of Assembly Technology and Systems, ISSN: 2212-8271. DOI: https://doi.org/10.1016/j.procir.2020.05.218. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2212827120314396.

[45] D. Reguera-Bakhache, I. Garitano, C. Cernuda, R. Uribeetxeberria, U. Zurutuza, and G. Lasa, "An adaptive industrial human-machine interface to optimise operators working performance," in *2021 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, 2021, pp. 1213–1219. DOI: 10.1109/AIM46487.2021.9517434.

[46] R. Leder, H. Stern, and M. Freitag, "Towards design guidance for the digitalisation of work instructions by focusing on technological possibilities and industrial requirements," *Procedia CIRP*, vol. 109, pp. 466–471, 2022, ISSN: 2212-8271. DOI: 10.1016/j.procir.2022.05.279. [Online]. Available: http://dx.doi.org/10.1016/j.procir.2022.05.279.

[47] P. Letmathe and M. Rößler, "Should firms use digital work instructions?—individual learning in an agile manufacturing setting," *Journal of Operations Manage-*

ment, vol. 68, no. 1, pp. 94–109, Oct. 2021, ISSN: 1873-1317. DOI: 10.1002/joom.1159. [Online]. Available: http://dx.doi.org/10.1002/joom.1159.

[48] Y. Zhang, J. Pang, and H. Li, "Research on the influence of digitalization on competitive advantage of manufacturing enterprises," *Managerial and Decision Economics*, vol. 45, no. 5, pp. 3316–3334, Apr. 2024, ISSN: 1099-1468. DOI: 10.1002/mde.4201. [Online]. Available: http://dx.doi.org/10.1002/mde.4201.

[49] N. Dr. Obermayer, T. Dr. Csizmadia, and Z. Dr. Banász, "Companies on thin ice due to digital transformation: The role of digital skills and human characteristics," *International and Multidisciplinary Journal of Social Sciences*, vol. 11, no. 3, pp. 88–118, Nov. 2022, ISSN: 2014-3680. DOI: 10.17583/rimcis.10641. [Online]. Available: http://dx.doi.org/10.17583/rimcis.10641.

[50] K. Stentoft and M. L. Petersen, "Electronics in harsh environments - product verification and validation," in *2008 Annual Reliability and Maintainability Symposium*, IEEE, 2008, pp. 456–462. DOI: 10.1109/rams.2008.4925839. [Online]. Available: http://dx.doi.org/10.1109/RAMS.2008.4925839.

[51] F. Longo, A. Padovano, and S. Umbrello, "Value-oriented and ethical technology engineering in industry 5.0: A human-centric perspective for the design of the factory of the future," *Applied Sciences*, vol. 10, no. 12, p. 4182, Jun. 2020, ISSN: 2076-3417. DOI: 10.3390/app10124182. [Online]. Available: http://dx.doi.org/10.3390/app10124182.

[52] S. De Treville, J. Antonakis, and N. M. Edelson, *Can standard operating procedures be motivating? reconciling process variability issues and behavioural outcomes1*, en, Mar. 2005. DOI: 10.1080/14783360500054236. [Online]. Available: http://dx.doi.org/10.1080/14783360500054236.

[53] P. E. Johansson, F. Delin, S. Jansson, L. Moestam, and Å. Fast-Berglund, "Global truck production – the importance of having a robust manufacturing preparation process," *Procedia CIRP*, vol. 57, pp. 631–636, 2016, Factories of the Future in the digital environment - Proceedings of the 49th CIRP Conference on Manufacturing Systems, ISSN: 2212-8271. DOI: https://doi.org/10.1016/j.procir.2016.11.109. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S221282711631263X.

[54] Microsoft Corporation, *What is microsoft teams?* Accessed: 2025-05-18, 2024. [Online]. Available: https://support.microsoft.com/en-us/topic/what-is-microsoft-teams-3de4d369-0167-8def-b93b-0eb5286d7a29.

[55] *Q-DAS qs-STAT — hexagon.com*, https://hexagon.com/products/q-das-qs-stat, [Accessed 15-05-2025].

[56] Microsoft, *What is sharepoint?* Accessed: 2025-05-12, 2024. [Online]. Available: https://support.microsoft.com/en-us/office/what-is-sharepoint-97b915e6-651b-43b2-827d-fb25777f446f.

[57] SAP, *What is sap?* Accessed: 2025-05-12, 2024. [Online]. Available: https://www.sap.com/sea/about/what-is-sap.html.

[58] Microsoft Corporation, *Power bi overview*, Accessed: 2025-05-18, 2024. [Online]. Available: https://learn.microsoft.com/en-us/power-bi/fundamentals/power-bi-overview.

[59] E. T. AB, *Edgecam*, Accessed: 2025-05-16, 2025. [Online]. Available: https://www.edgetech.se/edgecam.

A
Appendix A

Chalmers		Document Type	Requirement Specification				
IMSX30 - Spring 25		*Project*	Production Instruction System for Scania's Transmission Factory, Södertälje				
Issuer: Amanda Bergström Ohlsson, Linda Holmgren Faghihi			***Created:*** 2025-03-10 ***Modified:*** 2025-04-14				
	Criterias		***Target***	***R/DR****	***Weight***	***Verification method***	***Stakeholder***
1	**Function/s**						
	1.1	The user can export data from Catia V5 to the system	***Data export from Catia V5 to the system within 5 seconds for files up to 50 MB, with data integrity maintained.***	R		Monitor the automated data import process for a defined period (e.g., 1 week).	Process Planners
	1.2	Data imports automatically from Maximo** to the system	***Automated data import from Maximo every 10 minutes with 99% accuracy.***	R		Conduct automated monitoring of the data import process over a specified period (e.g., 1 week).	Process Planners & Operators
	1.3	The system shall ensure real time updates between the measuring room program and the system without manual intervention	***Real-time updates between the measuring room program and the system with a delay of no more than 2 seconds, without manual intervention.***	R		Monitor the data exchange between the measuring room program and the system in real-time during normal operation.	Process Planners & Operators
	1.4	User Guide for usability for the system	***Provide an accessible user guide, updated quarterly, in both online and offline formats.***	DR		Review the user guide for accessibility, content accuracy, and format availability (online and offline).	Operators & Literature
	1.5	The system notifies the user if instructions have been updated	***Notify users of updated instructions within 5 minutes, with a summary of changes.***	DR		Simulate an instruction update and track the notification process.	Operators
	1.6	The system shall allow users to provide real-time feedback to process planners.	***Allow users to submit feedback to process planners in 3 clicks, with automatic routing.***	DR		Test the feedback submission process by having users submit feedback within the system.	Operators
	1.7	The user must have the possibility to have multiple documents open at the same time	***Support at least 5 simultaneous documents, with no performance issues.***	R		Open 5 or more documents simultaneously and evaluate system performance (e.g., responsiveness, load time).	Process Planners & Operators
	1.8	The system shall alert the user when a document has not been updated within a specified period of time, indicating that a revision may be required.	***Each document shall trigger a notification if it has not been updated within 730 days (2 years) since the last revision date.***	DR		Trigger a system test by setting a document's last revision date to over 730 days ago and verify that a notification is sent to the user.	Thesis Workers
	1.9	The system shall provide a zoom function to enable users to magnify and reduce the view of relevant data, images, or models.	***Provide zoom functionality from 10% to 500% with no loss of image quality.***	DR		Test the zoom functionality on various data, images, or models, adjusting the zoom from 10% to 500%.	Operators
	1.10	The system should support interactive presentation of 3D drawings/models	***Support interactive presentation of 3D models with rotation, zoom, and pan, in common formats***	DR		Open and interact with 3D models in common formats (e.g., STEP, IGES, STL) within the system.	Operators & Literature
	1.11	The system shall provide an intuitive search function that allows users to find articles based on keywords, categories, or relevant metadata	***Implement a search function that allows users to find articles within 3 seconds using keywords, categories, or metadata, with 95% accuracy.***	R		Test the search function by searching for articles using various keywords, categories, and metadata. Measure search time and accuracy.	Operators & Thesis Workers
	1.12	The user must be able to update instruction documents	***Allow users to update instruction documents in under 5 minutes, with version control to track changes.***	R		Test the process of updating an instruction document, including making changes and tracking versions.	Process Planners
2	**Performance**						
	2.1	The system should have a short processing time	***System response time for retrieving documents should not exceed 3 seconds in 95% of cases.***	R		Measure the system's response time when retrieving documents under typical usage conditions.	Process Planners & Operators
	2.2	The instructions in the system are always up to date	***Changes to instructions should be reflected in the system within 1 minute of approval.***	R		Modify one of the instructions and measure the time it takes for the update to be reflected in the system.	Process Planners, Operators & Scania
	2.3	The system shall enable quick and efficient retrieval of relevant instruction documents	***At least 90% of users should be able to find the correct document within the first search attempt.***	R		Select a pilot group of approximately 50 individuals from diverse backgrounds and task them with locating a specific document. Measure how many successfully find the correct document.	Operators
3	**Information Content (Instructions)**						
	3.1	Instructions for rigging should always include tool type, supplier number, number of tools, tool life	***Automated validation should ensure all required fields are filled before an instruction is approved. System behavior must block approval and return a validation message when any required field is missing.***	R		Test the system's response when rigging instructions are submitted with one or more required fields left blank.	Process Planners & Operators
	3.2	The instructions should provide data regarding spare parts linked to the processing tools	***The instruction provides the operator with correct information about data on spare parts linked to the processing tools***	DR		Manual review, check if system updates data when changes have been made, e.g. change of name of a spare part	Operators
	3.3	Instructions for measuring shall always include measurement frequency, tool type, and the resepctive measurement position/s that the tool should measure	***Automated validation should ensure all required fields are filled before an instruction is approved. System behavior must block approval and return a validation message when any required field is missing.***	R		Test the system's response when rigging instructions are submitted with one or more required fields left blank.	Process Planners & Operators
	3.4	The tool should be visualized	***Each tool referenced in an instruction must be accompanied by a clear image, technical drawing, or 3D model. Should follow a standard format.***	R		Manual review.	Operators
	3.5	Information should be divided into categories "what", "how" and "why"	***All instructions must be structured into the three categories: "what" (task details), "how" (execution steps), and "why" (purpose and importance). The system should automatically prompt users to complete all three sections ("what", "how", "why") before allowing submission or publication.***	R		Manual review or if any section is left empty, the system must display a prompt or warning and revent submission or publication of the instruction.	Thesis Workers
	3.6	The instruction should clearly indicate the starting point of the tool's turning process.	***The instruction must visually mark the exact starting point of the tool's turning process with at least 95% accuracy in placement.***	DR		Manual review.	Operators
	3.7	Step-by-step video demonstrations to provide clear guidance on task execution.	***At least 90% of tasks requiring detailed guidance must have an instructional video. The video should be less than 5 minutes long, covering all critical steps in a clear and structured manner.***	DR		Manual review or if any section is left empty, the system must display a prompt or warning and revent submission or publication of the instruction.	Thesis Workers
	3.8	Detailed job breakdown for task categorised as critical for operator safety and quality of the article.	***All tasks classified as critical for operator safety and product quality must have a comprehensive job breakdown including risks, key actions, and verification steps. Instructions should be reviewed and validated by safety and quality teams before release.***	DR		Manual review.	Thesis Workers

	3.9	The workpiece should be visualized in all instruction documents	***Every instruction involving a workpiece must include a high-resolution image, technical drawing, or 3D rendering.***	R		Manual review.	Operators
4	**Ergonomics (Instructions)**						
	4.1	Color coding of tools	***Each tool category should have a distinct, standardized color code applied consistently across all instructions.***	R		Manual review.	Operators
	4.2	Tools used on the same surfaces (unpolished turning and fine turning) should be visually linked for clear identification.	***The system must provide a clear visual link between tools used on the same surfaces (rough turning and fine turning) through color coding, symbols, or annotations, ensuring 100% clarity.***	DR		Manual review.	Operators
	4.2	Color coding of adjustable dimensions	***Adjustable dimensions must be highlighted using a predefined and consistent color scheme across all instructions.***	R		Manual review.	Operators
	4.3	Color coding of processed surfaces	***Processed surfaces should be marked with a standard color across all visual instructions.***	R		Manual review.	Operators
	4.4	Step-by-step guidence for instructions	***All instructions must be structured in a clear, numbered sequence with a logical flow.***	R		Manual review.	Literature & Operators
	4.5	Suffciently large text size	***The text size must be at least 12pt for general instructions and 16pt for key warnings or safety notes.***	R		Measure font sizes using digital tools or print layout settings.Confirm that all standard text meets or exceeds 12pt. Confirm that all warnings/safety notes are at least 16pt and clearly distinguishable.	Operators
	4.6	Adaptable to different age groups	***Instructions should provide options for text enlargement and high-contrast modes for enhanced readability.***	DR		Manual review.	Literature
	4.7	Adaptable to different experience levels	***The system must offer both detailed and simplified instruction modes to accommodate beginners and experienced operators.***	DR		Manual review.	Literature & Operators.
	4.8	The instructions shall display task status	***The system should show clear task progression indicators (e.g., Not Started, In Progress, Completed).***	DR		Manual review.	Literature
	4.9	Text, images, measurement points shall be visually linked using elements such as arrows, lines, or other graphical elements to enchance clarity and readability	***Instructions must include arrows, lines, or highlights to clearly associate text with images and measurement points. Should follow a standard practice.***	R		Manual review.	Operators
	4.10	Only relevant information is displayed	***Instructions should be task-specific, displaying only necessary information for the current step.***	R		Manual review.	Literature & Operators
	4.11	Symbols shall follow industry standards where applicable and include explanatory labels when necessary to enhance user comprehension	***All symbols must comply with ISO, ANSI, or industry-specific standards where applicable. Symbols should include brief text descriptions when necessary for clarity.***	DR		Manual review.	Operators
	4.12	Reduced and consistent terminology	***Instruction terminology must be standardized and limited to essential terms. A predefined terminology list should be used, reducing variations in phrasing by at least 90% across documents.***	R		Manual review, checking with industry standards and operator knowledge level.	Operators & Thesis Workers
	4.13	Key points are highlighted	***Critical information (e.g., safety steps, key measurements) must be bolded, colored, or boxed for emphasis. Should follow a standard practice.***	R		Manual review.	Operators & Thesis Workers
	4.15	Appropriate number of information levels	***Instructions should be structured with a maximum of three levels (e.g., overview, step-by-step details, troubleshooting).***	R		Manual review.	Thesis Workers
	4.16	The instruction has simple language	***The language should be concise and free of technical jargon unless necessary.***	R		Manual review, checking with industry standards and operator knowledge level.	Operators & Thesis Workers
	4.17	Visualizations should have at least one 3D-picture	***Each instruction must contain at least one 3D-rendered image or model of the component or tool.***	R		Manual review.	Operators & Thesis Workers
5	**Lifetime**						
	5.1	The system design should be relevant for 10 years	***The design is scalable and adaptable to future technologies and requirements.***	DR		System review.	Thesis Workers
6	**Medium**						
	6.1	The instruction system medium is portable	***Ensure the system is lightweight (under 2 kg) and easily carried (managable by one hand).***	R		Weigh the medium, try to carry with one hand.	Operators
	6.2	The instruction system medium can be used with dirty hands	***Design with a rugged, wipeable surface for use with dirty hands***	R		Try to use the medium using dirty/oily hands.	
	6.3	Each instruction system unit should be dedicated to a specific operation/machine	***Assign one unit per operation/machine.***	R		Manual review.	Thesis Workers
	6.4	The instruction system medium should be digital	***Ensure the system is fully digital and supports common formats (e.g., PDF, HTML).***	DR		Test the various supported formats and verify whether the instruction system processes them correctly or encounters any failures.	Scania
	6.5	The instruction system medium shall be easily operable by individuals working in the factory.	***Design for easy use with gloves or in tough conditions, with responsive buttons or touchscreens.***	R		Try interacting with the medium while wearing gloves to determine whether buttons or touchscreens remain responsive.	Operators
7	**Environmental Impact**						
	7.1	The solution decreas the amount of paper needed in production	***Decrease paper consumption in production by 80% within the first year of implementation.***	DR		Compare the amount of paper used in the first year of implementation to the amount used in the previous year and measure the difference.	Scania & Operators
8	**Security**						
	8.1	Data*** leakage shall not occur	***Ensure 100% protection against data leakage through secure encryption, access controls, and regular security audits.***	R		Analysis of data leakage over time	Scania & GDPR
	8.3	Users are required to authenticate themselves before gaining access to the system.	***Users are unable to login to the system without a correct username and password***	R		Log in to the system	GDPR

	8.2	The user gets logged out automatically after a certain amount of time	***The user gets logged out automatically after 1 hour of inactivity***	DR		Log in to the system and remain inactive to observe any automatic timeouts or system responses.	Thesis Workers (GDPR)

* R = Requirement, DR = Desired Requirementm (wishes)

** IBM Maximo is an enterprise asset management software that optimizes asset performance, maintenance, and lifecycle management.

*** Data including details on articles, their production status, and user information, covering key attributes such as identifiers, progress updates, and user interactions.

B
Appendix B

Chalmers		**Document Type**	**Requirement Specification**				
IMSX30 - Spring 25		***Project***	Production Instruction System for Scania's Transmission Factory, Södertälje				
Issuer: Amanda Bergström Ohlsson, Linda Holmgren Faghihi			***Created:*** 2025-03-10				
			Modified: 2025-04-14				
	Criterias		***Target***	***R/DR****	***Weight***	***Verification method***	***Stakeholder***
1	**Function/s**						
	1.1	The user can export data from Catia V5 to the system	***Data export from Catia V5 to the system within 5 seconds for files up to 50 MB, with data integrity maintained.***	R		Monitor the automated data import process for a defined period (e.g., 1 week).	Process Planners
	1.2	Data imports automatically from Maximo** to the system	***Automated data import from Maximo every 10 minutes with 99% accuracy.***	R		Conduct automated monitoring of the data import process over a specified period (e.g., 1 week).	Process Planners & Operators
	1.3	The system shall ensure real time updates between the measuring room program and the system without manual intervention	***Real-time updates between the measuring room program and the system with a delay of no more than 2 seconds, without manual intervention.***	R		Monitor the data exchange between the measuring room program and the system in real-time during normal operation.	Process Planners & Operators
	1.4	User Guide for usability for the system	***Provide an accessible user guide, updated quarterly, in both online and offline formats.***	DR		Review the user guide for accessibility, content accuracy, and format availability (online and offline).	Operators & Literature
	1.5	The system notifies the user if instructions have been updated	***Notify users of updated instructions within 5 minutes, with a summary of changes.***	DR		Simulate an instruction update and track the notification process.	Operators
	1.6	The system shall allow users to provide real-time feedback to process planners.	***Allow users to submit feedback to process planners in 3 clicks, with automatic routing.***	DR		Test the feedback submission process by having users submit feedback within the system.	Operators
	1.7	The user must have the possibility to have multiple documents open at the same time	***Support at least 5 simultaneous documents, with no performance issues.***	R		Open 5 or more documents simultaneously and evaluate system performance (e.g., responsiveness, load time).	Process Planners & Operators
	1.8	The system shall alert the user when a document has not been updated within a specified period of time, indicating that a revision may be required.	***Each document shall trigger a notification if it has not been updated within 730 days (2 years) since the last revision date.***	DR		Trigger a system test by setting a document's last revision date to over 730 days ago and verify that a notification is sent to the user.	Thesis Workers
	1.9	The system shall provide a zoom function to enable users to magnify and reduce the view of relevant data, images, or models.	***Provide zoom functionality from 10% to 500% with no loss of image quality.***	DR		Test the zoom functionality on various data, images, or models, adjusting the zoom from 10% to 500%.	Operators
	1.10	The system should support interactive presentation of 3D drawings/models	***Support interactive presentation of 3D models with rotation, zoom, and pan, in common formats***	DR		Open and interact with 3D models in common formats (e.g., STEP, IGES, STL) within the system.	Operators & Literature
	1.11	The system shall provide an intuitive search function that allows users to find articles based on keywords, categories, or relevant metadata	***Implement a search function that allows users to find articles within 3 seconds using keywords, categories, or metadata, with 95% accuracy.***	R		Test the search function by searching for articles using various keywords, categories, and metadata. Measure search time and accuracy.	Operators & Thesis Workers
	1.12	The user must be able to update instruction documents	***Allow users to update instruction documents in under 5 minutes, with version control to track changes.***	R		Test the process of updating an instruction document, including making changes and tracking versions.	Process Planners
2	**Performance**						
	2.1	The system should have a short processing time	***System response time for retrieving documents should not exceed 3 seconds in 95% of cases.***	R		Measure the system's response time when retrieving documents under typical usage conditions.	Process Planners & Operators
	2.2	The instructions in the system are always up to date	***Changes to instructions should be reflected in the system within 1 minute of approval.***	R		Modify one of the instructions and measure the time it takes for the update to be reflected in the system.	Process Planners, Operators & Scania
	2.3	The system shall enable quick and efficient retrieval of relevant instruction documents	***At least 90% of users should be able to find the correct document within the first search attempt.***	R		Select a pilot group of approximately 50 individuals from diverse backgrounds and task them with locating a specific document. Measure how many successfully find the correct document.	Operators
3	**Information Content (Instructions)**						
	3.1	Instructions for rigging should always include tool type, supplier number, number of tools, tool life	***Automated validation should ensure all required fields are filled before an instruction is approved. System behavior must block approval and return a validation message when any required field is missing.***	R		Test the system's response when rigging instructions are submitted with one or more required fields left blank.	Process Planners & Operators
	3.2	The instructions should provide data regarding spare parts linked to the processing tools	***The instruction provides the operator with correct information about data on spare parts linked to the processing tools***	DR		Manual review, check if system updates data when changes have been made, e.g. change of name of a spare part	Operators
	3.3	Instructions for measuring shall always include measurement frequency, tool type, and the resepctive measurement position/s that the tool should measure	***Automated validation should ensure all required fields are filled before an instruction is approved. System behavior must block approval and return a validation message when any required field is missing.***	R		Test the system's response when rigging instructions are submitted with one or more required fields left blank.	Process Planners & Operators
	3.4	The tool should be visualized	***Each tool referenced in an instruction must be accompanied by a clear image, technical drawing, or 3D model. Should follow a standard format.***	R		Manual review.	Operators
	3.5	Information should be divided into categories "what", "how" and "why"	***All instructions must be structured into the three categories: "what" (task details), "how" (execution steps), and "why" (purpose and importance). The system should automatically prompt users to complete all three sections ("what", "how", "why") before allowing submission or publication.***	R		Manual review or if any section is left empty, the system must display a prompt or warning and revent submission or publication of the instruction.	Thesis Workers
	3.6	The instruction should clearly indicate the starting point of the tool's turning process.	***The instruction must visually mark the exact starting point of the tool's turning process with at least 95% accuracy in placement.***	DR		Manual review.	Operators
	3.7	Step-by-step video demonstrations to provide clear guidance on task execution.	***At least 90% of tasks requiring detailed guidance must have an instructional video. The video should be less than 5 minutes long, covering all critical steps in a clear and structured manner.***	DR		Manual review or if any section is left empty, the system must display a prompt or warning and revent submission or publication of the instruction.	Thesis Workers
	3.8	Detailed job breakdown for task categorised as critical for operator safety and quality of the article.	***All tasks classified as critical for operator safety and product quality must have a comprehensive job breakdown including risks, key actions, and verification steps. Instructions should be reviewed and validated by safety and quality teams before release.***	DR		Manual review.	Thesis Workers

	3.9	The workpiece should be visualized in all instruction documents	Every instruction involving a workpiece must include a high-resolution image, technical drawing, or 3D rendering.	R		Manual review.	Operators
4	Ergonomics (Instructions)						
	4.1	Color coding of tools	Each tool category should have a distinct, standardized color code applied consistently across all instructions.	R		Manual review.	Operators
	4.2	Tools used on the same surfaces (unpolished turning and fine turning) should be visually linked for clear identification.	The system must provide a clear visual link between tools used on the same surfaces (rough turning and fine turning) through color coding, symbols, or annotations, ensuring 100% clarity.	DR		Manual review.	Operators
	4.2	Color coding of adjustable dimensions	Adjustable dimensions must be highlighted using a predefined and consistent color scheme across all instructions.	R		Manual review.	Operators
	4.3	Color coding of processed surfaces	Processed surfaces should be marked with a standard color across all visual instructions.	R		Manual review.	Operators
	4.4	Step-by-step guidence for instructions	All instructions must be structured in a clear, numbered sequence with a logical flow.	R		Manual review.	Literature & Operators
	4.5	Suffciently large text size	The text size must be at least 12pt for general instructions and 16pt for key warnings or safety notes.	R		Measure font sizes using digital tools or print layout settings.Confirm that all standard text meets or exceeds 12pt. Confirm that all warnings/safety notes are at least 16pt and clearly distinguishable.	Operators
	4.6	Adaptable to different age groups	enlargement and high-contrast modes for enhanced readability.	DR		Manual review.	Literature
	4.7	Adaptable to different experience levels	The system must offer both detailed and simplified instruction modes to accommodate beginners and experienced operators.	DR		Manual review.	Literature & Operators.
	4.8	The instructions shall display task status	The system should show clear task progression indicators (e.g., Not Started, In Progress, Completed).	DR		Manual review.	Literature
	4.9	Text, images, measurement points shall be visually linked using elements such as arrows, lines, or other graphical elements to enchance clarity and readability	Instructions must include arrows, lines, or highlights to clearly associate text with images and measurement points. Should follow a standard practice.	R		Manual review.	Operators
	4.10	Only relevant information is displayed	Instructions should be task-specific, displaying only necessary information for the current step.	R		Manual review.	Literature & Operators
	4.11	Symbols shall follow industry standards where applicable and include explanatory labels when necessary to enhance user comprehension	All symbols must comply with ISO, ANSI, or industry-specific standards where applicable. Symbols should include brief text descriptions when necessary for clarity.	DR		Manual review.	Operators
	4.12	Reduced and consistent terminology	Instruction terminology must be standardized and limited to essential terms. A predefined terminology list should be used, reducing variations in phrasing by at least 90% across documents.	R		Manual review, checking with industry standards and operator knowledge level.	Operators & Thesis Workers
	4.13	Key points are highlighted	Critical information (e.g., safety steps, key measurements) must be bolded, colored, or boxed for emphasis. Should follow a standard practice.	R		Manual review.	Operators & Thesis Workers
	4.15	Appropriate number of information levels	three levels (e.g., overview, step-by-step details, troubleshooting).	R		Manual review.	Thesis Workers
	4.16	The instruction has simple language	The language should be concise and free of technical jargon unless necessary.	R		Manual review, checking with industry standards and operator knowledge level.	Operators & Thesis Workers
	4.17	Visualizations should have at least one 3D-picture	Each instruction must contain at least one 3D-rendered image or model of the component or tool.	R		Manual review.	Operators & Thesis Workers
5	Lifetime						
	5.1	The system design should be relevant for 10 years	The design is scalable and adaptable to future technologies and requirements.	DR		System review.	Thesis Workers
6	Medium						
	6.1	The instruction system medium is portable	Ensure the system is lightweight (under 2 kg) and easily carried (managable by one hand).	R		Weigh the medium, try to carry with one hand.	Operators
	6.2	The instruction system medium can be used with dirty hands	Design with a rugged, wipeable surface for use with dirty hands	R		Try to use the medium using dirty/oily hands.	
	6.3	Each instruction system unit should be dedicated to a specific operation/machine	Assign one unit per operation/machine.	R		Manual review.	Thesis Workers
	6.4	The instruction system medium should be digital	Ensure the system is fully digital and supports common formats (e.g., PDF, HTML).	DR		Test the various supported formats and verify whether the instruction system processes them correctly or encounters any failures.	Scania
	6.5	The instruction system medium shall be easily operable by individuals working in the factory.	Design for easy use with gloves or in tough conditions, with responsive buttons or touchscreens.	R		Try interacting with the medium while wearing gloves to determine whether buttons or touchscreens remain responsive.	Operators
7	Environmental Impact						
	7.1	The solution decreas the amount of paper needed in production	Decrease paper consumption in production by 80% within the first year of implementation.	DR		Compare the amount of paper used in the first year of implementation to the amount used in the previous year and measure the difference.	Scania & Operators
8	Security						
	8.1	Data*** leakage shall not occur	Ensure 100% protection against data leakage through secure encryption, access controls, and regular security audits.	R		Analysis of data leakage over time	Scania & GDPR
	8.3	Users are required to authenticate themselves before gaining access to the system.	Users are unable to login to the system without a correct username and password	R		Log in to the system	GDPR
	8.2	The user gets logged out automatically after a certain amount of time	The user gets logged out automatically after 1 hour of inactivity	DR		Log in to the system and remain inactive to observe any automatic timeouts or system responses.	Thesis Workers (GDPR)

* R = Requirement, DR = Desired Requirementm (wishes)

** IBM Maximo is an enterprise asset management software that optimizes asset performance, maintenance, and lifecycle management.

*** Data including details on articles, their production status, and user information, covering key attributes such as identifiers, progress updates, and user interactions.

C

Appendix C

SCANIA

Document type/Dokumenttyp	Title/Rubrik	Issue/Utgåva
DESCRIPTION	ArtHur Standard	1
Approved by/Godkänt av (tjänsteställebeteckning namn)	File name/Filnamn	Info class/Infoklass
	Arthur standard revision 1 - Rapportkopia.docx	Internal
Issued by/Utfärdat av (tjänsteställebeteckning namn telefon)	Date/Datum	Page/Sida
DXTPR Amanda Bergström / Linda Faghihi	2025-04-07	1(16)

To/Till (tjänsteställebeteckning namn)

ArtHur Standard

Innehållsförteckning

ArtHur Struktur ... 2
Artikel-specifika instruktioner ... 4
Övergripande Riktlinjer för Dokument ... 5
Dokument-specifika riktlinjer ... 6
Bearbetningsdokument ... 6
Riggningsdokument ... 9
Korrektörsdokument ... 11
Kvalitetsstyrningsdokument ... 13
Verktygsförteckning ... 15

ArtHur

ArtHur är ett verktyg som beskriver de processteg som behövs för att tillverka en produkt. Detta verktyg ska beskriva i vilken ordning, på vilket sätt, utifrån vilka förutsättningar och till vilka toleranser en produkt ska produceras från ämne till färdig artikel. Informationen som finns i ArtHur ska vara överskådlig, lättläst, standardiserad och uppbyggd för att hjälpa operatörer i produktion i deras dagliga arbete.

ArtHur Struktur

ArtHur-programvaran är uppbyggd i flera hierarkiska nivåer. När man öppnar programmet möts man av en trädstruktur som representerar olika delar av produktionen. För DX-produkter återfinns relevant information under sektionen "ARTTRANSMO".

Vid klick på ARTTRANSMO öppnas den första nivån i en ny trädstruktur, där informationen är organiserad efter olika artikelfamiljer. Varje familj bör vara tydligt definierad med ett övergripande och standardiserat familjenamn, som speglar den artikelgrupp den tillhör.

När en artikelgrupp öppnas visas nästa nivå i trädstrukturen, där samtliga artiklar som tillhör gruppen listas. Varje artikel är definierad med ett specifikt namn som är kopplad till den produkt den ingår i. Till varje artikel hör även ett artikelnummer bestående av sju siffror, men i produktionen används främst de tre sista siffrorna för att identifiera komponenten.

Följande riktlinjer bör efterföljas vi namngivning av artiklar:

Namn: [Artikelnummer][Benämning (+ växelsteg*)][Växellåda]
**Gäller endast för kugghjul*

Tabell 1: Visar benämning av artiklar samt tillhörande förkortning

Benämning	*Förkortning*
Ingående kugghjul	Ing-Kugghjul
Huvudaxelkugghjul	HA-kugghjul
Sidoaxelkugghjul	SA-kugghjul
Solhjul	Solhjul
Retarderkugghjul	Ret-Kugghjul
Backaxelkugghjul	BA-Kugghjul
Ringhjul	Ringhjul
Artiklar (lägg till från alla byggnader)	

Exempel på namngivning av artikel:

Gamla exempel

a. [XXXXXXX][SA-Kugghjul 2:an][AAAXXX]
b. [XXXXXXX][Ing-Kugghjul][AAAXXX]

På artikelnivå finns ett antal fler nivåer med information som specificerar processen för att tillverka artikeln. På den andra informationsnivån i Arthur för den specifika artikeln beskrivs tillverkningsprocessen genom en följd av operationer (OP). Varje operation tilldelas en unik sifferkod som anger vilken typ av bearbetning som ska utföras. Exempelvis representerar OP 030 mjukbearbetning och OP 140 härdning. Operationerna listas i exakt den ordning de ska utföras i produktionen. För alternativoperations gång, till exempel om två parallella maskiner används för samma operation, förekommer operationsnumret två gånger i listan – varav den ena markeras som alternativ maskin med ett tillagt "A" (t.ex. 030A). Detta justeras genom att välja ”Alt-op” under ”kommentarskod” i programvaran.

Se Tabell 2 för standard för operationsnummer och benämning.

Tabell 2: Samtliga operationsnummer och deras respektive operationsbenämningar

Operationsnummer	*Operationsbenämning*
010	Ämnesförråd
030	Mjukbearbetning
140	Härdning
150	Blästring
170	Hårdbearbetning
180	Polering
190	Shot peening
200	Förråd

Artikel-specifika instruktioner

Operatören ska, innan riggning påbörjas, skriva ut och kontrollera alla dokument som är specifika för aktuell artikel. Detta innefattar till exempel ritningar, arbetsinstruktioner och kvalitetskrav. Syftet är att säkerställa att dokumentationen är den senaste versionen och att informationen stämmer överens med den artikel som ska produceras.

Endast information som är nödvändig vid rigg av line och körning av artikel i ordinarie produktion ska finnas i de dokument som skrivs ut till rigg dvs ordinarie artikelinstruktioner.

Varje process ska delas upp i följande typer av dokumentation:

1. Bearbetningsdokument (Bd)
2. Riggningsdokument (Rd)
3. Korrektörsdokument (Kd)
4. Kvalitetsstyrnigsdokument (Qd)
5. Verktygsförteckning (Vf)

Övergripande Riktlinjer för Dokument

De övergripande riktlinjerna beskriver generella principer och krav som gäller för samtliga ArtHur-dokument.

Typsnitt

- Arial

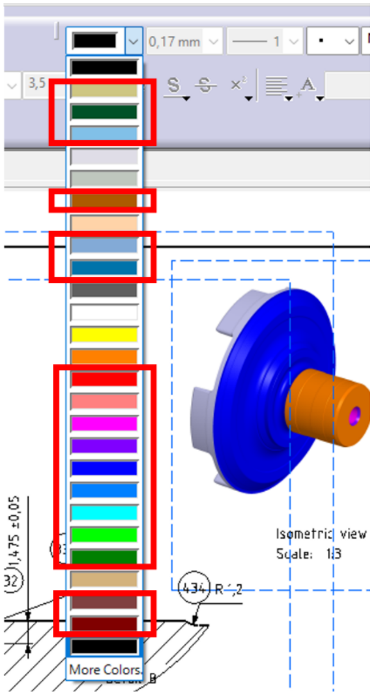
Textstorlek

- Titlar: 16
- Metadata: 14
- Mått & Övrig text: 12 (10-11 om nödvändigt, men ska helst undvikas)

Färgkodning

Se tillgängliga färger för färgkodning i CATIA i Figur 1.

- Antal tillåtna färger: 17 st (se rödmarkering i Figur 1 för tillåtna färger)
- Färgkod för uppdatering/revision: Gult
- Färgkod för utfasning av verktyg: Orange



Figur 1. Tillgängliga färger i CATIA för färgkodning av bearbetande ytor.

Dokument-specifika riktlinjer

Bearbetningsdokument

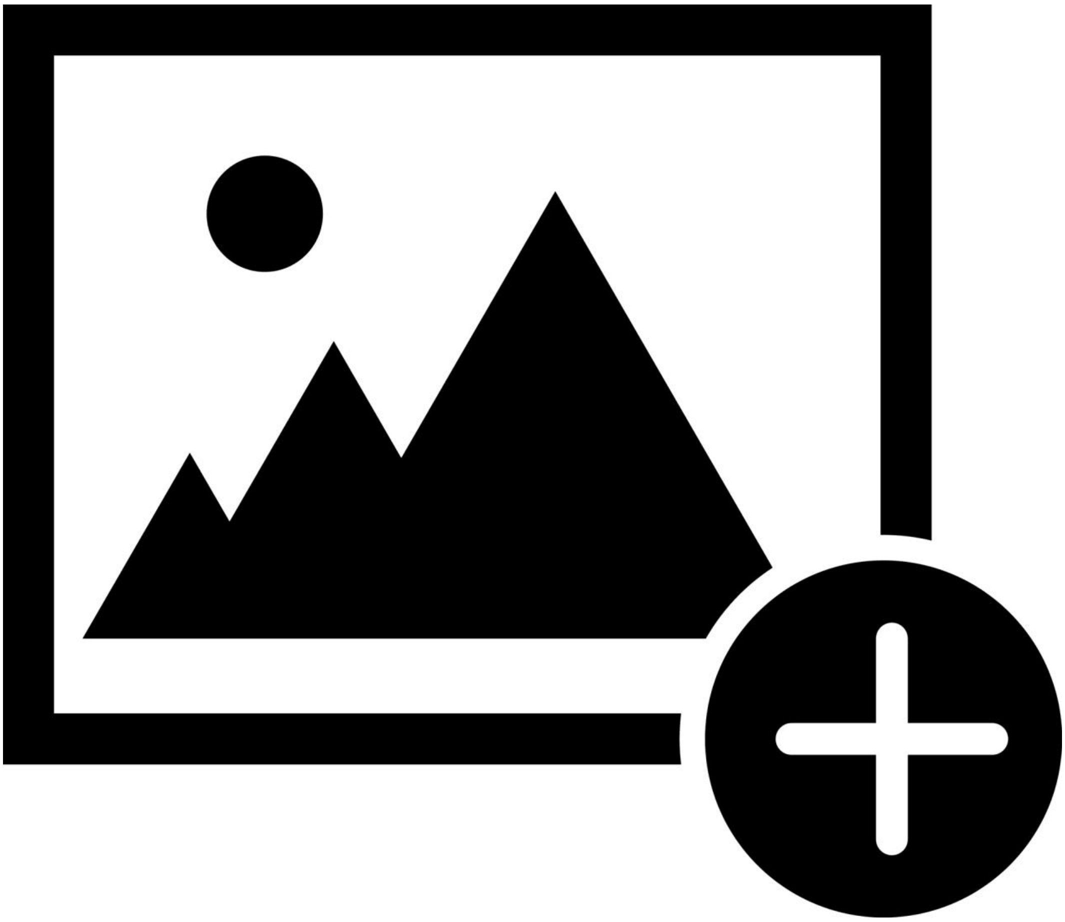
Syfte:
Bearbetningsdokumentet beskriver hur en artikel ska bearbetas i ett specifikt processteg. Det ska tydligt visualisera relevanta geometrier, mått och toleranser, samt eventuella kritiska detaljer som påverkar tillverkningen. Syftet är att säkerställa att korrekt och konsekvent information når operatörer, processplanerare, mättekniker och maskin programmerare.

Innehållskrav:

1. *Titel och Metadata*
   Dokumentet ska ha en tydlig rubrik med benämningen **”Bearbetningsdokument”** och specificera vilken process eller operation det avser. Det ska även innehålla följande information i dokumentets övre del:
   a. Ansvarig avdelning
   b. Tempobenämning (t.ex. "Svarvning 1")
   c. Utskriftsdatum
   d. Artikelbenämning
   e. Märkning
   f. Artikelnummer
   g. Maskinnummer
   h. Operationsnummer (Opnr)
   i. ECO om tillämpligt
2. *Huvudvy*
   a. Översiktsritning i 2D i svart färg som visar artikelns tvärsnitt och samtliga bearbetningsrelevanta mått med korrekt placering i artikelns geometri (se Figur X).
      i. Mått ska anges med nominellt värde och tolerans (ex. *⌀100,0 ±0,05*).
      ii. Alla mått ska presenteras i svart färg, med undantag för mått som avser härdkompensering – dessa får avvika i färg.
   b. Varje mätpunkt ska ha ett unik positionsnummer utifrån standard (t.ex. 5, 6, 105, 107…), baserat på måttets eller dimensionens typ. [Länk till standard för olika typer av positionsnummer](#).
   c. En uppdaterad DXF-fil med samtliga relevanta mått, positionsnummer och övrig ritningstext ska finnas tillgänglig i samma DXF-fil som ritningen.
      i. Skärmdupmar av ritningen är inte tillåtet.
      ii. Ny verison kommer tillåta direkt överföring från CATIA.

3. *Detaljvyer*
    a. In-zoomade vyer för komplexa områden (hörnradier, spår, vinklar) ska användas för att förtydliga detaljerade områden av artikeln där måtten är svåra att urskilja i helhetsvyn, se Figur X.
        i. Mått i detaljvyer ska markeras tydligt med positionsnummer, även om de förekommer i huvudvyn.
    b. Kompletterande 3D-vy i färg ska inkluderas som orienteringshjälp för verktygspåverkan och mätytor.
        i. Färgade zoner ska följa samma färgkodning som används i andra dokument (t.ex. korrektörs- eller riggdokument).
4. *Specialmärkta mått*
    a. Mått som endast ska mätas vid programändring ska markeras i **blått**.
        i. Texten **"Blå mått: Mäts vid programändring"** ska anges tydligt i dokumentet.
    b. För vinklar/ utan tolerans ska en generell regel anges (ex. Vinklar utan tol: ±2°).
5. *Visuell tydlighet*
    a. Uppdateringar i dokumentet samt utfasningsmarkeringar ("bubblor") ska följa en standardiserad färgkod enligt gällande riktlinjer.
    b. Alla komponenter och mått ska vara skarpa och lätta att läsa.
    c. Samtliga positionsummer ska peka till rätt position med linjer utan att korsa varandra i onödan.

Exempelbilder



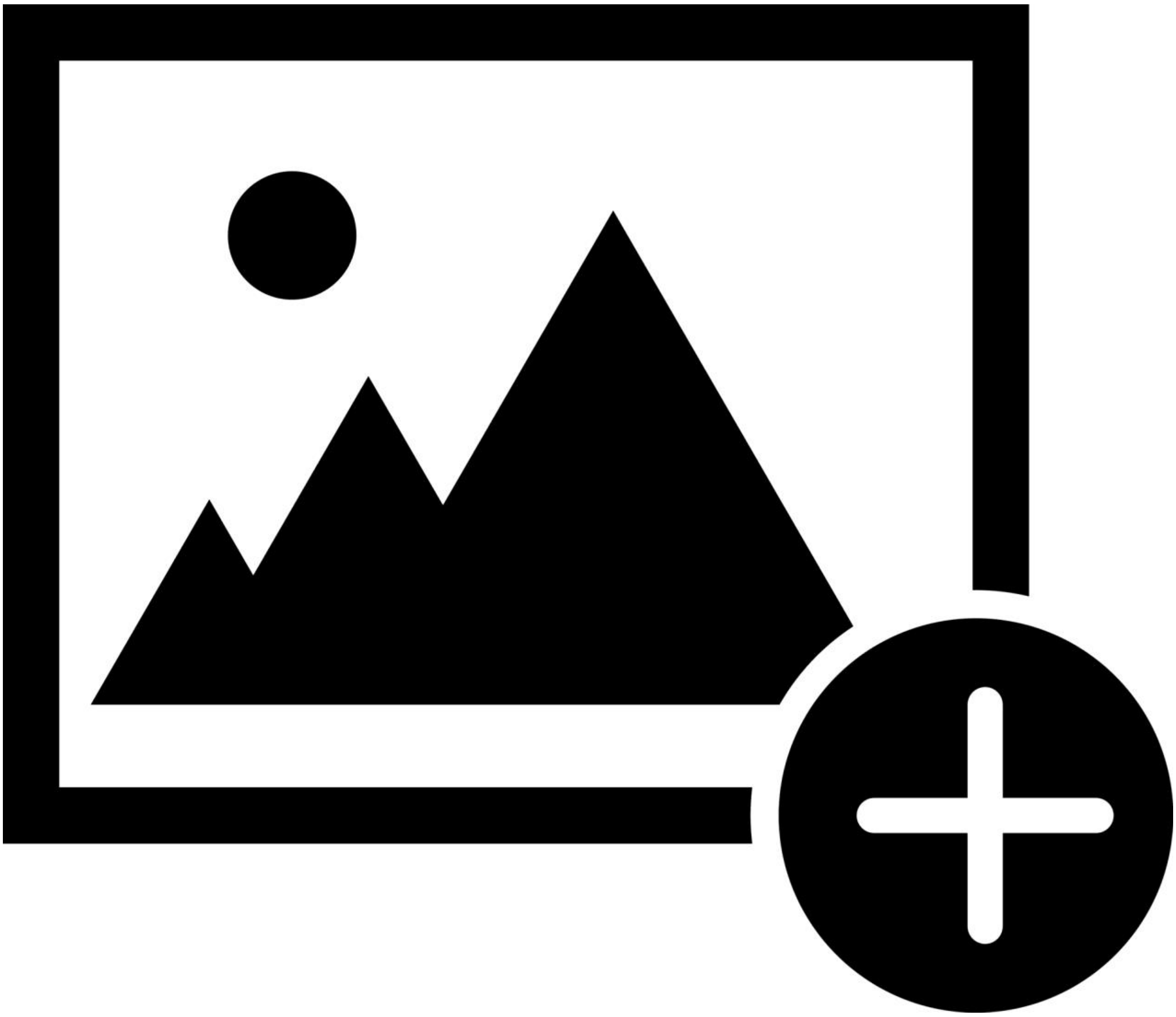
Riggningsdokument

Syfte:
Riggdokumentet ska fungera som ett praktiskt stöd vid riggning och förberedelse av maskin inför bearbetning av en specifik artikel. Riggdokumentet ska **endast innehålla den information som är nödvändig för att rigga eller förbereda maskinen** inför körning av aktuell artikel.

Innehållskrav:

1. *Titel och metadata*
   Dokumentet ska ha en tydlig rubrik med benämningen **”Riggningsdokument”** och specificera vilken process eller operation det avser. Det ska även innehålla följande information i dokumentets övre del:
   a. Ansvarig avdelning
   b. Tempobenämning (t.ex. "1 Svarvning 1")
   c. Utskriftsdatum
   d. Artikelbenämning
   e. Märkning
   f. Artikelnummer
   g. Maskinnummer
   h. Operationsnummer (Opnr)
   i. ECO om tillämpligt
2. *Huvudbild(riggvy)*
   a. 3D-vy som visar riggen i monterat läge.
   b. För alla komponenter som ingår i riggen ska följande specificeras i textboxar enligt standard, se Figur X:
      i. Artikelnummer (VR-/Std-nummer)
      ii. Namn/benämning
      iii. Antal och ”L” för lagerlagt (t.ex. "1L", "4L")
   c. Ordningen för riggningen ska tydligt anges genom att varje textbox numreras enligt monteringssekvens, om applicerbart.
   d. Komponenterna ska presenteras i ballongformat runt riggillustrationen, kopplade med ledande linjer till sin fysiska placering.
3. *Detaljvy (sidovy eller perspektivvy)*
   a. En kompletterande bild ska inkluderas, som visar artikeln i riggat läge – t.ex. från sidan eller i vinkel. Syftet är att illustrera hur artikeln placeras och orienteras i riggen.
4. *Visuell tydlighet*
   a. Alla komponenter och mått ska vara skarpa och lätta att läsa.
   b. Samtliga ballonger ska peka till rätt position med linjer utan att korsa varandra i onödan.

Exempelbilder



Korrektörsdokument

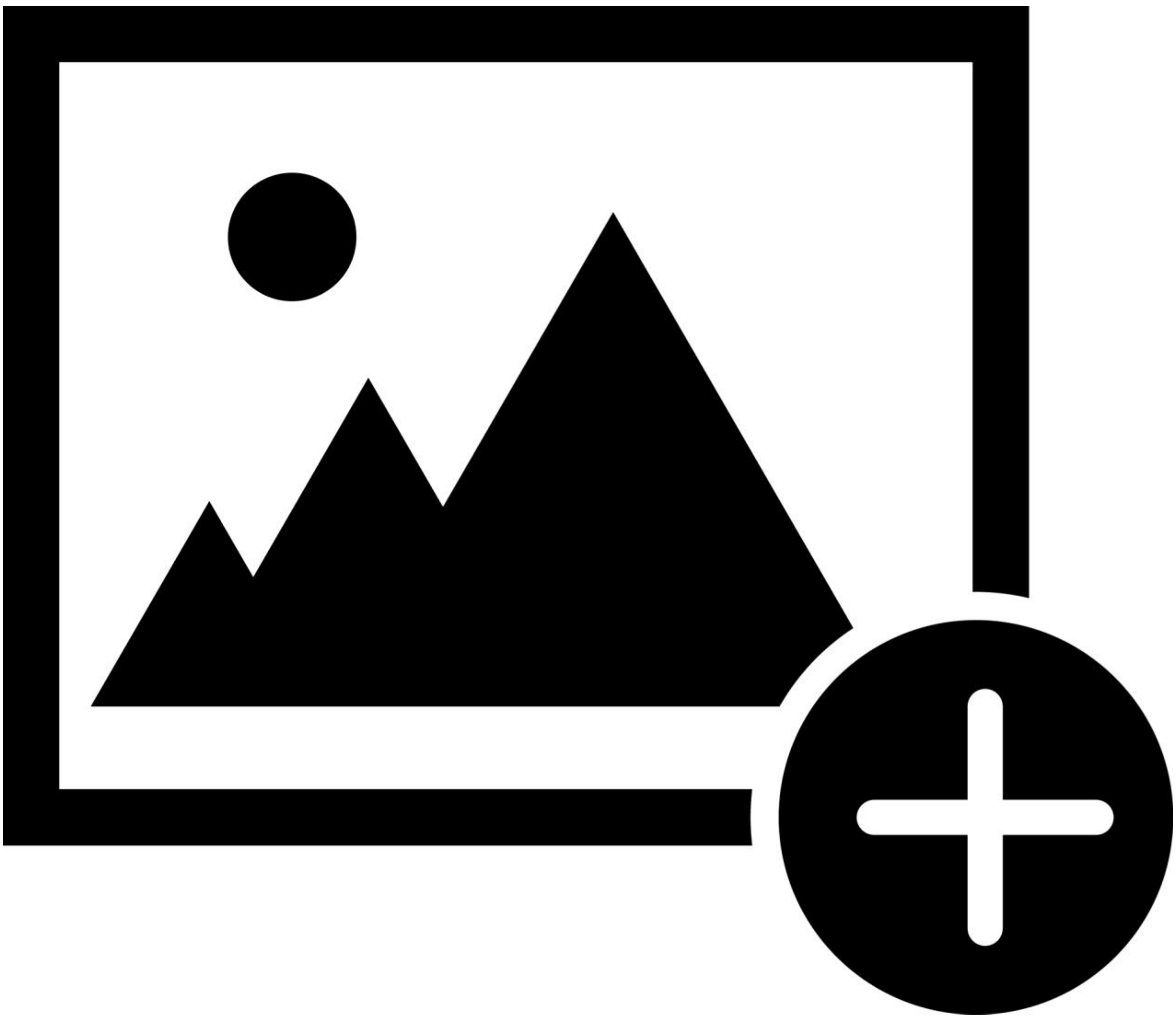
Syfte: Korrektörsdokumentet ska användas som stöd vid verktygsinställning, kontroll av bearbetningsområden och simulering av verktygsbanor. Det ska tydligt visa vilka verktyg som används, i vilken ordning de påverkar artikeln samt på vilka ytor.

Innehållskrav:

1. *Titel och metadata*
   Dokumentet ska ha en tydlig rubrik med benämningen **”Korrektörsdokument”** och specificera vilken process eller operation det avser. Det ska även innehålla följande information i dokumentets övre del:
   a. Ansvarig avdelning
   b. Tempobenämning (t.ex. "1 Svarvning 1")
   c. Utskriftsdatum
   d. Artikelbenämning
   e. Märkning
   f. Artikelnummer
   g. Maskinnummer
   h. Operationsnummer (Opnr)
   i. ECO om tillämpligt
2. *Huvudvy*
   3D-modellvy av artikeln med verktygspåverkan.
   a. En isometrisk eller sidovy av artikeln där varje verktygs bana och kontaktområde är färgkodat.
   b. Verktygets korrektörnummer ska framgå direkt i bilden, i anslutning till respektive kontaktpunkt.
   c. Verktygspåverkan bör delas upp efter bearbetningssteg:
      i. Grov
      ii. Fin
   d. Artikelns ytor bör vara tydligt färgkodade för att särskilja olika zoner bearbetade av olika verktyg/skär.
   e. Riktningen för verktygens bearbetning, samt start- och slutpunkt, bör också markeras med en markering (om möjligt).
   f. En teknisk ritning kan användas som komplement till 3D-vyn om det behövs för att visa ytor som bearbetas.
3. *Etiketter & Färgkodning*
   a. Varje verktyg ska ha en etikett med:
      i. Korrektörsnamn/verktygsnummer
      ii. Typ av bearbetning (t.ex. Grov)
   b. Färgkodningen ska vara unik per verktyg och konsekvent för resterande ArtHur dokument för processen (ingen färg får upprepas i samma bild).

4. *Bearbetningsordning*
    a. Om sekvensen är viktig, ska verktygen numreras enligt den sekvens de används.
5. *Visuell tydlighet*
    a. Bilden ska vara högupplöst, fri från visuell överbelastning och med god kontrast mellan färger.
    b. Eventuella snitt, vinklar eller alternativa vyer bör läggas till vid behov för att tydliggöra komplexa ytor eller överlappande verktyg.

Exempelbilder



Kvalitetsstyrningsdokument

Syfte: Kvalitetssäkringsdokumentet används dels som ett riggkvitto för att verifiera att processen är stabil vid produktionsstart, dels som ett styrande dokument för operatörerna under pågående produktion. Dokumentet ska tydligt specificera alla mått och toleranser som operatörerna har möjlighet att justera och därmed aktivt använda för att styra processen, vilka mätpositioner som ska kontrolleras manuellt, inklusive vilka mätverktyg som ska användas och med vilken frekvens mätningarna ska genomföras samt vad som ska kontrolleras via automatisk mätning, med angivelse av mätfrekvens samt vilken mätutrustning eller maskin som används.

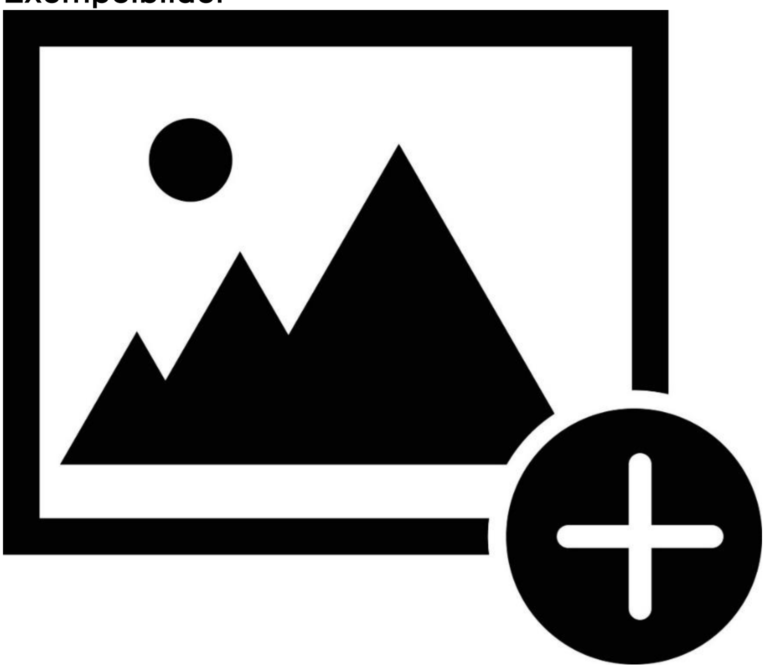
Innehållskrav:

1. *Titel och metadata*
   Dokumentet ska ha en tydlig rubrik med benämningen **"Bearbetningsdokument"** och specificera vilken process eller operation det avser. Det ska även innehålla följande information i dokumentets övre del:
    a. Ansvarig avdelning
    b. Tempobenämning (t.ex. "1 Svarvning 1")
    c. Utskriftsdatum
    d. Artikelbenämning
    e. Märkning
    f. Artikelnummer
    g. Maskinnummer
    h. Operationsnummer (Opnr)
    i. ECO om tillämpligt
2. *Huvudbild (måttsatt teknisk ritning)*
    a. Endast mått som kan mätas med manuellt mätning och är relevanta för kvalitetsstyrning ska anges med toleranser.
    b. Varje mätpunkt ska ha en unik positionsetikett utifrån standard (t.ex. 5, 6, 105, 107...).
    c. Färgkodning ska användas för att visa koppling till specifika verktyg.
    d. Mätpunkterna ska visas tydligt på en sektionsritning (som i Figur X) med korrekt placering i artikelns geometri.
    e. Eventuella axlar (X/Z) eller riktningar ska markeras där relevant.
3. *Visualisering i 3D-vy*
    a. Kompletterande 3D-bild av artikeln med färglagda zoner motsvarande bearbetnigsområden ska inkluderas. Syftet är att underlätta visuell identifiering av kontrollpunkter på den fysiska

komponenten. Om möjligt bör 3D-bilden visualiseras så som artikeln ska ligga på arbetsytan vid mätning.

4. ***Mättabell – Manuell Mätning***
   a. En strukturerad tabell i dokumentets högra del ska visa:
      i. Position(er) (t.ex. 5, 7)
      ii. Mätfrekvens (t.ex. var 20:e detalj)
      iii. Verktyg/instrumentbeteckning (t.ex. höjdmätare, OD-tolk, skjutmått)
      iv. Fält för artikelnummer på mätutrustning ska anges för spårbarhet.
5. ***Mättabell – Automatiserad Mätning (mätmaskin)***
   a. Separat sektion för automatisk mätning med:
      i. Angivna mätpositioner eller "Enligt Bd" (ritningsunderlag).
      ii. Frekvens (ex. var 80:e detalj)
      iii. Mätmaskin (ex. *Zeiss*)
      iv. Mätmaskinens ID eller verktygsnummer ska inkluderas.
6. ***Visuell tydlighet och Struktur***
   a. Färgkodning, symboler och textstorlek ska följa en konsekvent mall.
   b. Samtliga element (ritningar, etiketter, tabeller) ska vara lättlästa och inte överlappa.
   c. Om många mätpunkter finns ska dessa delas upp i vyer för att undvika överbelastning.

Exempelbilder



Verktygsförteckning

Syfte:
Verktygsförteckningen är maskinspecifik och visar vilka bearbetningsverktyg som används samt deras respektive benämningar. Den redogör även för verktygens olika komponenter och deras funktioner.

Innehållskrav:

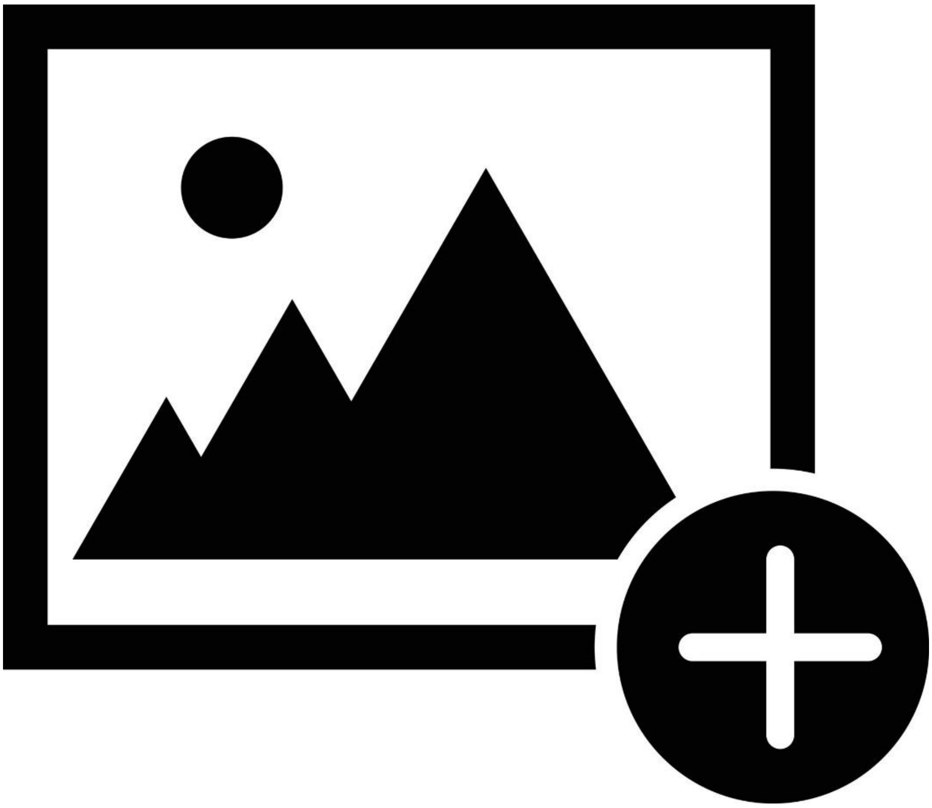
1. *Titel och metadata*
   Dokumentet ska ha en tydlig rubrik med benämningen **"Bearbetningsdokument"** och specificera vilken process eller operation det avser. Det ska även innehålla följande information i dokumentets övre del:
   a. Ansvarig avdelning
   b. Tempobenämning (t.ex. "1 Svarvning 1")
   c. Utskriftsdatum
   d. Artikelbenämning
   e. Märkning
   f. Artikelnummer
   g. Maskinnummer
   h. Operationsnummer (Opnr)
   i. ECO om tillämpligt
2. *Huvudvy*
   a. Huvudvyn ska illustrera samtliga verktyg som är relevanta för processen med 3D-modeller.
   b. Varje verktyg ska förses med en etikett innehållande följande information:
      i. Verktygsnummer
      ii. Typ av bearbetning (t.ex. Grov)
      iii. Den övre textlådan i verktygsrutan ska ange beteckningen för adaptern
      iv. Den nedre textlådan, placerad i nederkant av verktygsrutan, ska ange beteckningen för skäret.
   c. Verktygets livslängd ska anges tydligt, inramat och placerat inuti respektive verktygsruta.
   d. **Ett instruktionsblad får innehålla maximalt 8 verktyg.** Om antalet verktyg överstiger detta, ska ytterligare instruktionsblad användas.
3. *Etiketter & Färgkodning*
   a. I största möjliga mån bör **samma färgkod användas för ett specifikt verktyg** över flera artiklar. Det är upp till respektive

produktionslina att bedöma hur detta kan implementeras och hanteras i praktiken.

   b. Färgkodningen ska vara unik per verktyg och konsekvent för resterande ArtHur dokument för processen (ingen färg får upprepas i samma bild).

4. *Övrigt innehåll*
   a. Övriga relevanta dokument som ska arkiveras här inkluderar reservdelslistor för samtliga verktyg.

Exempelbilder



D

Appendix D

Id	Starttid	Slutförandetid	E-post
1	5/9/2025 21:02	5/9/2025 21:22	anonymous
2	5/13/2025 12:07	5/13/2025 12:15	anonymous
3	5/14/2025 11:46	5/14/2025 11:56	anonymous

Namn	Hur tydlig och förståelig tycker du att den nya standarden för att skapa produktionsinstruktioner är?	Hur väl stämmer den nya standarden överens med de befintliga produktionsplaneringsprocesserna?	Hur lätt är det att tillämpa den nya standarden i dina dagliga arbetsuppgifter?
	7	3	7
	8	8	8
	2	3	10

Känner du att den nya standarden förbättrar den övergripande effektiviteten i skapandet av produktionsinstruktioner?	Hur säker är du på att den nya standarden effektivt minskar fel eller inkonsekvenser i produktionsinstruktionerna?	Hur användarvänlig tycker du att formatet och strukturen för den nya standarden är?	Hur mycket tid sparar eller tillför den nya standarden i din process för att skapa produktionsinstruktioner?
7	7	7	5
8	9	8	7
10	10	4	8

Ger den nya standarden tillräcklig flexibilitet för att anpassas till specifika produktionskrav eller scenarier?	Hur ska man på bästa sätt namnge en artikel? Samt hur bör opertion- och tempobenämning struktureras?	Vilka utmaningar, om några, ser du med den nya standarden?
2	Som beskrivet i standard. Op per maskingrupp eller op per operation, beroende på hur stor maskingruppen är. Där artiklar körs Ax->limpa i samma mgr är det mycket mer logiskt att ha op på operationsnivå. Där artiklar skickas över avdelnings/maskingruppsgränser är det kanske bättre att ha op på ”Avdelnings/maskingruppsnivå”. Numreringen går nog inte att standardisera, då artiklar skiljer väldigt mycket i operationsgång. Här bör bara god exempel visas i standarden.	Väldigt knepigt att få det att funk ”fur alle”
7	Svår fråga, det viktigaste tror jag är att alla gör på samma sätt. Jag gillar själv så som det benämns och struktureras på UGA och PWC men är lite färgad eftersom det är där jag lagt ner mest tid.	Att hålla den uppdaterad
10	Namnge precis enligt benämningen på artikelritning. Bestäm dock gemensamt språk för alla artiklar på DX (Svenska?) Operation/Tempo vågar jag inte uttala mig om. Båda sätt som används idag har för- och nackdelar. Viktigt att kolla vilken statistik vi tar från ArtHur idag och hur strukturen förenklar eller försämra möjligheterna till det.	Det måste bli väldigt tydligt

Finns det några delar av den nya standarden som du tycker är oklara eller svåra att följa?	Vilka delar av den nya standarden tycker du bör revideras eller tas bort för att bättre passa ditt arbetsflöde?	Behövs ytterligare utbildning eller resurser för att fullt ut implementera den nya standarden?	Vilka förslag har du för att förbättra den nya standarden för att skapa produktionsinstruktioner?
Kommentarer i Word	Kommentarer i Word	3	Kommentarer i Word
Nej	Nej	2	Jag tror att man kan bygga på standarden mer med hur vissa kopplingar till andra program görs och vad man kan påverka om man gör vissa ändringar
Hittills saknas tydligheten vad som ska ingå i vilken typ av dokument. Bara nominella mått, med toleranser, programmeringsmått, ...	Finns den del, men det återkopplades med dokumentet och återkopplingen blir tydligare där.	9	Se återkoppling i mejlform med bifogade kommenterade dokument

Hur kan standarden förbättras i syfte att gälla för olika bearbetningsprocesser, utöver svarvning (som den främst bygger på nu)?	Vilket typsnitt används i CATIA vid framtagning av ritningar? Använder man A3- eller A2-format i CATIA för att sedan överföra ritningen till A4-format i ArtHur? Vilken textstorlek bör användas i ritni	Hur nöjd är du med den övergripande innehållet och strukturen i den nya standarden?
Kommentarer i Word	Standard Catia A3 med font 3,5 fungerar bra.	6
Man kanske ska se över något liknande på kugg/splinetillverkning som nästa steg då nästan alla artiklar på DX har en kugg eller spline	Jag har främst exporterat filer som pdf och då har jag använt stdtypsnittet i Catia. Storleken har jag anpassat efter storleken på ritningen	8
Håll den så allmännt som möjligt. Ta exempel för olika typer av dokument från olika processer	Har ingen aktuell erfarenhet av det, då jag inte skapar dokument	3

Skulle du rekommendera några förändringar i standarden innan den slutgiltigt implementeras över alla produktionsteam?
10
2
10

E
Appendix E

Id	Starttid	Slutförandetid	E-post
1	4/29/2025 16:19	4/29/2025 16:53	anonymous
2	5/1/2025 11:10	5/1/2025 11:21	anonymous
3	5/14/2025 21:46	5/14/2025 21:53	anonym

Namn	Gränssnittet var lätt att förstå och navigera.	Hur lång tid tror du att det hade tagit för dig att lära dig ett sådant här system, om du får upplärning först?	Jag kände mig säker på att använda verktyget utan hjälp.
	10	10	7
	9	10	9
	9	9	9

Instruktionerna var tydliga och lätta att följa.	Kändes mängden information som visades lämplig?	Detta verktyg skulle kunna hjälpa mig att undvika misstag.	Jag skulle föredra detta digitala format framför pappersinstruktioner.
10	10	10	10
10	9	10	10
9	10	10	5

Verktyget skulle kunna spara tid i verklig produktion.	Text och bilder var lätta att läsa och förstå.	Utformningen och layouten kändes bra.	Vad tyckte du mest om med de digitala arbetsinstruktionerna?
10	10	10	Lätt tillgängligt
10	10	10	Enkelt och tydligt.
8	9	10	Jag tycker att de underlätta processen.först

Var det något som kändes otydligt eller svårt att använda?	Finns det något du tycker saknas i verktyget?	Kan du tänka dig att använda detta i ditt dagliga arbete? Varför eller varför inte?	Vilka fördelar tror du att detta verktyg kan ge?
Nej	Tycker att de var bra, såklart att man kan bygga på det med tiden men en sak i taget.	Allt är nära till hands	Slippa springa runt, allt finns nära. Vi kommer med tiden veta mer om de saker vi har så som verktyg mm.
Nej.	Möjlighet att skriva ut papperskopia.	Ja skulle spara tid och göra det lättare.	Spara tid och göra det lättare.
I början när man lär sig nånting nytt det är lite svårt men när jag repetera processen några ggr det blir mycke lättare.	Jag tror inte det, det var helt fullständig	ja, kan behöva det, ibland vi har svårt och koncentresera i nån punkt så det blir lättare att använda 3D bild på så fallet.	Först och främst de som orkar inte med papper så de kan enkel använda detta.

Skulle du rekommendera det till en kollega?	Skulle ni se ett värde i att ha en digital lösning där man jobbar stationärt, men att papper fortfarande finns tillgängligt vid behov?	Bör någon information presenteras på annat sätt än det som presenterades i prototypen?
Absolut	Ja	Tycker att allt var bra.
Ja.	Ja.	Nej.
ja absolut, vissa gillar att lära sig nya saker.	Ja, jag tycker det är bra och ha papper också på vissa fall.	Jag tycker det är mycket bra jobbat tills vi börjar med och se vad kan förbättra det.

DEPARTMENT OF SOME SUBJECT OR TECHNOLOGY
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY