ANALYZING THE NATURE AND TIME ALLOCATION OF PRODUCTION WORK IN PROCESS INDUSTRIAL SITE – FOUNDATIONS FOR SUSTAINABLE WORK DESIGN

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Examiners: Docent Nina Tura, D.Sc. (Tech)

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ABSTRACT

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Analyzing the nature and time allocation of production work in process industrial site - Foundations for sustainable work design

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This thesis examines production work in a continuous process industrial site. The aim is to analyse how production tasks are distributed across different roles, how working time is allocated between machine-paced tasks and process monitoring activities, and how this information can support sustainable work organization. The study was conducted as a qualitative case study. The empirical material consisted of production task mapping, time allocation analysis, role-related background material and interviews. Work System Theory was used as the main analytical framework.

The findings show that production work cannot be understood through a simple division between machine-paced work and supervisory-control work. Different roles combine monitoring, field-based tasks, quality-related activities, disturbance handling, maintenance-related responsibilities and coordination in different ways. Although time allocation is mainly monitoring-oriented in several roles, machine-paced and physically bound tasks remain important because they structure the timing of work, limit autonomy and affect opportunities for proactive work.

The study concludes that task and time allocation data provides useful foundation for the work design, but they should not be used alone. Sustainable work organization requires understanding how tasks affect monitoring capacity, role-specific competence, disturbance handling and proactive work. Production work should therefore be developed as a whole work system that supports stable production, employee well-being and proactive work.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

LUTin insinööritieteiden tiedekunta

Tuotantotalous

Tommi Raijas

Tuotantotyön luonteen ja ajankäytön analyysi prosessiteollisuudessa – perusteet kestävälle työnjaolle

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Tämä diplomityö tarkastelee tuotantotyön luonnetta ja ajankäyttöä prosessiteollisuudessa. Työn tavoitteena on analysoida, miten tuotantotehtävät jakautuvat eri roolien välillä, miten työaika jakautuu pakkotahtisten tehtävien ja prosessin monitorointiin perustuvien tehtävien välillä sekä miten tätä tietoa voidaan hyödyntää kestävän työn organisoinnin kehittämisessä. Tutkimus toteutettiin laadullisena tapaustutkimuksena. Aineisto koostui tuotantotyön tehtäväkartoituksesta, ajankäytön analyysista, rooleihin liittyvästä taustamateriaalista sekä työntekijöiden haastatteluista. Work System Theory toimi työn pääasiallisena analyyttisena viitekehyksenä.

Tulokset osoittavat, että tuotantotyötä ei voida ymmärtää yksinkertaisena jakona pakkotahtiseen työhön ja prosessin monitorointiin perustuvaan työhön. Eri roolit yhdistävät eri tavoin monitorointia, kenttätyötä, laatu-, häiriö-, kunnossapito- ja koordinointitehtäviä. Vaikka ajankäyttö on useissa rooleissa pääosin monitorointiin painottuvaa, pakkotahtiset ja fyysistä läsnäoloa edellyttävät tehtävät ovat edelleen merkittäviä, koska ne rytmittävät työtä, rajoittavat autonomiaa ja vaikuttavat ennakoivaan työhön.

Tutkimuksen johtopäätöksenä on, että tehtävä- ja ajankäyttötieto muodostaa hyödyllisen perustan työn suunnittelulle, mutta sitä ei tule käyttää yksin. Kestävä työn organisointi edellyttää ymmärrystä siitä, miten tehtävät vaikuttavat monitorointikykyyn, roolikohtaiseen osaamiseen, häiriöiden hallintaan ja ennakoivaan työhön. Tuotantotyötä tulisi siksi kehittää kokonaisena työjärjestelmänä, joka tukee vakaata tuotantoa, työntekijöiden hyvinvointia ja ennakoivaa toimintaa.

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Tommi Raijas

SYMBOLS AND ABBREVIATIONS

WST = Work System Theory

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DECLARATIONS

Turnitin

The originality of this thesis has been reviewed with the Turnitin similarity checking service.

AI usage

The author of the thesis, Tommi Raijas, used the following AI-tools during the preparation of the thesis:

1. ChatGPT 5.2 and 5.3
    a. Purpose of use: Search for academic studies and research papers, translating the text, planning the structure
    b. Explanation of the use of the tool: Used to search relevant academic studies and research papers in order to find suitable and correct literature for thesis. Used to translate the text from English to Finnish and vice versa in order to understand and interpret ideas better and support writing thesis in author's second language. Used to help to plan the structure of the thesis. No changes to content or interpretation were made by the tool.
2. Microsoft 365 Copilot
    a. Purpose of use: Used as a supporting tool in data analysis
    b. Explanation of the use of the tool: Used as discussion partner to analyse large number of qualitative data collected from the 25 interviews. No changes to content or interpretation were made by the tool.
3. LUT Primo AI search
    a. Purpose of use: Search for academic studies and research papers
    b. Explanation of the use of the tool: Used to search relevant academic studies, research papers and books in order to find suitable and correct literature for thesis.

Responsibility

The author, Tommi Raijas, takes full responsibility for the content of this thesis and has reviewed and edited the content generated by the possible use of AI tools.

1 Introduction

This thesis examines the content and time use of production work in the context of a continuous process industry, focusing on the operating environment in the process industrial site. This work is research how production tasks are distributed across working roles and how working time is divided between machine-paced tasks and monitoring-based tasks. Monitoring-based tasks are also called supervisory-control in this context, meaning the operator's role in supervising and controlling the process (Pütz et al., 2024, p. 801). The actual nature of production work is particularly important to understand at a time, when the industrial organizations face need for operational efficiency, sustainability and competitive positioning, as well as challenges related to fluctuating raw material costs, regulatory pressure to reduce carbon emissions and optimized resource management (Othen et al., 2025, pp. 1–2). For example, one sector of the process industry is the paper and pulp industry, which is highly energy- and resource-intensive, which makes decarbonization and environmental sustainability key development pressures for the sector (Furszyfer Del Rio et al., 2022, p. 1).

Previous research on production work in continuous process industries has shown that increasing automation changes rather than removes the role of human operators. Bainbridge (1983, p. 775) argues that automation does not remove the need for human involvement, because even highly automated systems still require operators for supervision, adjustment, maintenance and responses to abnormal situations. Strauch (2018, pp. 419–420) shows that these observations remain still relevant, as automation-related concerns identified by Bainbridge (1983) continue to affect the role of operators in automated systems even today. This shift makes production work cognitively demanding. Endsley (1995, pp. 36–37) explains that effective performance in dynamic systems depends on situation awareness, including the perception of relevant information, comprehension of its meaning and projection of future states. Pütz et al. (2024, pp. 801–802) further show that in supervisory-control tasks cognitive demands may remain low during routine monitoring, but abnormal events can create high demands and time pressure for the operator to understand the situation and choose an appropriate response. Thus, visible task execution or time-use data do not fully explain the demands of production work, because operators may appear physically

inactive while still maintaining attention, interpreting process information and remaining ready to intervene.

Earlier research has also described the pulp and paper industry, being part of process industry, as a technically complex production environment. Mercangöz and Doyle (2006) explains that pulp and paper production is affected by raw material variability, quality requirements and the need to maintain stable process control. They also emphasize that the objective of process control is to meet specified quality and production targets while minimizing operational costs. More recent research has examined digital transformation in the paper industry. Othen et al. (2025) argue that digital technologies are increasingly important because the industry faces pressure to improve operational efficiency, sustainability and competitiveness, while also dealing with challenges such as legacy systems, data quality issues and fragmented digitalisation efforts. These perspectives are important for understanding the technological and operational context of the process industry, but they do not fully explain how production work is organized in daily shift work at the level of roles, tasks and time allocation. For this reason, this thesis also uses work organization literature and Work System Theory to connect task-level observations with the broader organization of work. Work System Theory is suitable for this thesis because it views work as an interaction between processes and activities, participants, information, technologies and organizational conditions rather than as isolated tasks only (Alter, 2013). This perspective supports the aim of the thesis by linking task- and time-allocation analysis with questions of monitoring capacity, role-specific responsibilities, proactive work and sustainable work organization.

1.1 Background of the thesis

Case company in this thesis operates globally in the bioeconomy industry. This thesis focuses on more specifically into one industrial site of the company, which operates under the continuous process industry environment.

The motivation for this study arises from the need to form a fact-based and multi-perspective understanding of production work following recent organizational changes. Rather than focusing on individual performance or numbers of personnels, this thesis approaches production work at the level of tasks, roles and work organization.

In continuous processes, the production work is characterized by a combination of machine-paced, repetitive routine tasks and process monitoring activities. These together shape employee's workload, autonomy and possibilities for proactive actions. Understanding how production work is practically structured is essential for developing sustainable work organizations models that supports both operational efficiency and employee well-being.

1.2 Objectives and research questions

The aim is to analyse how tasks in the production work are distributed across different roles and how the working time is allocated between different task types and how these factors influence perceived workload and possibilities for monitoring and proactive work.

The previous sections showed that existing research has examined process industrial work mainly through automation, supervisory-control work, human factors and digital transformation. Related research also indicates that changes in industrial work should be examined at the task level. Cimini et al. (2023) argue that the effects of smart and digital technologies on operator job profiles can be analysed through job-task analysis, including distinctions between routine and non-routine, physical and cognitive, and individual and social tasks. Ciccarelli et al. (2023) similarly show that Operator 4.0 research has focused on how new industrial technologies transform operators' work and how technologies should support employees' capabilities and improve safety instead of replacing them. What remains less visible is the everyday organization of production work: how tasks are distributed between roles, how working time is allocated and how machine-paced and monitoring-based activities are combined during shift work. This thesis addresses this gap by connecting task- and time-allocation analysis with the question of sustainable work organization.

Sustainable work organization is understood as work organization that supports both operational performance and employee well-being in this thesis. This interpretation is supported by Brunoro et al. (2020), who describes sustainable work as work, that improves organizational performance while also supporting professional development, employee's health and well-being. In continuous process industry, this interpretation is also connected to the need to keep the production process under control and in stable condition. Kaasinen et al. (2020) emphasizes that this requires rapid perception, analysis and forwarding of

process-relevant information. They also note that many tasks still require human recognition, decision-making and input even when information processing is highly automated.

Objective of this thesis is to provide analytically grounded insights that can support the development of sustainable division of work in the current and future operating environment without making normative or prescriptive claims about reducing or increasing personnel by focusing on work roles and task characteristics rather than individuals or personnel quantities.

The first main research question of the thesis is:

> *RQ1: How are production tasks in process industrial site divided between machine-paced tasks and process monitoring activities?*

This question is supported by the following sub-questions:

> *SQ1: What are the key tasks in production work that are performed in different roles?*
>
> *SQ2: How is working time divided between machine-paced tasks and process monitoring in different work tasks?*
>
> *SQ3: Which tasks and process stages allow operators to have the opportunity to temporarily disengage from the other work?*
>
> *SQ4: Which tasks require constant physical presence and mechanical repetitive work?*

The second main research question of the thesis is:

> *RQ2: How can this information be used to support sustainable work organization?*

This question is further guided by following sub-questions:

> *SQ5: How do the different parties perceive the functionality and workload of the current division of work?*
>
> *SQ6: What principles can be identified for developing a sustainable division of work in the future production environment?*

This thesis emphasizes on understanding production work as a work system and identifying structural constraints and opportunities related to the organization of work, instead of addressing to individual employee performance, personnel numbers or decisions related to headcount. Decisions regarding human resources and arrangements remain outside the scope of this study.

1.3 Research methodology and limitations

The research is conducted as a participatory development research project. Participatory action research is based on the idea that research is conducted with people rather than only on people, and that the process combines knowledge creation with practical action and reflection (Reason & Bradbury, 2008). This approach allows for the inclusion of multiple perspectives from the production personnel and managers, and it supports both empirical analysis and practical development. The participatory orientation is suitable for this thesis because the purpose is to produce knowledge that can support the development of work organization in the case organization.

The empirical data is collected through production task mapping, examination of time use and task allocation, and primarily by qualitative interviews with employees and supervisors. This combination of methods is used because the research questions require both a structured description of work tasks and an understanding of how the current organization of work is experienced by different parties. Work analysis provides a basis for documenting operators work and for using this information in organizational and individual development, performance improvement and learning-related purposes (Jacobs, 2019). Also, earlier research related to work sampling illustrates how categorizing work activities can support the examination of how work is distributed between different activity types and helping to identify potential improvements in work processes (Calvetti & Ferreira, 2025, pp. 122–123). However, in this thesis task and time allocation data are used descriptively to support the role-level analysis of production work, not as a formal productivity monitoring method.

Thesis focuses on the structure, content and temporal characteristics of production work in a continuous process industry. The analysis is conducted at the level of production work roles and task structures, examining how different types of tasks are distributed and how they shape opportunities in monitoring, observation and anticipatory work.

Abductive thematic analysis was chosen to be the analysing method for the collected interview data. Timmermans and Tavory (2012, p. 167) argue that abduction supports the development of theoretical explanations from empirical observations. In the other hand, Thompson (2022, pp. 1410–1411) describes abductive thematic analysis as a way to combine thematic analysis with abductive reasoning while maintaining a balance between theorising and empirical data. Therefore, abductive thematic analysis was suitable for this thesis because it allowed for the interpretation of the empirical interview themes through the theoretical framework without limiting the analysis to only predefined categories.

The thesis is limited to only one industrial site and one organizational context. The results are therefore not intended to be statistically generalizable to all process industrial environments. Thesis does not directly measure individual mental workload, situation awareness or physiological strain. Instead, the findings should be understood as perceived and work system-related implications. The purpose is to provide an analytically grounded understanding of the studied production work system and to support later discussions on sustainable work organization.

1.4 Structure of the thesis

The thesis is structured as shown in the Table 1, shaped into six chapters, where the first one introduces the background, objectives, research questions, methodology and limitations of the thesis.

Chapter 2 presents the theoretical framework by discussing production work in continuous process industry, machine-paced and supervisory-control work, situation awareness, workload, human factors, work organization and Work System Theory. The chapter ends with a synthesis of the theoretical framework.

The third chapter describes the research context and methodology. It introduces the case context, production departments and production roles included in the study and explains the research design, data collection methods, data analysis process, and the reliability and validity considerations. The chapter 4 presents the empirical findings, characterizing the production tasks and time allocation in different departments. The chapter then presents the

main themes that emerged from the interviews and ends in a summary of the empirical findings.

Table 1. Structure of the thesis.

Input	Chapter	Output
Background and research gap	#1 Introduction	Aim, research questions and scope
Literature review	#2 Theoretical framework	Analytical framework
Case context and research methods	#3 Research context and methodology	Research design and data collection approach
Empirical data	#4 Empirical findings	Task, time allocation and interview findings
Empirical findings interpreted through theory	#5 Discussion	Interpretation and implications
Main results	#6 Conclusions	Answers to research questions, contributions and future research

The fifth chapter discusses the findings in relation to the theoretical framework and research questions. It interprets production work between machine-paced and supervisory-control work, discusses implications for workload, autonomy and proactive work, and considers what the findings mean for sustainable work organization. The chapter also presents the limitations of the study.

Finally, the sixth chapter concludes the thesis. It summarizes the main findings, answers the research questions, presents the theoretical and practical contributions of the study and suggests directions for future research.

2 Theoretical framework

This chapter introduces the main theoretical concepts and research related to production work in continuous process industries. The literature review provides the theoretical foundation for examining the work content, task structures, time use, process monitoring and human factors in production environments. These perspectives are used to support the analysis and interpretation of the empirical findings and position the study within the existing academic discussion on work organization in continuous process industry.

In this study, production work at a process industry is analysed as a work system comprising multiple operator roles working in continuous shift-based production. The focus is on task structures and time use across the roles rather than on specific machines or individual operators. Production work in continuous process industries involves a combination of physical tasks, monitoring activities and coordination across roles. Analysing this type of work in overall, the thesis adopts the concept of a Work System Theory by Steven Alter (2013).

2.1 Production work in continuous process industry

Production work in continuous process industries environments is commonly discussed within the broader scope of process industries that creates value by mixing, separating, forming and by chemical reactions (Dennis & Meredith, 2000, p. 683). In process industries, the raw material is processed, converted or changed usually chemically and/or physically into wanted product. General examples of process industries are the paper, energy and food industries, and the variation of end product is large. However, the principles of the organization of work processes remain the same. When automation and computerization have advanced, the control rooms have become necessary to control the larger process units. (Ivergård & Hunt, 2009, p. 3-5)

Rasmussen (1983, p. 257) describes that most of the technical systems are highly automated and the reliance on human control in normal functions is decreased. However, automation does not remove the need for human intervention and even highly automated systems require human support to maintain satisfactory operation and to cope with all unforeseen situations.

This classical observation remains relevant in current automation research, as later reviews indicate that the core concerns related to automation and operator performance have not been resolved, while recent supervisory-control research shows that human tasks continue to shift toward supervision, monitoring and corrective intervention rather than disappearing (Strauch, 2018, pp. 419–420; Pütz et al., 2024, pp. 801–802).

Bainbridge (1983, p. 775) observed the paradoxical effect of automation. The more advanced and reliable a control system becomes, the more critical the role of the human operator is when deviations occur. Ivergård and Hunt (2009, p. 5) noticed, that working in a control rooms move operators further away from the actual process. In continuous process industries, this means that operators are less involved in direct control of process during normal operation but are still required and expected to intervene when the deviations happen. In those situations, operators have to act under time pressure and often based on incomplete or ambiguous information, which makes the intervention more demanding than routine control. Thus, automation does not eliminate the need for skilled human performance but instead focuses on cognitive demands on rare and difficult situations. This paradox has become a defining feature of modern process work and continues to shape the nature of operator tasks in automated production environments still nowadays.

Continuous process industries are characterized by complex systems that consist of numerous interconnected components that require continuous monitoring and control effectively. When the levels of automation increase in the industry, it creates new challenges that are related to the extraction of useful information and valuable knowledge from large volumes of real-time data produced by sensors and actuators. In addition, the effective interoperability between industrial automation systems and information systems is critical for the development of intelligent and knowledge-aware production environments. Process systems generate substantial amounts of real-time data on daily basis, and this information is often analysed using conventional tools. Decision-making is partially performed by process operators and managers at the later stages. (Ziogou et al., 2016, pp. 1325)

Furthermore, continuous operation and high reliability requirements mean that production work is closely linked to safety and risk management. Historical analyses of accidents in highly automated systems demonstrate that the interaction between operators and automation plays a big role in both the prevention and the escalation of system failures and errors. Automation-related incidents are often caused by reduced situation awareness, skill

decline and difficulties understanding how the system operates during abnormal conditions. (Strauch, 2018, pp. 428–430)

Strauch (2018, pp. 419–423) shows that major failures in highly automated industries should not be understood simply as isolated human errors. Instead, accidents often result from disruptions in the interaction between operators and automation within tightly coupled sociotechnical systems. This view is highly relevant in continuous process industries, where technical subsystems are strongly interconnected and local deviations can become more severe if they are not recognized and managed in time.

Another important challenge is that automation may reduce operators' opportunities to maintain the practical skills needed in non-routine situations. When automation handles most routine control, operators may have less direct experience of abnormal conditions and fewer opportunities to rehearse intervention. This might lead to skill degradation and reduced familiarity with system behaviour in situations where the system has failures. In such cases, operators must rely more on knowledge-based reasoning than on well-practiced procedures, which could increase the risk of delayed or inappropriate responses. (Strauch, 2018, pp. 424–428)

In the paper industry, which is working in the continuous process environment, the increasing need for efficiency, sustainability and competitive positioning makes it very important to adopt digital technologies. However, challenges have been faced such as variable raw material costs, pressure from the regulatory, carbon emission reductions and perceived need for better optimized resource management. Some technologies have been found to provide solutions, such as data-driven analytics, IoT and automation. These technologies solve the challenges by improving process control, energy efficiency and reducing waste. (Othen et al., 2025, pp. 1-2)

These findings suggest that production work in continuous process industries should not be viewed only through routine tasks or formal job descriptions. In practice, production work also includes monitoring, readiness, interpretation and response under abnormal conditions. For this reason, production work in continuous processes is better understood as adaptive activity within a dynamic sociotechnical system rather than as a fixed set of predefined tasks (Rasmussen, 1983, pp. 257–259; Bainbridge, 1983, p. 775; Strauch, 2018, pp. 419–430).

Thus, production work in continuous process industries is shaped by both technical automation and the continuing need for human intervention. To clarify this dual nature of operator work, the following sub-sections introduce two concepts that are central for this thesis: machine-paced work and supervisory-control work. Machine-paced work is used to describe tasks in which the timing and rhythm of work are strongly determined by the production process or equipment (Hurrell & Colligan, 1987, p. 160). Supervisory-control work, in turn, describes monitoring-based work in which the operator supervises an automated process, interprets process information and intervenes when necessary (Pütz et al., 2024, pp. 801-802). These concepts are introduced separately because they provide the analytical basis for examining how production tasks and working time are distributed across different roles in the empirical part of the thesis.

2.1.1 Machine-paced work

The first concept used to characterize production work is machine-paced work. Machine-paced work is common term used to describe activity where the operator must perform a task or multiple work tasks at a rate that is set by the external factor and not by the operator itself (Hurrell & Colligan, 1987, p. 160). It is predictable, but still uncontrollable, as it involves limitations on control of the work cycle, and it depends on individuals' characteristics if it is seen as stress factor or not (Hurrell, 1985). Process design determines the commitment of the operator to the machine. In continuous process industry, the process determines itself the time and pattern of work, which forces operators to perform in a way process requires. There is a lot of time-bounded work in the process industries, and the time scales often depends on dynamic time characteristics and process's response times. If the processes have high inertia, it rarely is experienced as stressful by operators. (Ivergård & Hunt, 2009, p. 14)

In this thesis, this concept is used to describe tasks in which the operator's work rhythm is determined primarily by the production process, equipment or externally defined timing rather than by the operator's own discretion.

2.1.2 Supervisory-control work

The second concept used to characterize production work is supervisory-control work. A useful modern way to describe the work of an operator in process industry is the concept of supervisory process control. In this context, supervisory does not mean the managerial supervision of employees but it means the operators' role in supervising an automated process. Thus, it can also be called another term monitoring-based work. The system performs continuous process control, while the human operator receives periodic feedback and does corrective commands on process when it is needed. Thus, operators' work does not disappear with increasing automation, but shifts towards functions such as task planning, system monitoring, intervention and learning from experience. (Pütz et al., 2024, pp. 801-802)

In this thesis, this concept is used to describe tasks which include process control, monitoring, interpretation and intervention in relation to the automated process, and is not limited to physical task execution.

2.2 Cognitive demands in production work

This chapter presents cognitive demands in production work and narrates importance of situation awareness in operators' work, as well as how workload and human factors affect the work itself.

2.2.1 Situation awareness and operator work

Automation reduces the need for physical intervention, but at the same time it simultaneously increases the importance of cognitive activities such as monitoring, interpretation, decision-making and anticipation. How to understand operators work in such context requires a shift in analytical focus from observable actions to the underlying cognitive processes that support effective system supervision. (Endsley, 1995)

Pütz et al (2024, p. 801) demonstrates that production work in continuous processing industry places significant cognitive demands on operators, especially in highly automated environments. Although industrial automation continues to advance, human involvement is still major part of it. Shift has happened in the nature of the work itself, where direct manual control has moved towards supervision of automated processes.

This shift makes cognitive demands central to operator work. Pütz et al. (2024, pp. 802-803) observes, that in supervisory process control the cognitive demands vary significantly, depending on the mode of the operation. The major challenges in supervisory process control tasks are the cognitive demands of the operators. These vary prominently, as the cognitive demands might be low in routine activities, which forces the operator to passive monitoring leading to the loss of vigilance and situation awareness. When abnormal situations happen, it can lead to high cognitive demands with time pressure to response to a situation. Thus, operators' work in automated process environment cannot be understood only through observable actions or physical interventions, but also by analysing through the cognitive processes that support monitoring, interpretation and timely intervention.

Central concept for analysing cognitive demands in complex systems is situation awareness, which, to quote directly, means:

> "The perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995, p. 36)

Situation awareness has been widely applied in studies of cognitive psychology and human factor fields, including process industry such as oil and gas production, where effective performance depends on maintaining an accurate and timely understanding of system states rather than performing predefined actions. Effective operator work requires more than noticing individual values or alarms, it also requires understanding what the available information means and anticipating how the process is likely to develop. This three level structure of situation awareness is built around perception, comprehension and projection, which is consistent in dynamic systems and remains still one of the most widely used and most cited models in the field. (Endsley, 2015, p. 4-5; Endsley & Kiris, 1995, p. 382)

These three levels of situation awareness are shown in Figure 1 below. Perception is the first level in achieving situation awareness and it means perceiving the status, attributes and

dynamics of relevant elements in the environment. Comprehension is the second level, and it involves combining separate elements into an overall picture of the environment and understanding the significance in relation to the operators' goals. Third level is a projection, where the operator projects the future status of relevant elements by drawing on knowledge of their current state, their dynamics and the meaning of the situation as a whole. (Endsley, 1995, pp. 36-37)

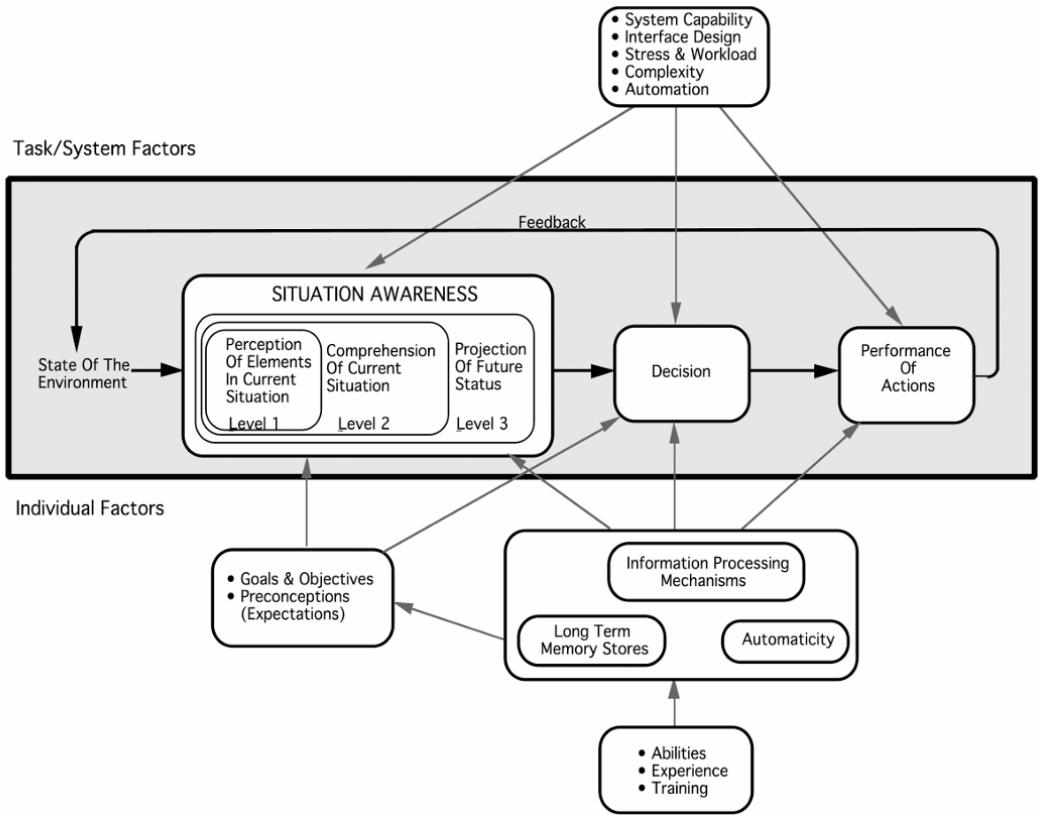

Figure 1. Situation awareness model related to decision-making (Endsley, 2015, p. 5).

Thus, situation awareness is a suitable conceptual lens for continuous process environments, even if it is described as framework. Besides these three key factors of situation awareness, it also includes a few more factors that are relevant to process industry, such as goal-directed and data-driven processing and the role of mental models in directing attention and interpreting information (Endsley, 2015, pp. 5-6). This interpretative work is further supported by experience, schemata and mental models that help operators understand available information and distinguish expected conditions from deviant interpretations.

Situation awareness itself makes a basis for operators' decision-making, even if it is separate construct itself. Experts might understand situations by comparing the overall picture of them with similar situations stored in the memory. Recognizing the situations by memory makes it faster to understand and react to it. However, even if the situation awareness is good, the wrong decision can still occur due to poor training on proper procedures or due to poor performance from inability to do necessary actions. Performance is itself also a separate construct from decision-making and situation awareness. All of these three - situation awareness, decision-making and performance – has different factors affecting to them and also different approaches to deal with them. Thus, it is necessary to note that there are factors influencing situation awareness, but which can be seen as separate constructs, such as attention, workload, working memory and stress. (Endsley, 1995, p. 34, 36)

Endsley (1995, p. 43) argues that situation awareness places noticeable demands on working memory, because new information must be combined with existing knowledge and integrated into a composite picture of the situation, and used simultaneously for projection and decision-making. In this sense, working memory may become a bottleneck, especially in new situations. At the same time, Endsley (1995, pp. 43–44) suggests that long-term memory structures, such as schemata and mental models, helps to overcome these limitations by providing coherent frameworks for understanding information and supporting the interpretation of separate cues as part of an overall picture. This highlights the importance of experience and process knowledge in continuous process industry, in supporting operators' ability to interpret ongoing conditions and anticipate how the situation could develop.

Automation can both support and weaken these cognitive processes. Pütz et al. (2024, p. 802) describes system automation to mean allocating functions formerly performed by humans to the system, so it differs from system autonomy where the system itself learns and evolves by changing its operational capacities. Pütz et al. (2024, p. 802) also notes, that as long as system autonomy cannot be realized as it is expected to be in the future, the effective interaction between humans and automation is important aspect. Achieving this leads to empowering operators to control highly complex systems.

It is likewise argued by Endsley & Kiris (1995, pp. 381-383), that the out-of-the-loop performance problem is a significant potential consequence of automation. It means leaving the operators less capable of taking over manual control when the automated system fails.

The issue is mainly related to reduced manual skills and weaker awareness of the current state and processes of the system. Losing the situation awareness leads to slower problem detection and requires more time to reorient to the system state in case of proceeding to diagnosing the problem and intervening manually. Three factors are identified, where automation might weaken situation awareness:

1. Reduced vigilance and increased complacency associated with a monitoring role
2. Shift from active information processing to passive reception of information
3. Loss of or change in the feedback operators get from the system

For operators work in continuous process industry this is important, as in automated process control environments, operators must rely on alarms, displays and other presented process information to monitor system behaviour. High amount of alarms in normal work also leads operators to have lot of experience of controlling and thinking the process. In the context of situation awareness, perception at the first level of situation awareness involves the status, attributes and dynamics of relevant elements in the environment. Applied to process control, this suggests that operator work depends on observing display values and alarms, but also on recognizing how process conditions are changing over time (Bainbridge, 1983, pp. 777; Endsley, 1995, pp. 36-37)

Endsley and Kiris (1995, p. 392) suggest that by maintaining relatively high level of operator control in the process beside the automation helps to minimize the out-of-the-loop problem. In continuous process work, the key question is not only what available information there is, but also whether operators are sufficiently engaged to interpret them, recognizing developing disturbances and preparing to intervene effectively when abnormal situations occur (Pütz et al., 2024, pp. 801-802). It is also important in sense of comprehension, second level of situation awareness, which depends on integrating separate cues into a holistic picture of the environment rather than simply perceiving individual signals (Endsley, 1995, p. 37).

These concerns have been recognized with broader literature also. Bainbridge (1983, pp 775-776) noted that take-over in abnormal situations requires both manual control skills and cognitive skills for diagnosing the problem and recovery. Later reviews show a similar conclusion, as Strauch (2018, pp. 419-420) noted that the concerns identified by Bainbridge remain relevant and the core issues associated with automation and operator performance remain unresolved.

Thus, from the perspective of production work analysis, cognitive demands in operator work cannot be captured through task frequency or time allocation alone. It is also necessary to examine whether work conditions support the development and maintenance of situation awareness across different operating situations, also across shifts and work roles. Understanding operators work in highly automated process environment requires attention to how available information supports perception, comprehension and projection and how the operator engagement is maintained when abnormal events occur (Endsley & Kiris, 1995, pp. 382-383).

A related challenge is noted by Sarter et al. (1997), who observed the possibility of "automation surprises", where system behaviour differs from the operator's understanding or expectations. Such problems are linked to breakdowns in mode awareness, gaps in operators' mental models and insufficiently transparent system feedback. In these situations, operators may remain formally responsible for supervision but still lack a clear understanding of what the system is doing or why it is behaving in a particular way.

This issue is relevant in highly automated process environments, where the system might change its operating mode or control behaviour without a direct and immediately visible operator. Mode awareness is described as operators' ability to track and anticipate the behaviour of automated systems by Sarter et al. (1997, p. 5). When this awareness breaks down, the operator might fail to notice that the system has changed its status, or its behaviour has become undesirable in the current context. This is especially problematic, because the behaviour itself might not always be abnormal, but it might become problematic only under particular process conditions. (Sarter et al., 1997, pp. 6-7)

Automation surprises demonstrate for this thesis that monitoring work cannot be understood only as passive observation of process values. Effective monitoring and supervisory-control work requires that operators are able to form expectations about automation behaviour, notice when these expectations are violated and understand if the intervention is needed. This depends on the operators' mental model of the system, but also on the quality of system feedback. If the interface does not clearly indicate automation status, mode transitions or the reasons behind system actions, the operator's situation awareness may weaken even when the relevant information is technically available. (Sarter et al., 1997, pp. 10-11)

2.2.2 Workload and human factors

Workload is a central concept in human factors research and an important perspective for understanding operator performance in automated production environments. Workload is closely related to situation awareness, but it should not be treated as same construct (Endsley, 1995). Contrary to early assumptions that automation would reduce human workload, research has shown that automation primarily changes the nature and timing of workload rather than removing it. In highly automated continuous process industries, workload shifts from physical performance towards monitoring, interpretation, disturbance handling and coordination with automated systems. (Bainbridge, 1983, p. 775; Sarter et al., 1997, pp. 3–4).

This shift means that low levels of visible activity do not necessarily imply low workload. Operators may be physically inactive for long periods while still maintaining attention, monitoring process variables, interpreting system information and preparing for possible intervention. From this perspective, analysing production work only through observable tasks or time-use measures may underestimate the cognitive demands associated with supervisory control (Bainbridge, 1983, p. 775; Endsley, 1995, pp. 36–40; Sarter et al., 1997, pp. 3–4).

High mental workload is an important stress factor in many dynamic systems. Situation awareness and workload might vary independently of each other. Low workload does not necessarily mean good situation awareness, as inattention or vigilance problems may also lead to poor understanding of the situation. Similarly, high workload does not automatically imply low situation awareness if the operator is still able to maintain an accurate and complete picture of ongoing conditions. Situation awareness is more likely to decline, when the demands of the task exceed the operators limited cognitive capacity. (Endsley, 1995, p. 53)

Ivergård and Hunt (2009, p. 5) notes, that since the economic value of machines and process units have increased, it has led to larger responsibility and to the fear of failures. Sarter et al. (1997, pp. 3–4) observes that automation introduces new attentional and knowledge demands. Operators must understand not only how the system behaves during normal operation, but also how it may behave under abnormal or unexpected conditions. In continuous processes, this challenge is especially important because stable operation may

continue for long periods, while disturbances may still escalate rapidly once control limits are exceeded (Sarter et al., 1997, pp. 7–8).

It is also demonstrated by Sarter et al. (1997, pp. 3-4), that automation brings qualitative changes in these dimensions. The workload becomes less about physical performance and more about maintaining a consistent mental representation of system's behaviour over time. This mental representation must include knowledge of the process dynamics, interactions between subsystems and the limits of automation authority in continuous processes.

It is important to note, that cognitive workload is closely related to observability and feedback planning. Sarter et al. (1997, p. 19) defines observability as the cognitive work required to extract meaning from available data. High data availability does not necessarily imply high observability. Operators may have to invest considerable cognitive effort in interpreting alarms, trends and mode transitions in poorly structured systems. Thus, the workload is not only due to the number of variables to be monitored, but also to the interpretative effort required to understand their interrelations.

Workload must also be considered in relation to system design and organisational context. Problems in human–automation coordination often arise when the levels of system autonomy, operator authority and system observability do not match. When automated systems operate with high autonomy but provide limited information about their status or behaviour, operators must invest additional cognitive effort to understand what the system is doing. In these situations, workload is not determined only by the number of tasks performed, but also by the effort required to interpret system information and infer the current state of the process. (Sarter et al., 1997, pp. 19-20)

Operators often monitor multiple process variables, alarms and performance indicators simultaneously. The cognitive workload involved in integrating these elements into a coherent system-level understanding can be significant even during nominal operations. Therefore, workload assessments in such contexts must consider the ongoing cognitive effort required to maintain intervention readiness, rather than focusing solely on observable manual actions. (Bainbridge, 1983, p. 775; Sarter et al., 1997, pp. 3–4)

System and interface design are important factors affecting workload in supervisory-control work. In highly automated environments, operators often interact with the process through displays, alarms and automation interfaces rather than only through direct contact with the

physical process. Therefore, the interface should support the operator's ability to understand system status, automation modes, process trends and possible deviations without requiring excessive interpretative effort. This is important because situation awareness is affected by system complexity, interface effectiveness, workload and automation characteristics, while automation-related problems may also emerge from insufficient feedback and difficulties in tracking system behaviour. (Sarter et al., 1997; Endsley, 2015, pp. 6–7; Pütz et al., 2024, pp. 801–803)

Working memory is also an important factor in understanding workload in process control work. Operators must maintain an understanding of the current process state while interpreting new information, comparing it with previous experience and anticipating how the situation could develop. This becomes especially demanding in new, abnormal or rapidly changing situations, where established routines and mental models may not be sufficient to support interpretation and projection. However, situation awareness should not be understood as being located only in working memory, as experienced operators also rely on long-term memory structures, such as schemata and mental models, to integrate information and reduce cognitive effort. Thus, system and interface design can either increase or reduce cognitive workload depending on how well they support attention, working memory, mental models and the operator's ability to maintain situation awareness. (Endsley, 1995, p. 43; Endsley, 2015, pp. 14–16)

Endsley (1995, p. 52) also notes a stress as an important human factor in process control work. There are two types of stress factors: the physical and social psychological. The physical stress factors include noise, vibration, heat and cold, lighting, atmospheric conditions, drugs, boredom and fatigue and also cyclical changes. Social psychological stress factors can be fear and anxiety, uncertainty, importance or consequences of events, aspects of tasks that affect financial gains, self-esteem, prestige, work advancement or loss, mental load and pressure of time.

Mandler (1982, p. 91) observed, that stressors become effective, if they are seen as threatening or dangerous. Also, Endsley (1995, p. 52) notes, that stress factors are only effective, if the employee perceives them as stressing. A moderate level of stress may help focus attention, but excessive stress can weaken performance and make it more difficult to process the situation effectively.. One important aspect is attentional narrowing, where

attention becomes focused on central or dominant information at the expense of peripheral cues. This phenomenon is described as cognitive tunnel vision by Sheridan (1981).

Stress can also affect to situation awareness through reductions in working memory capacity and retrieval (Endsley, 1995, pp. 52-53). This is significant in tasks that require the integration of multiple information sources, as high working memory load is likely to affect comprehension of the situation and projection of future status (Endsley, 1995, p. 53). In production work in process industry, this means that stress can impair not only the perception of information, but also the operators' ability to interpret process conditions and anticipate the likely development of the situation.

Complexity of systems is an important factor, that affects to workload and situation awareness in operator work. Increasing complexity affects negatively by increasing the number of system components, the interactions between them and the rate at which system states change. Task complexity could also increase through the number of goals, tasks and decisions required from the operator. All of these factors increase mental workload of operator. When the demand is too high, the situation awareness suffers. Well-developed internal representations of a system can help users cope with complexity by supporting attention, information integration, and higher levels of situational awareness. (Endsley, 1995, p. 53)

2.3 Work organization

Work organization is a key factor in production work in continuous process industries, as it shapes the distribution of tasks, responsibilities and coordination between roles. In automated production environments, work is not only defined by the technical process itself, but also by how the organization structures working roles, shift arrangements, decision-making, communication and the relationship between people and technology. Changes in industrial production and information technology have also brought about broader changes in work organization, including teamwork, process work and new forms of coordination between functions and shifts. These developments suggest that production work should be understood not only as the technical execution of processes but also as organized collective action within a changing work organization (Clegg, 2000, pp. 463–464).

Work organization should support the collaboration of social and technical elements from a sociotechnical perspective, rather than treating them as separate domains. Clegg (2000, p. 464) argues that sociotechnical design is fundamentally systemic and that technical and social systems are interdependent, which means that an exclusive design focus on just one component, such as technology, leads to suboptimal results. Thus, the whole organization of work in production environment is shaped by the interactions between interdependent parts of the broader production system and not only by the internal content of individual roles (Alter, 2018, pp. 234-235).

The division of labour creates interactions between systems that are essential for efficiency, control and specialization. At the same time, these interactions also bring risks, as direct and indirect connections between systems can degrade performance, create inefficiencies or in some cases contribute to serious disruptions. Specialization improves manageability and task focus, but also creates additional communication and coordination demands that are necessary. These principles are highly relevant in continuous process production, where work organization must define how operators, supervisors and technical systems share tasks and authority under both normal and abnormal operating conditions. (Alter, 2018, pp. 234, 246)

In practice, work organization influences production work through role definitions, coordination mechanisms, and the way tasks are grouped or divided (Alter, 2013, pp. 77–78; Clegg, 2000, pp. 464, 468). The temporal structure of work can affect the practical performance of tasks. When task boundaries and time frames are loosely defined, work can expand and become less focused, while tighter temporal structures can support coordination and prioritization (Järvinen, 2020, p. 120-121).

Operators do not just perform individual tasks in highly automated environments, but they participate in an organized system of monitoring, control, support and communication (Alter, 2013, pp. 75–78). This means that production work often depends on coordination between multiple roles. In shift-based operations, process responsibility also shifts over time from one crew to another, and disruptions may require cooperation between operators, supervisors and maintenance or technical support. From this perspective, work organization affects not only efficiency but also how well the production system supports anticipation, response and business continuity (Clegg, 2000, pp. 463–464, 468).

The importance of organizational conditions is also evident in research on cognitive ergonomics in industrial work. Wollter Bergman et al. (2021) shows that cognitive demands are shaped not only by task characteristics but also by organizational resources, such as sufficient staffing, standardized orientation, training, practical learning support and opportunities to participate in improvement work. Their findings also show that organizational demands, such as insufficient staffing, inadequate instructions and poor training, increase cognitive demands and weaken the conditions for effective performance. Although these findings originate from assembly work, a broader implication is also relevant here as work organization affects how demanding the work becomes and how well employees are able to manage this demand. (Wollter Bergman et al., 2021, pp. 16, 22–23)

One important aspect of work organization is the division of labour between roles and between people and machines. In continuous process environments, automation can perform much of the routine monitoring, while humans are still responsible for monitoring, interpreting, coordinating and intervening. As a result, work organization must define not only who performs which tasks, but also how responsibility is shared when the process moves outside of expected conditions. In sociotechnical terms, this is a matter of dividing tasks between people and machines and ensuring that system components are consistent with each other. A poorly aligned work organization can create situations where operators are formally responsible for the results of the process without being adequately supported by personnel, information, authority, or visibility into process conditions. (Clegg, 2000, pp. 468-469)

Shift-based production adds another important organizational dimension to production work. In continuous processes, work is distributed both in time and across roles, which means that production continuity depends on effective coordination between shifts and on how work is organized in the larger system. In practice, this means that production continuity depends on effective handovers, consistent practices and a shared understanding of the state of the process between shifts. Research on industrial work has shown that gaps in shift-ending routines can delay or increase the amount of work needed to effectively start the next shift, and that poor shift transitions can impair the workflow and starting conditions of the next work group. Thus, even if the technical process remains stable, the organization of work can affect how well information about deviations, priorities and pending issues is transferred between work groups. For this reason, the organization of work in continuous process

industries is not only about personnel structures or formal roles, but also about maintaining process awareness and the continuity of coordinated action over time. (Clegg, 2000, pp. 464, 468; Wollter Bergman et al., 2021, p. 13)

Work organization is also closely linked to improvement and adaptation. Research on industrial work has shown that participation in decision-making, structured improvement practices, and direct communication of suggestions to supervisors or support functions can reduce workload and improve workflow (Wollter Bergman et al., 2021, p. 16). From the perspective of this study, such findings suggest that work organization should be analyzed not only as a formal structure but also as an arrangement that can either support or hinder efficient production work in practice.

For this thesis, work organization is understood as the arrangement of roles, task distribution, coordination and organizational conditions through which production work is carried out in a continuous process environment (Alter, 2013, pp. 77–78). This perspective supports the later empirical analysis by making it possible to examine how work is divided across roles, how responsibilities are coordinated in shift-based production and how organizational conditions shape the balance between routine tasks, process monitoring and intervention.

2.4 Work System Theory as an analytical framework

Work System Theory, developed by Steven Alter, provides a conceptual approach to the analysis of systems in which human participants and technological resources interact to produce products or services for internal or external customers. Work System Theory conceptualizes organizational activities as work systems, defined as sociotechnical systems in which human participants perform processes and activities using information, technology and other resources to produce products or services for internal or external customers. In this view, work systems include not only the tasks performed by individuals, but also the tools, information, organizational rules and environmental conditions that shape the way these tasks are performed. (Alter, 2013, pp. 75-77)

Another reason for applying Work System Theory in this thesis is that it draws attention to the central elements of the work. Because a work system consists of interdependent

elements, its activities, participants, information, technologies and organizational conditions should support the same overall purpose. There are few important reasons to modify the work system, which are inconsistencies and performance differences between components, component interactions and the work system as a whole. In addition, specific elements of a work system should be aligned: the knowledge, skills, interests and motivation of employees. (Alter, 2013, p. 76, 79)

To analyze production work in continuous process industries, it is necessary to adopt a framework that views work as part of a larger organizational and technological system. Production activities do not occur in isolation, but arise from the interaction between people, technological systems, information flows and organizational structures (Alter, 2013, p. 78). Thus, Work System Theory provides a structured way to observe how work is organized across roles. This perspective fits well with the objectives of this thesis, which are to understand how production work is structured across roles and how time is divided between routine tasks and process monitoring activities. This is another reason why Work System Theory is used as an analytical framework.

According to Alter (2013, pp. 77–78), a work system consists of several key elements that interact with each other. These include participants, processes and activities, information, technologies, products or services, customers, organizational environment, infrastructure and strategies shown in the Figure 2. Together, these elements form the structure through which work is performed and coordinated. The relationships between these elements affect how effectively the work system operates and how work is divided among participants.

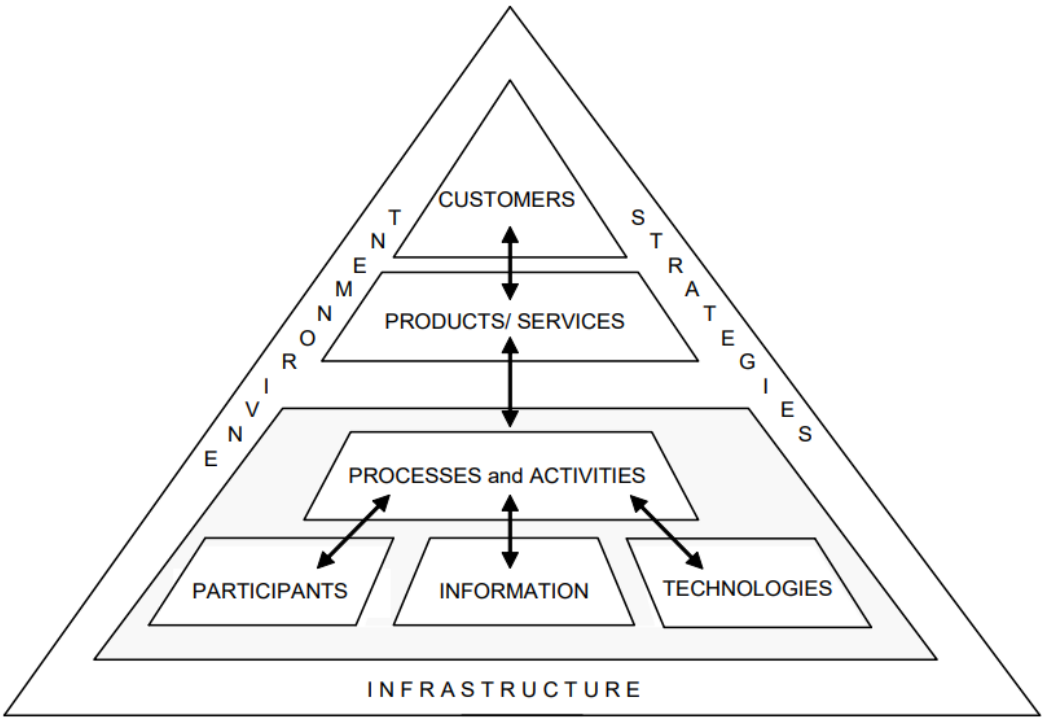

Figure 2. Work System Theory framework.

From the perspective of analysing production work, Work System Theory is particularly useful because it emphasizes the interaction between people and technological systems. In continuous processes, production activities rely heavily on automated systems, control interfaces and monitoring tools. Operators perform their work in interaction with these technological systems and simultaneously coordinate their actions with other roles in the organization. As a result, production work cannot be fully understood by examining only the formal job descriptions of individual employees. (Alter, 2013, pp. 75–77)

According to Alter (2013, pp. 77–78), a work system consists of nine core elements: participants, processes and activities, information, technologies, products or services, customers, environment, infrastructure and strategies. The analysis focuses on the elements most directly related to the organization of production work: participants, processes and activities, information, technologies and the organizational environment.

- Participants refer to the people who perform the work within the system. In this study, participants include operators, supervisors and other roles involved in running and supporting the production process.

- Processes and activities describe the work carried out within the system. In continuous process industries, these include routine tasks, monitoring, control actions, maintenance-related work and coordination between roles.
- Information includes the data and knowledge used and produced in the work system, such as process measurements, alarms, reports, and other forms of process-related information that support monitoring and decision-making.
- Technologies refers to the tools and systems used to perform work, including process control systems, automation technologies, user interfaces and monitoring tools.
- Organizational environment refers to the structures, rules and operating conditions within which production work takes place, including role definitions, production targets, management practices and safety requirements.

This framework is also useful, as it treats work system as evolving and not as fully stable system. A complete perspective on work systems requires both a static view of their structure at a given point in time and a dynamic view of how it changes. In this dynamic perspective, change does not only occur through formal development efforts, but also through everyday adjustments made in practice. (Alter, 2013, p. 77)

Another strength comes from the assumption that all work is not limited to strictly defined formal processes (Alter, 2013, p. 79). The term, “processes and activities”, is used because the performed work might not be a set of clearly defined steps with a sufficiently well-defined beginning, sequence and end to be called a process by some definitions. Important work systems that perform organized activities and rely highly on judgement and improvisation of people are better described as a set of interrelated activities. Furthermore, Work System Theory distinguishes between describing work as it is formally expected to be performed and how it is performed in practice. This is particularly useful in the context of production work, where formal task descriptions might not capture fully the actual practical execution of work, thus making a foundation also for the chosen research method, presented later in the Chapter 3.3.

Work System Theory has also been discussed and developed further in the information systems literature. Alter (2013) presents WST as an integrated body of theory that emerged from the development of the Work System Method, which was originally created to support

systems analysis and design by business professionals. In this formulation, WST consists of the work system concept, the work system framework and the work system life cycle model. The purpose of the theory is to move analysis away from a narrow technology-as-system perspective toward a broader view in which participants, processes and activities, information, technologies, customers, products and services, environment, infrastructure and strategies are all relevant elements of the system being analysed (Alter, 2013).

The theoretical status and development of WST have also been debated by others. Niederman and March (2014) examine WST as a transformation of earlier information system artefacts, including the Work System Method, the work system framework and the work system life cycle model, into a theoretical approach. They recognize the potential value of the work system approach but also argue that further theory development and empirical testing are needed to evaluate its usefulness more broadly and to clarify its contribution compared with alternative approaches. This discussion is important for the present thesis because it suggests that WST is most appropriately used here as an analytical framework for structuring and interpreting the empirical findings rather than as a predictive theory. (Niederman & March, 2014)

Alter (2015) later responded to this debate by positioning WST as a platform for further applications and extensions rather than as a narrow explanatory-predictive theory. This view is relevant for the present study because production work in a continuous process environment involves several interacting roles, technologies, information flows and organizational conditions. Later work has also extended the work system perspective through Alters (2018) System Interaction Theory, which focuses on interactions between work systems instead of analysing only the internal elements of one work system. This is useful for understanding production work, because the functioning of one production role is often dependent on its interaction with other roles, maintenance, information systems and technical infrastructure. (Alter, 2015, pp. 485–489; Alter, 2018, pp. 233–240)

The debate around WST is important for the present thesis because it supports a cautious use of the theory. Work System Theory is not used here as a predictive theory for explaining causal relationships, but as an analytical framework for structuring and interpreting empirical findings. In this role, its value lies in helping to connect task-level observations with broader work system elements.

These elements provide the conceptual structure for analysing production work in this study. They make it possible to examine not only what tasks are performed, but also how work is distributed across roles and how information, technologies and organizational conditions shape that work. Thus, Work System Theory is used as an analytical lens to examine the organization of production work in a continuous process environment. The framework supports the analysis of how different roles participate in the work system, how technologies shape the tasks performed by operators and how information flows influence control and decision-making. By analysing production work through the elements of the work system, it is possible to develop a more comprehensive understanding of how work is actually performed in the production process.

2.5 Synthesis of the theoretical framework

Building on these theories discussed above, the theoretical framework of this study combines four complementary perspectives on production work in continuous process industries. First, research on continuous process production highlights that production work takes place in complex, automated and tightly interconnected environments in which operators play a key roles in monitoring and managing process disturbances.

Second, theories of cognitive demands and situation awareness show that operator work in such environments depends not only on observable actions, but also on perception, interpretation, anticipation and the ability to maintain an accurate understanding of process states. Third, human factors research on workload demonstrates that automation changes the quality and timing of workload rather than removing it, creating conditions in which low physical activity may coexist with high cognitive demand. Finally, Work System Theory provides a system-level framework for analysing how work is organised across roles, activities, technologies, information and organisational conditions.

Together, these perspectives support the analysis of production work as more than a set of isolated tasks. They make it possible to examine how work is distributed between roles, how time is divided between routine and non-routine activities, and how technologies and information shape operator work in practice. In this study, Work System Theory is used as

the main analytical framework, while the perspectives of situation awareness, cognitive demands and workload help interpret the nature of the work performed within that system. This is illustrated in the Figure 3 to present the structure how they are interrelated and used in this thesis.

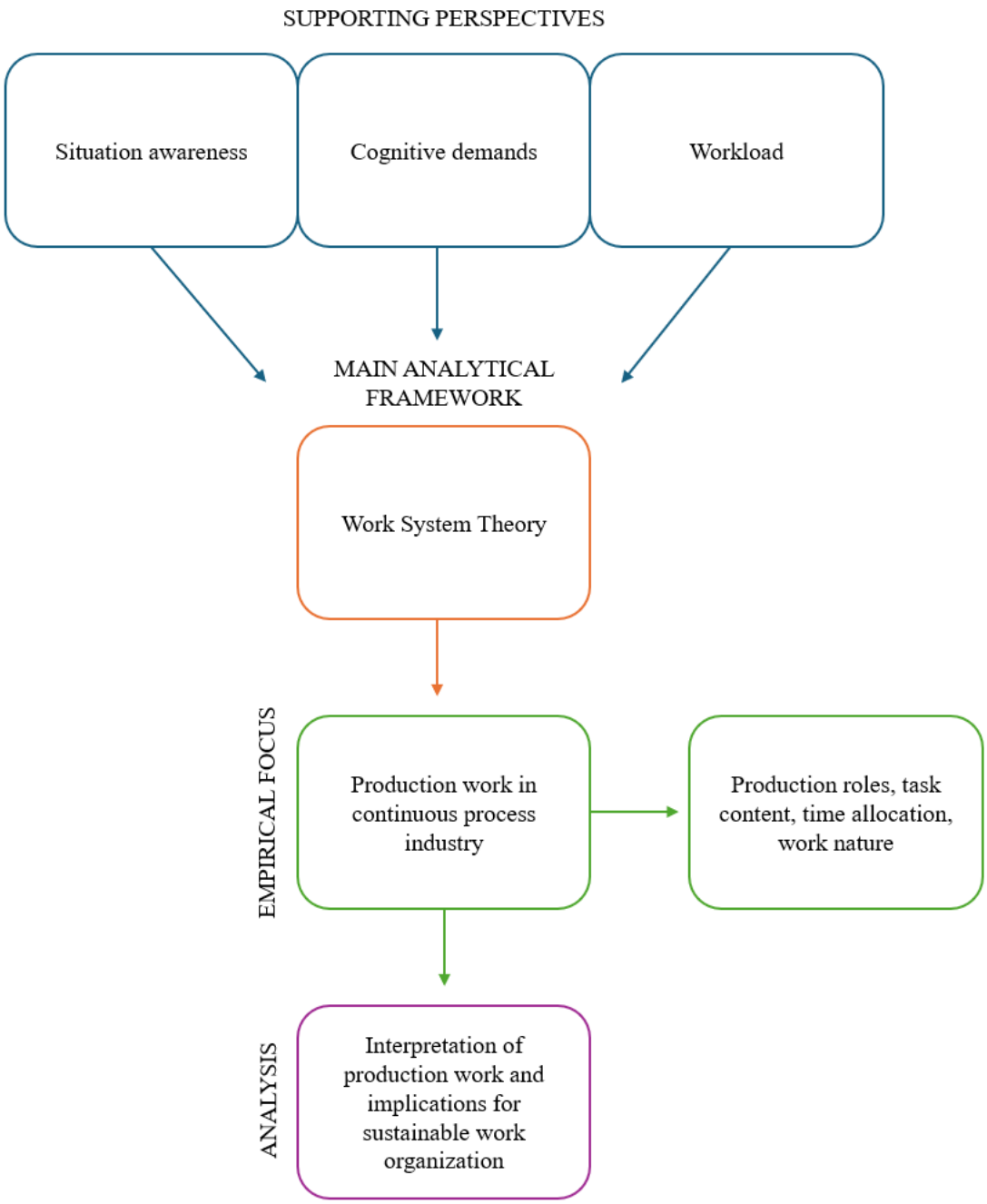

Figure 3. Work System Theory provides the main analytical framework, while situation awareness, cognitive demands and workload are used as supporting perspectives for interpreting production work in a continuous process environment.

This theoretical combination also defines the scope of the study. The analysis focuses on production work roles, task structures, time use, process monitoring and the interaction between operators and production technologies. In contrast, the study does not aim to evaluate the technical performance of specific machines, or optimizing control system design, or assess individual psychological traits of operators. The purpose is instead to understand how production work is structured and performed within a continuous process work system.

These theories build a foundation, that makes it possible to analyse work roles through two parallel dimensions: the visible task performance and less visible monitoring and intervention responsibility and readiness. Therefore, in this thesis, the work roles are examined as task profiles, in which machine-paced tasks and monitoring and supervising of process vary. It is also necessary to notice, that no matter in which profile the task belongs, it depends full-time readiness to act in terms of intervening the process in situations requiring that, as mentioned in several materials (Rasmussen, 1983; Bainbridge, 1983; Endsley, 1995; Endsley & Kiris, 1995; Strauch, 2018; Pütz et al., 2024).

3 Research context and methodology

This chapter presents the research context and methodology choices of this thesis. It describes the production environment where the thesis was conducted, the production work roles included in the empirical analysis and the research design used to examine work content across roles. The chapter also explains the data collection and analysis methods and discusses the reliability and validity of the study,

3.1 Research context

This study was conducted in a continuous process manufacturing environment. The case context is a production organization in which work is carried out in a highly automated, shift-based process environment. Production continues across shifts without interruption, and the

functioning of the process depends on coordination between multiple production roles operating within the same production system.

The research context is relevant because continuous production combines several features that are central to the objectives of this thesis. These include a high degree of automation, continuous monitoring of the production process, a role-based division of labour and the need to coordinate routine tasks and process control across shifts. In this type of environment, production work is not limited to direct manual tasks, but also includes process monitoring, control actions, communication between roles and responses to disturbances.

The empirical focus of the thesis is on the production work roles involved in process operation. The aim is not to analyse the technical performance of individual machines or specific production equipment, but to examine how work is organized across different roles within the production system. This makes the context particularly suitable for a role-based analysis of task content, time use, and process control. Because the work is carried out within a shared production system, the case also makes it possible to analyse both differences between roles and the wider organizational structure through which production work is coordinated.

3.2 Description of production work roles

The empirical part of this study focuses on the production work roles involved in the operations in the continuous production process in this study. The purpose of describing these roles is to clarify the scope of the study and to provide the basis for the later analysis of task content, time use and process monitoring across roles. The thesis does not examine individual employees, but production work as it is performed through different work roles in the production system.

The selected roles represent different positions within the production process and involve varying combinations of routine tasks, process monitoring, control actions, coordination responsibilities and responses to disturbances. The roles provide a suitable basis for examining how production work is distributed across the organization and how role-specific responsibilities shape the overall structure of work, because they operate in a shared production system.

This thesis includes production work roles from five production departments (A, B, C, D and E) within the same mill and continuous process environment. The purpose of this section is to describe the organizational scope of the empirical material and to clarify how the examined roles are positioned within the production system. Because many roles occur in more than one department, the description is structured around both departments and broader role categories. This makes it possible to present the overall structure of production work, without repeating largely similar role descriptions department by department.

3.2.1 Production departments

The empirical material covers five production departments operating within the same mill and the personnel are working in the five shifts continuously. Although all departments are part of the same overall production system, their roles in the process differ. Three of the departments are responsible for their own production processes, one department is responsible for post-processing and one department produces raw material which is used by the three production departments. The departments are divided as demonstrated in the Table 2:

Table 2. Departments and descriptions.

Departments	**Description**
A	Production line
B	Post-processing line
C	Production line
D	Production line
E	Production line of raw material

While the departments operate within the same mill, and they are organizationally connected, their work differs slightly in terms of products and processes. This makes it possible to study both similarities and differences in production work across departments that are linked to the same wider production environment.

For the purposes of this thesis, the departments are treated as distinct but interconnected parts of the mill's production system. This allows the analysis to consider how production work is organized not only within individual departments, but also across the departments.

3.2.2 Production roles

In this chapter, the main production role categories are presented across the departments in the Table 3 below. It summarizes the roles assigned to each department. It provides an overview of the departmental role structure and supports the later analysis of task distribution, role comparability and work organization. Each role is described as "Task 1", Task 2", etc. to keep the secrecy for the case company. As it can be seen, Departments A, C and D, that are production lines, have 5-7 tasks, while the post-processing line Department B and raw material production line Department E only 2-3 tasks.

Table 3. Main production roles in each of the departments.

Department A	Department B	Department C	Department D	Department E
Task A1	Task B1	Task C1	Task D1	Task E1
Task A2	Task B2	Task C3	Task D2	Task E2
Task A3	Task B3	Task C2	Task D3	
Task A4		Task C4	Task D4	
Task A5		Task C5	Task D5	
		Task C6		
		Task C7		

There are 22 different task roles across the departments. Some of those positions have two employees, as shown in the Table 4, where it is explained how many employees are assigned to each position. Department E has two employees assigned into both tasks E1 and E2. Also, the tasks A5, C5 and D5 share two-employee assignments.

Table 4. Count of employees assigned to each task role.

Task	Count	Task	Count	Task	Count	Task	Count	Task	Count
A1	1	B1	1	C1	1	D1	1	E1	2
A2	1	B2	1	C3	1	D2	1	E2	2
A3	1	B3	1	C2	1	D3	1		
A4	1			C4	1	D4	1		
A5	2			C5	2	D5	2		
				C6	1				
				C7	1				

Table 5 shows the production work tasks, which are comparable across the departments. It is noticeable that there are only comparable roles between departments A, C and D. Thus, departments B and E are left outside of this table.

Table 5. Tasks that are comparable between departments.

Comparability	Department A	Department C	Department D
A, C and D	A1	C1	D1
A and D	A2		D2
A, C and D	A3	C3	D3
A, C and D	A4	C4	D4
A, C and D	A5	C5	D5

3.3 Research design and approach

This study applies a qualitative case study approach to examine production work in a continuous process industry. The aim is to analyse how work is structured across different production roles, how time is allocated across different types of activities and how process monitoring fits into the overall content of production work. Eriksson and Kovalainen (2016, pp. 131-132) emphasize that case study research should be understood as a research approach or research strategy rather than as a single method, and that it is valuable when the

aim is to understand the logic of the case rather than to produce statistical generalizations. Also Bell and Warren (2023, p. 3) describe case study research as a research strategy, methodology or design that is inseparable from context and valuable for gaining insight into a phenomenon in its context. Thus, case study approach is suitable, because the study focuses on a real organizational setting and seeks to understand work and work roles in its operational context rather than in an abstract or experimental environment.

Eriksson and Kovalainen (2016, pp. 4-5) emphasize qualitative research as focusing on interpretation and understanding, and the data collection and analysis to be sensitive to the social context that aims to a holistic understanding of issues under research. Because in this thesis the aim is not only to quantify tasks, but also to understand how production work and the roles in it is described, interpreted and organized in practice, the qualitative research was chosen as method. Production work in a continuous process industry involves routine tasks, monitoring activities, coordination between roles and responding to disturbances. These dimensions cannot be properly understood by numerical task counts alone, as the meaning and significance of work activities depends on few things, such as the broader production context, the role of the operator and the interaction between people and technology.

The study adopts a structured approach to analysing task content and time use across roles, following the logic of work analysis in which work is documented and made explicit for further examination (Jacobs, 2019, p. 4). For this reason, the research combines qualitative interpretation with a systematic comparison of work activities across different production roles. The aim is to produce an empirically grounded and diverse understanding of how production work is organized in a continuous process environment and how different roles influence the functioning of the production system.

Bell and Warren (2023, pp. 3–4) argue that case study research is valuable, because it supports in-depth investigation of a phenomenon or problem within a specific real-life context and recognizes that organizational context might influence the phenomenon being studied. Thus, this research can be described as an applied organizational case study with a work analytical orientation from a methodological perspective. It focuses on one industrial case to produce context-sensitive information about production work in that environment. At the same time, the thesis is guided by theoretical concepts that make it possible to analyse these findings in a structured and transparent way. Work System Theory is used as the main analytical framework because it allows production work to be examined as a system of

interrelated roles, activities, information, technologies and organizational conditions rather than as isolated individual tasks (Alter, 2013, pp. 75–78).

The choice of research design is also related to the research questions. The thesis aims to investigate how production work is divided between repetitive tasks, mechanical or routine activities and process monitoring work, and how these forms of work are distributed across different roles. Such questions require access to employees' descriptions of their own work, their practical responsibilities and their interpretation of how work is actually performed in the production process. A qualitative research design is therefore suitable, because it allows for the detection of differences between formal role descriptions and actual work practice by examining how work is described and interpreted in its organizational context (Eriksson & Kovalainen, 2016, pp. 5–6).

The thesis does not aim to evaluate individual performance or to measure the technical efficiency of specific machines or systems. Instead, it focuses on the organization of work and the content of work roles in the production system. This means that the primary unit of analysis is not the individual employee, but the production work as performed through different roles in the continuous process industry's environment. In this sense, the study combines role-based analysis with a broader systems perspective.

Overall, the selected research design supports the purpose of this thesis well. It allows the analysis of production work in sufficient contextual depth and at the same time enables a systematic comparison between different roles. This combination is important for producing a credible description of work content in continuous process production and linking the empirical findings to the theoretical framework, presented in Chapter 2.

3.4 Data collection

The empirical material for this study was collected using qualitative interviews and role-related background material provided by the case organization. The purpose of the data collection was to gain a detailed understanding of production work in a continuous process environment across different roles. The data collection focused on identifying the content of work, the main task categories associated with each role and the relative emphasis placed on

different types of activities, such as routine tasks, process monitoring, coordination and responses to disturbances.

Interviews were chosen as the primary data collection method because the study aims to examine how production work is described and understood by those involved in it. This made it possible to gather role-specific information about work tasks, practical responsibilities and the ways how work is organized in everyday production. Interviews were especially suitable for this purpose because the study aims not only to identify formal role descriptions, but also to understand how work is actually performed in practice.

In addition to work tasks and time use, the interviews also addressed factors related to workload and work demands. These included, for example, the perceived demandingness of the work, sources of mental or physical strain, the role of process monitoring in daily work and the kinds of situations that were experienced as particularly demanding or disruptive. Including these themes made it possible to complement the task-based description of work with a broader understanding of the conditions under which the work is performed.

The data collection was designed to cover production roles from multiple departments within the same mill. This allowed the thesis to examine both role-specific work content and department-specific differences in how similar roles were performed. The purpose was not to achieve statistical representativeness, but to generate sufficiently rich qualitative material for comparing work content across roles and departments. Even though not all the roles could not be interviewed, the remaining three roles were interviewed in the other departments, where the working role was mainly the same and difference came from the production line itself. Also, the company's formal descriptions of tasks were then used to get the more accurate picture of the role.

The interviews for production operators followed a semi-structured format of six different themes, related to the theoretical framework and background. The structure was used to ensure that similar themes were discussed across interviews, while still allowing flexibility for role-specific details and clarifications. The interview themes included following:

1) Practical implementation of the role and work

2) Time use and division of work

3) Situational awareness and cognitive load

4) The importance of the role in the process system

5) Automation and work change

6) Disturbances and critical moments

In the end of the interview included final questions, where a few more questions were asked, most importantly a question “Which role do you find most problematic if you consider it through the questions asked in this survey?”.

For the supervisors, the interview questions were formulated differently but following the semi-structured format. The interview was built on themes that emerged from the production operators, but at the same time were structured around the research questions. The answers were given from the supervisor’s perspective. This interview structure contained also six themes, which were:

1) Production work
2) The job rotation
3) Workload factors
4) Disturbances & maintenance-related matters
5) Anticipating and developing work
6) Division of work and work organization

The data collection process also involved practical considerations related to confidentiality and the handling of sensitive organizational information. Because the thesis was conducted in an industrial setting and included internal work role-related material, the data collection is described at a level that supports methodological transparency without disclosing confidential operational details.

A total of 25 interviews were conducted for the personnel in the production lines in Finnish language during the daytime (09:00-21:00), including supervisors and operators. Most of the interviews were held in morning shifts (07-19) and few of them during the beginning of night shift (19-07) but before 21:00, so the late time and tiredness did not affect the responses. Interviews were conducted from March 2026 to April 2026. One interview took approximately 30-65 minutes. The interviews conducted with departments, dates and roles

in the production work are shown in the Table 6. In this table, the roles are presented simply as a general terms “operator” and “supervisor” to keep the anonymity of interviewees.

Table 6. Realized interviews showing departments, roles and dates.

Interview	Department	Role	Date
#1	D	Operator	March 2026
#2	A	Operator	March 2026
#3	E	Operator	March 2026
#4	B	Operator	March 2026
#5	A	Operator	March 2026
#6	E	Operator	March 2026
#7	A	Operator	March 2026
#8	E	Operator	March 2026
#9	B	Operator	March 2026
#10	C	Operator	March 2026
#11	B	Operator	March 2026
#12	A	Operator	March 2026
#13	A	Operator	March 2026
#14	B	Operator	March 2026
#15	C	Operator	March 2026
#16	D	Operator	March 2026
#17	D	Operator	March 2026
#18	C	Operator	March 2026
#19	C	Operator	March 2026
#20	D	Operator	March 2026
#21	C	Operator	March 2026
#22	E	Operator	April 2026
#23	All dep.	Supervisor	April 2026
#24	All dep.	Supervisor	April 2026
#25	All dep.	Supervisor	April 2026

The interviews were transcribed using Microsoft Word and then cleaned into written form for analysis. This process made it possible to transform spoken responses into a more systematic textual format that could be compared across interviews and roles. Transcribing 25 interviews was time-consuming, but necessary part of the data collection in terms of chosen research method of abductive thematic analysis.

Participation in the interviews was voluntary, and the interviews were conducted in a way that preserved anonymity. Individual responses were not disclosed to other parties in any point, and they were saved on a memory stick. All the interview answers were deleted after the analysis was done.

The interviewees represented a broad range of experience and competence, from more experienced employees to newer workers, and from broader expertise to more limited role-specific experience. The interviewees were asked to participate widely from the five different shifts where employees are working to get comprehensive perspective. Also, both genders (male and female) participated in the interviews. Personnel with maintenance-related expertise (electrical/automation and mechanical) were also interviewed extensively, 40 % of the interviewees, shown in the Table 7.

Table 7. Conducted interviews for the production operators with maintenance expertise.

Maintenance expertise	**Count**
Mechanical	4
Electric and automation	5
Total number of all interviewees:	41 %

Since the departments have 22 working roles overall, not all of them could be included in the interviews due to the thesis schedule and production line problems, such as staff shortages or abnormal production situations. The missing work roles for which interviews were not possible are marked in red in the Table 8, and the interviews conducted are marked in the green colour. The main reason was staff shortages, as employees were not able to leave their workplaces for the time that the interview would have taken. For this reason, some of the interviews were conducted in the process control rooms during work, if the interviewee was working alone and there were no unusual situations. When conducting the research, it

was also necessary to consider that conducting the interviews at the same time as the interviewee was working might affect some of the answers, because the environment does not necessarily provide the opportunity to think about the answers as much as in a quiet and peaceful office room.

Table 8. Work roles in the departments. The ones interviewed marked in the green and lacking interviews marked in the red colour.

Department A	Department B	Department C	Department D	Department E
Task A1	Task B1	Task C1	Task D1	Task E1
Task A2	Task B2	Task C3	Task D2	Task E2
Task A3	Task B3	Task C2	Task D3	
Task A4		Task C4	Task D4	
Task A5		Task C5	Task D5	
		Task C6		
		Task C7		

Table 9 demonstrates the number of interviews conducted by each work tasks. Here, it is noticeable that the tasks B1 and B2 were interviewed at the same time by the same interviewee, as the tasks are very close to each other and are working as workmates in the same department and process control room.

Table 9. Count of conducted interviews by work task.

Task	Count	Task	Count	Task	Count	Task	Count	Task	Count
A1	1	B1	2	C1	1	D1	1	E1	3
A2	1	B2	2	C3	0	D2	0	E2	1
A3	1	B3	2	C2	1	D3	1		
A4	1			C4	1	D4	1		
A5	1			C5	0	D5	1		
				C6	1				
				C7	1				

Thesis also utilized background material gathered in 2021-2023 related to the production work roles and organization. These materials were used to support the interpretation of the interview data and to provide additional information about the formal structure of the included roles. The combined use of interview data and role-related background material made it possible to compare formal role descriptions with employees' own accounts of their work.

3.5 Data analysis

The interview data were analysed using abductive thematic analysis, as Thompson (2022, pp. 1411–1412) describes abductive thematic analysis as an approach that combines thematic analysis with abductive reasoning and aims to maintain a balance between theorising and empirical data. This fits the purpose of the thesis, because the analysis develops themes from the interview material and interprets them through the theoretical framework that is presented in Chapter 2.

Abductive thematic analysis does not seek to proceed inductively only from the data, or deductively by testing a predefined theoretical model. The analysis is instead based on parallel empirical data and existing theoretical understanding, and it seeks the most useful and logically justified explanation for the phenomenon which is under the studying. (Thompson, 2022, pp. 1411-1412; Timmermans & Tavory, 2012, pp. 167)

The analysis began with repeated familiarisation with the material. Thompson (2022, pp. 1412–1413) describes familiarisation as an active process of reading, transcription, taking notes and identifying potential patterns and codes in the data. Similarly, Khurshid et al. (2026, pp. 108–109) emphasizes that familiarization requires active immersion in the corpus through re-reading, coding and note-taking, making it possible to identifying additional details. Thus, the interview material and task descriptions were read during the research several times to identifying recurring tasks, observations related to work and role-specific features relevant to the research questions

Thompson (2022, pp. 1413–1414) notes that coding condenses qualitative material by giving concise titles to meaningful sections of the text. The process is also more cyclical rather than linear. The first round of coding should capture all meaningful points made in the interviews,

whereas later rounds of checking the transcriptions should become more selective and consolidate overlapping codes. Thompson (2022, pp. 1411–1412, 1415–1416) also states that the abductive thematic analysis applies theory and literature together with the raw data and that theorization should be guided, but not determined, by existing theory. Timmermans and Tavory (2012, pp. 176–177) similarly describe abductive analysis as a process that is strengthened by revisiting the data and defamiliarizing what initially seems obvious and considering alternative ways of conceptually framing the data. Iterative process of revisiting the material is also noted by Khurshid et al. (2026, pp. 110-111), highlighting that it helps to identifying the relevant data and clarifying the recurring patterns and analysis.

The analysis was not limited to listing tasks but also considered how interviewees described the relative importance and practical role of different activities in their daily work. This made it possible to examine how work was distributed between different task types and to compare how strongly different roles were oriented toward, for example, monitoring, routine work, coordination, or intervention. The analysis combined qualitative interpretation with a structured comparison of work content across roles.

To illustrate the coding logic, the emerged themes from the interviews were labelled as codes such as “team spirit”, “asking of others”, “helping between roles”, “job rotation”, “role flexibility”, “broad competence”, “deep expertise”, “role-specific competence”, “loss of routine”, “equipment failures”, “disturbances” and “interrupted stable work/process”. Later these codes were grouped under broader themes that are presented in the Chapter 4.

Role-related background material provided by the case organization was used after the interviews as a complementary source in the analysis. These materials supported the interpretation of the interview data by providing additional information about the formal structure of the roles. They were not used to determine the content of work in advance, but rather to compare formal role descriptions with the accounts provided by the interviewees.

The analysis was guided by the theoretical framework presented in Chapter 2. Work System Theory served as the main analytical framework by supporting the examination of production work through roles, activities, information, technologies, and organisational conditions. At the same time, the concepts of situation awareness, cognitive demands, and workload were used as supporting perspectives when interpreting monitoring-related work,

demanding situations, and the human factors associated with different roles. This made it possible to connect the empirical material to the theoretical discussion in a systematic way.

3.6 Reliability and validity

The reliability and validity of this study were considered throughout the research process, from data collection to analysis and interpretation. Riege (2003, pp. 80–83) argues that case study validity and reliability can be strengthened through practical procedures such as clear research design, defined case boundaries, triangulation and documentation of the research process. Because the thesis is qualitative, reliability is not understood in the same way as in quantitative research, where measurement conditions are often more stable and repeatable (Riege, 2003, p. 80). Instead, the aim in this study is to ensure that the research process is transparent, logically structured and sufficiently well described to support the credibility of the findings.

One factor supporting the reliability of the study is the use of a common interview structure across the interviews. Although the interviews were semi-structured and allowed flexibility for role-specific clarification, the same core themes were addressed with all interviewees. This improved the comparability of the material and supported systematic analysis across different roles and departments. The documentation of clear research procedures and a chain of evidence is also consistent with reliability strategies in qualitative case study research (Riege, 2003, p. 80). Also, the number of interviews was relatively broad in relation to the scope of the study, which strengthened the empirical basis for identifying recurring patterns and differences in production work. Comparing to the number of all personnel working in the production line belonging to the personnel group HR5, approximately 18 % of it were interviewed for this study.

The thesis also sought to ensure validity by collecting material from a diverse group of interviewees. Similar quality assurance principles are used by Wollter Bergman et al. (2021, pp. 20–21), who emphasize triangulation, rich descriptions, clear scope and boundaries, mechanical data recording and peer debriefing in qualitative case study research. The interviewees in this thesis represented different levels of experience, different degrees of role-specific expertise, and different positions within the production environment. This supported a broader understanding of production work and reduced the risk that the analysis

would reflect only one narrow perspective on the work. The inclusion of interviewees with maintenance-related expertise in the production work roles, which also strengthened the contextual understanding of production work and its practical demands in the mill environment.

Another factor supporting validity is that the study did not rely only on formal role descriptions. Instead, the analysis was based primarily on interviewees' own descriptions of their work, while role-related background material was used as a complementary source after the interviews. This made it possible to compare formal role structures with practical work as experienced and described by those performing it. In this way the thesis was able to capture actual work practice rather than only formal organizational definitions. This supported triangulation by comparing interview data with role-related background material and formal task structures, following case study validity strategies such as the use of multiple sources of evidence and the establishment of a chain of evidence (Riege, 2003, p. 82).

The researcher's own prior experience in some of the same work roles, as well as previous experience as a supervisor of those roles, also influenced the research process. This background supported the interpretation of the material by providing contextual understanding of the production environment, the terminology used in the interviews and the practical meaning of different work tasks. At the same time, it is noticeable that this familiarity may also create a risk of interpretation bias, as prior knowledge can influence what is noticed, how responses are understood and which themes appear especially significant. For this reason, the analysis was based primarily on the interview material itself, and the role-related documents were used only as a supporting source rather than as the starting point of interpretation.

The case study design also places limits on the generalizability of the findings. The study focuses on one mill environment and on the production work roles included in that specific case. The purpose is therefore not to produce statistically generalizable results, but to generate context-sensitive understanding of production work in a continuous process environment. Bell and Warren (2023, pp. 4–5) note that case study research is often particularistic and context-bound, which limits statistical generalizability, but can support contextual understanding of phenomenon and interaction of different factors and events. The findings may nevertheless have analytical relevance beyond the case itself, particularly in

relation to continuous production environments where work is organized across multiple roles, departments and shift-based operations.

Confidentiality and anonymity were also important aspects of the reliability and ethics of the study. The interviews were conducted in a way that preserved anonymity and individual responses were not disclosed to other parties. Because the study was conducted in an industrial setting and included potentially sensitive organizational information, the methodological description and presentation of results are kept at a level that supports academic transparency without revealing confidential operational details.

4 Empirical findings

This chapter presents the empirical results of the study. The results are reported at the role level to provide a structured description of the content of production work, the variation of tasks and the differences between roles and departments. The purpose of this chapter is to show what was identified in the empirical data in a systematic way.

Production tasks are presented at a relatively high level of abstraction, since this thesis is a public document. Individual tasks are described at a generalized level in terms of broader functional categories. Abstraction is necessary for two reasons. First, the case context includes confidential information and second, the aim of this thesis is to examine broader patterns in the production work and not to document the detailed specifics of each individual tasks. Detailed technical descriptions of specific process steps, work instructions or operational responses are avoided. This level of presentation allows for analysis of the structure and content of production work and avoids the disclosure of confidential information. Therefore, abstraction supports the analytical purpose by shifting the focus from specific details of tasks into the structural characteristics of the work.

4.1 Characterization of production tasks

This section presents a characterization of production tasks identified in the empirical data. The purpose of the characterization is to provide a structured overview of the tasks

performed in different production roles and to create a common basis for subsequent analysis of work content, time use and role-specific differences.

In continuous process industry, these two profiles cannot be delimited into either-or type of dimensions, as the one work role can be partly both of them. Instead, they must create an analytical framework to describe in more accurate way the profile of work role, which is shown in the Figure 4 below. Machine-paced task does not exclude the task also being supervisory-controlled one, instead they can be profiled to both categories same time.

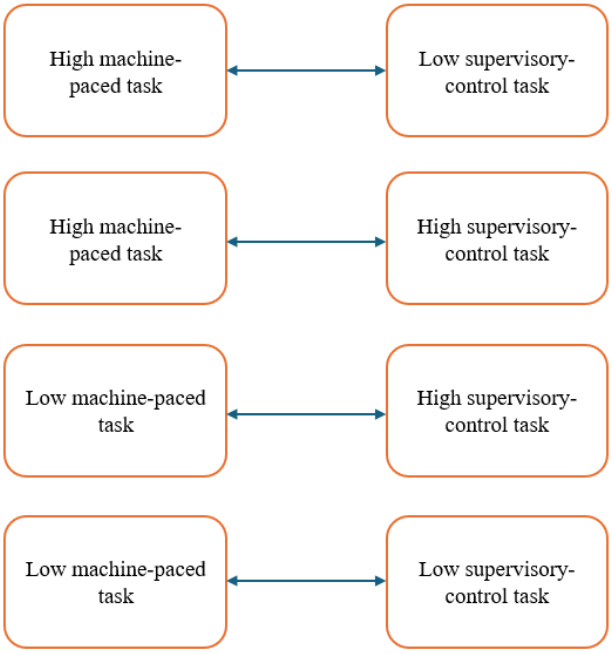

Figure 4. Dimensions of machine-paced and supervisory-control task categories.

In the task classification, the categories high and low describe the intensity of machine-paced and supervisory-control characteristics, demonstrated in the Figure 5. High refers to tasks in which the respective characteristic is dominant, while low refers to tasks in which the characteristic is present but limited. In addition, category “No” is used when a task does not meaningfully include the respective characteristic. Thus, no should not be interpreted as a lower intensity level than low, but as an indication that the dimension is not applicable to the task.

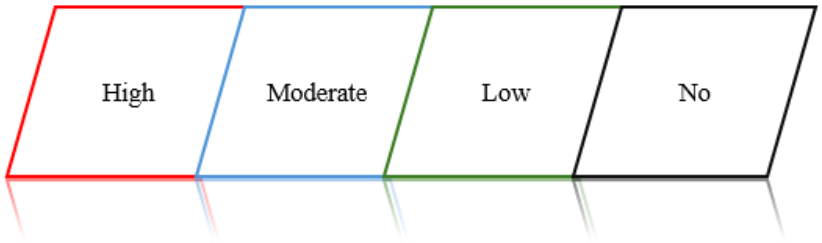

Figure 5. Categorization of tasks intensity.

It is also noticeable, that routine field checks are part of all the tasks performed in each department. Thus, this is not included in the section of illustrative tasks, as it would be unnecessary to mention it throughout the tables.

4.1.1 Production tasks in Department A

In Department A production work consisted of both machine-paced and supervisory-control tasks. Table 10 demonstrates the classification of tasks. Tasks A1 and A2 were classified as high supervisory-control tasks and as not significantly machine-paced. In these tasks operators' main responsibilities are to observe the state of the process, interpret process information, maintain awareness of the process situation and coordinate actions when needed. Thus, the operators work in these tasks are less tied to physical performance, it is more dependent on the physical presence. When the process is stable, the disengagement is possible for Tasks A2 to disengage for a while, if the other operator A1 of the same control room stays monitoring and controlling the process and has competence to perform both tasks.

In contrast, tasks A4 and A5 were mainly identified as high machine-paced tasks with limited supervisory-control characteristics. These tasks are more tied to the physical rhythm of production and require direct execution according to the pace of the process. Task A3, however, represents an intermediate profile, as it is classified as high machine-paced and moderate supervisory-control. This indicates that the task includes both physical performance and monitoring and process-following elements of these classifications.

Table 10. Production tasks in Department A classified to machine-paced and supervisory-control tasks and illustrative generalized tasks of each role.

Task	Machine-paced tasks	Supervisory-control task	Illustrative generalized tasks
A1	No	High	Periodic quality-checks Constant monitoring Change of product-type
A2	No	High	Periodic quality-checks Constant monitoring Change of product-type
A3	High	Moderate	Periodic sampling Periodic quality-check Change of product-type
A4	High	Low	Periodic sampling Regular material feeding
A5	High	Low	Refinement of product and related tasks

The intensity matrix in the Table 11 demonstrates these differences mentioned above. Tasks A1 and A2 show high intensity in monitoring and quality-related tasks, whereas routine manual tasks remain at a low level. Task A3 combines high routine manual work with moderate monitoring and quality-related tasks. A4 is characterized by high routine manual work and high disturbance handling, which indicates that the task may become especially demanding when the normal workflow is interrupted. Also, A5 is strongly machine-paced task, but its disturbance-handling intensity remains more moderate.

Table 11. Intensity matrix of performed tasks in Department A.

Task	Routine manual tasks	Monitoring	Quality-related tasks	Disturbance handling
A1	Low	High	High	Moderate
A2	Low	High	Moderate	Moderate
A3	High	Moderate	Moderate	Moderate
A4	High	Low	Low	High
A5	High	Moderate	Low	Moderate

In overall, Department A includes a clear division between monitoring-oriented roles and physically bounded machine-paced tasks. This means that the possibility to disengage from the immediate workstation or perform proactive work differs considerably between tasks. Monitoring-oriented tasks appear to allow more situational overview, while machine-paced tasks are more dependent on the immediate rhythm and condition of production process.

4.1.2 Production tasks in Department B

The task classification of Department B in the Table 12 shows a more clearly divided task structure. Tasks B1 and B2 were classified as high supervisory-control tasks with low meaningful machine-paced characteristics. These tasks appear to be primarily monitoring-based and connected to observing the process, interpreting information and maintaining control over the production situation. Both tasks are also similar to each other in the profile of the work. If the production is very low and process is stable, it is possible for other one of the tasks B1 or B2 to disengage for a while, if the other operator stays monitoring and controlling the process in control room and has competence to perform both tasks.

Task B3 differs clearly from B1 and B2. The working area is separate and the process vastly different, though it belongs to the same Department. It is classified as high machine-paced and not supervisory-control oriented. This indicates, that B3 is more directly tied to physical execution and the pace of the production process. However, in this task the high autonomy of work is also observed, as the task is as more dependent on operators own pace as machines pace.

Table 12. Production tasks in Department B classified to machine-paced and supervisory-control tasks and illustrative generalized tasks of each role.

Task	Machine-paced tasks	Supervisory-control task	Illustrative generalized tasks
B1	Low	High	Product handling Constant monitoring Replacement of supplies
B2	Low	High	Product handling Constant monitoring Replacement of supplies
B3	High	No	Refinement of product and related tasks Re-handling process

The intensity matrix in the Table 13 below specifies the differences between the tasks in Department B. As Tasks B1 and B2 work in the same control room and area, sharing a similar work role, the profile is also same, including high monitoring intensity, low routine manual task intensity that focuses only on supplies replacements and low quality-related task intensity. This indicates that B1 and B2 are primarily monitoring-oriented and require continuous observation of the production situation. However, disturbance handling occurs at moderate level in these tasks. Thus, the work is not only limited to passive monitoring but also involves reacting to abnormal situations and deviations when they occur.

Task B3 includes high routine manual task intensity and low monitoring intensity, which supports its classification as a primarily machine-paced task. It also includes moderate quality-related work, indicating that quality control is part of the role, even though monitoring is not dominant part of the task. Disturbance handling is classified as low, suggesting that the task is mainly shaped by routine execution and product or process handling rather than by frequent intervention in abnormal situations. However, disturbances occur and require involvement from the operator.

Table 13. Intensity matrix of performed tasks in Department B.

Task	Routine manual tasks	Monitoring	Quality-related tasks	Disturbance handling
B1	Low	High	Low	Moderate
B2	Low	High	Low	Moderate
B3	High	Low	Moderate	Low

In overall, the classification suggests that Department B contains a distinction between monitoring-oriented and machine-paced roles, which is explained by their different working areas and tasks. While Department B is post-processing line of the products produced by Departments A, C and D, Tasks B1 and B2 handles the product and B3 focuses on refining the product and re-handling it if needed. Thus, B1 and B2 represent supervisory-control oriented work profiles, while B3 represents more physically and temporally bound task profile. This distinction is important for understanding differences in work flexibility and the possibility to disengage from the immediate workstation during the shift. For example, a post-process line and control room where B1 and B2 are stationed require a constant presence of at least other of the operators, depending on situation. Preferably, the number of operators should be two most of the time, but light situations allow the other one to disengage from a task for a while.

4.1.3 Production tasks in Department C

Department C shows the most heterogeneous task profile among all the departments. The classification shown in the Table 14, suggests that production work in Department C cannot be described through one dominant work type, but rather through several different task profiles.

Tasks C1 and C7 were classified as high supervisory-control tasks with no significant machine-paced characteristics. These tasks are mainly connected to monitoring, process awareness and interpretation of process. C1 includes routine field checks, periodic quality checks and constant monitoring, while C7 includes handling the process supply and chemicals. Although these tasks are not classified as machine-paced, they require continuous awareness of the production situation.

Tasks C3 and C2 were classified as high machine-paced tasks with moderate supervisory-control characteristics. This indicates that these tasks are strongly tied to the rhythm of production but also include monitoring or process-following elements, mostly as quality-related matters. C3 includes also periodic sampling and constant monitoring, while C2 includes surface treatment. These tasks therefore combine direct production-related execution with the need to follow the process state. These tasks work as a work group from same control room with task C4.

Tasks C4 and C5, however, were classified as high machine-paced tasks with low supervisory-control characteristics. These tasks are more strongly connected to direct execution and the physical flow of process. C4 includes periodic sampling and regular material feeding, whereas C5 is connected to refinement of the product. In these tasks, the work is more dependent on timely execution than on continuous process interpretation.

Task C6 represents the most demanding combined task profile in Department C, as it was classified as high in both machine-paced and supervisory-control characteristics. The task includes surface material making, which makes it machine-paced but at the same time supervisory-controlled task. Another huge part of the task profile is regular material feeding. This means that the task requires both timely execution and continuous process awareness, but also physical field-tasks related to material feeding. Such a profile limits the operator's ability to disengage from the immediate work situation, because the task combines process-paced execution with monitoring responsibility.

Table 14. Production tasks in Department C classified to machine-paced and supervisory-control tasks and illustrative generalized tasks of each role.

Task	**Machine-paced tasks**	**Supervisory-control task**	**Illustrative generalized tasks**
C1	No	High	Periodic quality-checks Constant monitoring Change of product-type
C3	High	Moderate	Periodic sampling Periodic quality-checks Constant monitoring

			Change of product-type
C2	High	Moderate	Surface treatment Periodic sampling Periodic quality-check Change of product-type
C4	High	Low	Periodic sampling Regular material feeding
C5	High	Low	Refinement of product and related tasks
C6	High	High	Surface material making Regular material feeding Change of product-type
C7	No	High	Process supply handling Chemical handling

The intensity matrix demonstrated in the Table 15 supports this interpretation. C1 is characterized by low routine manual task intensity, but high monitoring and high quality-related intensity. This confirms its monitoring-oriented profile. C3 and C2 both include high routine manual task intensity, moderate monitoring intensity and high quality-related task intensity, indicating that these roles combine physical or routine execution with quality-related responsibility and process-following. C4 and C5 are more clearly machine-paced, as both include high routine manual task intensity, low monitoring intensity and low quality-related intensity.

C6 differs from the other machine-paced tasks because it combines high routine manual task intensity with high monitoring intensity. This supports its interpretation as a combined high-demand task profile. C7, in contrast, includes low routine manual task intensity and high monitoring intensity, while quality-related task intensity remains low. Disturbance handling is classified as moderate across all Department C tasks, suggesting that all roles require some readiness to respond to deviations or abnormal process situations. For some tasks such as C1, C3 and C2, disturbance situations emphasize the role and responsibilities.

Table 15. Intensity matrix of performed tasks in Department C.

Task	Routine manual tasks	Monitoring	Quality-related tasks	Disturbance handling
C1	Low	High	High	Moderate
C3	High	Moderate	High	Moderate
C2	High	Moderate	High	Moderate
C4	High	Low	Low	Moderate
C5	High	Low	Low	Moderate
C6	High	High	Low	Moderate
C7	Low	High	Low	Moderate

In overall, Department C have the widest variation of task profiles among all the departments. Some tasks are primarily monitoring-oriented, while some are primarily machine-paced. Some tasks also combine both dimensions. This variation is important for understanding job rotation and task allocation, because moving between roles in Department C may require employees to shift between substantially different physical, cognitive and temporal demands.

4.1.4 Production tasks in Department D

The classification of Department D, shown in the Table 16, indicates a task structure relatively similar to Department A. Tasks D1 and D2 are classified as high supervisory-control tasks with no significant machine-paced features. Therefore, these tasks are mainly characterized by monitoring and controlling the process and maintaining situational awareness. When the process is stable, the disengagement is possible for Tasks D2 to disengage for a while, if the other operator D1 of the same control room stays monitoring and controlling the process and has competence to perform both tasks.

Task D3 is classified as high machine-paced and moderate supervisory-control. This indicates that the task is primarily tied to the rhythm of production, while still containing monitoring or process-control elements at a moderate level. Tasks D4 and D5 are classified as high machine-paced tasks with low supervisory-control. These tasks are more strongly connected to direct physical execution and process-paced activity.

Table 16. Production tasks in Department D classified to machine-paced and supervisory-control tasks and illustrative generalized tasks of each role.

Task	Machine-paced tasks	Supervisory-control task	Illustrative generalized tasks
D1	No	High	Periodic quality-checks Constant monitoring Change of product-type
D2	No	High	Periodic quality-checks Constant monitoring Change of product-type
D3	High	Moderate	Periodic sampling Periodic quality-check Change of product-type
D4	High	Low	Periodic sampling Regular material feeding
D5	High	Low	Refinement of product and related tasks

The intensity matrix of Department D, shown in the Table 17, clarifies the differences between the identified task profiles. Tasks D1 and D2 are characterized by high monitoring intensity and low routine manual task intensity. They also include moderate disturbance handling, meaning that the work is not limited to observing the process, but also involves responding to deviations when necessary. Especially in D1 disturbance handling emphasizes the role. Also, the quality-related intensity is higher in D1 than in D2, where it stands on more moderate level.

Task D3 represents a mixed task profile. It includes high machine-paced routine manual task intensity, but also moderate monitoring, quality-related work and disturbance handling. Thus, D3 is not purely machine-paced task, even though it establishes a regular rhythm. Instead, the task combines physical routine execution with process-following and controlling responsibilities.

Tasks D4 and D5 are more clearly machine-paced tasks. Both include high routine manual task intensity and low quality-related task intensity. D4 is especially notable because

disturbance handling is classified as high, suggesting that the task may become demanding when the normal production flow is interrupted. Usually, the high disturbance handling in this position comes from regular failures in the equipment that needs correct actions from the operator. D5 includes low monitoring and moderate disturbance handling, which indicates that it must respond to disturbances when needed.

Table 17. Intensity matrix of performed tasks in Department D.

Task	Routine manual tasks	Monitoring	Quality-related tasks	Disturbance handling
D1	Low	High	High	Moderate
D2	Low	High	Moderate	Moderate
D3	High	Moderate	Moderate	Moderate
D4	High	Low	Low	High
D5	High	Low	Low	Moderate

In overall, Department D contains a clear distinction between monitoring-oriented and machine-paced production tasks. This distinction is important for understanding differences in work flexibility, because monitoring-oriented tasks appear to provide a broader overview of the process, while machine-paced tasks are more immediately tied to physical presence and timely execution. The intensity matrix also shows that the division of tasks is not absolute, as some tasks combine routine manual work with monitoring and disturbance handling. This is important for understanding work flexibility, because tasks with high routine manual intensity are more immediately tied to physical presence and timely execution, while monitoring-oriented tasks appear to provide a broader overview of the process. However, this does not directly mean that there is not an opportunity to disengage for a while from the task position.

4.1.5 Production tasks in Department E

Department E differs from the other departments, because the identified tasks were classified as high supervisory-control tasks with no significant machine-paced characteristics. Tabel 18 presents the categorizations. Both E1 and E2 are primarily supervisory-control tasks,

where the work is centered on observing and controlling the process, interpreting production information and maintaining readiness to intervene when needed.

Table 18. Production tasks in Department E classified to machine-paced and supervisory-control tasks and illustrative generalized tasks of each role.

Task	Machine-paced tasks	Supervisory-control task	Illustrative generalized tasks
E1	No	High	Process handling Raw material making Change of product-type Constant monitoring
E2	No	High	Process handling Refinement of product Constant monitoring

The intensity matrix, shown in the Table 19 below, highlights a clearly monitoring-oriented task profile in both tasks. Both E1 and E2 include high monitoring intensity and low routine manual task intensity. This supports the interpretation that work in Department E is primarily based on observing the process, interpreting production information and maintaining readiness to act, when necessary, rather than on continuous manual execution. When the process is stable, the disengagement is possible for one operator from both tasks E1 and E2 to disengage for a while, if the other operator stays monitoring and controlling the process.

The main difference between E1 and E2 concerns quality-related tasks. In E1, quality-related intensity is moderate, whereas in E2 it is low. This indicates that quality-related activities are more visible in E1, although they do not dominate the task profile. This difference comes from a diversity between the working areas. Operators in E1 are working in raw material production, while operators in E2 are refining the product. Both tasks include moderate disturbance handling, meaning that the work involves responding to deviations or abnormal process situations.

Table 19. Intensity matrix of performed tasks in Department E.

Task	Routine manual tasks	Monitoring	Quality-related tasks	Disturbance handling
E1	Low	High	Moderate	Moderate
E2	Low	High	Low	Moderate

Sometimes the job rotation crosses the departments, as some of the operators in Departments D and E have competence to work in both departments. This is relevant because the task profile of Department E differs from the more mixed profile of Department D. Moving between these departments may therefore require employees to shift between different task demands, especially between monitoring-oriented work and more machine-paced production tasks.

Overall, Department E appears to represent a primarily supervisory-control oriented work environment. The low routine manual intensity indicates that the tasks are less physically bound than the more machine-paced roles identified in other departments. However, the high monitoring intensity and moderate disturbance handling mean that the work still requires continuous process awareness and readiness to intervene when production conditions change, which often means to act physically in the field.

4.1.6 Time allocation between task categories

The time allocation data provides a complementary perspective to the task classification presented in the previous sections. While the task classification describes the nature of the work, the time allocation data illustrates the estimated share of working time spent on field-based tasks, machine-paced tasks and process monitoring. The data is shown in the Table 20 and is based on internal company material from 2022–2023 and is used here to provide a complementary view of the relative weight of different task categories in daily production work, not to produce an exact productivity measurement. It is also notable that in this data collection, Department B was included in Department C data material. Task E2 was also left outside of the data collection.

Field-based production tasks refer to tasks performed physically in the production area outside the control room. This category can also include checks, sampling, preparation activities and disturbance-related actions. These tasks can also be machine-paced. Unlike machine-paced and supervisory-control work, field-based work describes the location of the task rather than the underlying work logic.

Table 20. Time allocation data from the internal material of company.

Time allocation				
Department	**Tasks**	**Field-based tasks**	**Machine-paced tasks**	**Monitoring the process**
A	A1 A2	18 %	4 %	78 %
A	A3 A4 A5	11 %	13 %	76 %
C	C1	21 %	6 %	73 %
C+B	C3 C2 C4 C5 C6 C7 B1 B2 B3	11 %	18 %	71 %
D	D1 D2	19 %	4 %	77 %
D	D3 D4 D5	17 %	13 %	70 %
E	E1	32 %	3 %	65 %

The results show that monitoring the process accounts for the largest share of working time in all task groups included, ranging from 65% to 78%. Field-based tasks account for 11% to 32% of working time, while machine-paced tasks account for 3% to 18%. At first glance, the share of machine-paced tasks may appear relatively limited in terms of active task execution time. However, this does not mean that machine-paced work has only a minor influence on the role.

The reason is that machine-paced tasks might structure the work even when their direct execution time is limited. For example, a recurring task that must be performed at a specific interval may take only a limited number of minutes during a 12-hour shift, but it still requires the operator to remain available, anticipate the task and be present at the correct time. Therefore, the temporal binding effect of machine-paced work can be stronger than its percentage share of direct working time suggests.

This distinction is important for interpreting the findings. The time allocation data describes how working time is distributed between task categories, whereas the machine-paced classification describes how strongly a task constrains the operator's autonomy, timing and possibility to disengage from the immediate production situation. Thus, a role may have a relatively low percentage of machine-paced task execution, while it still is strongly shaped by machine-paced work characteristics.

In terms of time allocation, it is also necessary to consider the experience and perceptions of interviewees. In most tasks, that were classified as machine-paced, the interviewees usually described that the shifts differ often a lot from each other, but the common experience was to spend 50 % of time in the field-based activities and rest 50 % in the control room tasks. In the supervisory-control based tasks, including A1, A2, B1, B2, C1 and D1 the gut feeling was naturally more control room-based, such as descriptions 20 % of field-based work and 80 % of control room work, which reflects to the time allocation data. However, task E1 was described more as 50 % and 50 % share of field-based and control room-based work, even if its classified as supervisory-control task.

Overall, the time allocation data supports the interpretation that production work is dominated by process monitoring in terms of working time. However, the data also shows that field-based and machine-paced tasks remain important because they create temporal and

physical constraints within the shift. Sustainable work organization should therefore not be based only on the percentage share of active task execution, but also on how tasks structure availability, movement, attention and opportunities for proactive work.

4.2 Emergent themes from the interviews

This chapter introduces emergent themes from the interviews using abductive thematic analysis. A more accurate explanation of the analysis method is in chapter 3.5. The purpose of this section is to present the main recurring patterns that emerged from the employees' interviews. The analysis groups the results into broader themes that describe how the interviewees experienced the current division of labour, the functioning of the work cycle, the role of collective support and factors that increase or complicate the workload in practice. These emergent themes help interpret production work not only through formal task categories but also through employees' experiences of how the work is actually performed.

4.2.1 Team spirit as a resource

One of the clearest themes emerging from the interviews across all departments was the importance of the team spirit as a resource in everyday production work. The interviewees described production work as strongly dependent on cooperation, mutual support and the possibility to ask help from the others. Especially the situations, where tasks were demanding, rare or cognitively burdening came up. Teamwork was presented as a practical condition that supports continuity of work, problem solving and coping in everyday work, and not only as a social benefit.

The importance of mutual support was emphasized particularly in disturbance situations and other moments, where the normal workflow was interrupted somehow. Also, the situations where the production lines were shutdown for the maintenance was one example of the situations that an individual employee might encounter rarely in their current task. This was highlighted especially when the employee was inexperienced working in abnormal situations in the current task. In such situations, the possibility to rely on colleagues' experience, know-

how and assistance was perceived as highly valuable asset. The interviewees also linked good team spirit to flexibility in the shift, because it made it easier to divide tasks and react to the changing situations in the production line or change in the production lines' personnel in the middle of shift – meaning the situations, where the production line employee with maintenance expertise has to leave his/her position for maintenance-related tasks and other employees' has to cover the task.

In addition, the interview material suggests that the significance of team spirit is connected to the current work structure and job rotation. The work organization in case company demands broader range of task expertise than before and when work roles are broad and certain tasks are performed only occasionally by individual, employees cannot always rely only on their own memory or routine. In these cases, asking from others or discussing and thinking in a group to solve the problems becomes an essential part of getting the work done.

Sometimes, the expertise of tasks extends across departments. This is especially emphasized between departments D and E, where the cross-functional competence occurs a lot. Also noticeable is, that employees working in the Tasks D1 and D2 are in the same control room as the two employees assigned to the Task E1, which makes it possible to ask for help across departments, if there are multi-skilled employees present.

Teamwork functions as a positive feature of the work community and especially in the shiftwork, where everyone has an important task in operating the production line. Important resource is also the possibility to ask help, that compensates the limits of individuals memory, uneven frequency of the job rotation and possible weakening of role-specific expertise. However, the reverse side is negative team spirit, which affect also a lot in the shift dynamics and performance in work. Although it did not raise up in the interviews as a challenge, interviewees described the possibility of negative team spirit influencing the well-being at the work, comfort, performance and motivation.

4.2.2 Job rotation perceived both pleasing and burdensome

Another clear theme that emerged from the interviews was the job rotation, which was seen as contradictory by the interviewees. They did not describe the job rotation only as beneficial

or problematic. The perceived value of the job rotation was instead depending on the scope of the tasks employees are rotating and how many different tasks they were expected to perform within the rotation system. Thus, job rotation was experienced both meaningful and burdensome.

The relatively narrow job rotation was generally described positively across the departments. The collected data from the interviews suggests that when the number of rotation tasks remained limited, employees were better able to maintain deep expertise in the tasks, keep track of changes in their operating area and approach problem-solving with better confidence and know-how. However, in smaller departments such as B and E, the rotation covers only 2-3 tasks, and this arrangement was perceived as functioning well and mainly as a positive feature of the work organization. The interviewees associate this type of rotation with stronger self-confidence as the expertise is better, smoother daily work and more pleasant work experience overall. It was also noted as positive feature that when there are multi-skilled personnel with expertise in different tasks, it improves teamwork and flexibility, and it is easier to ask a colleague for help in an abnormal situation.

At the same time, the findings indicate that broader job rotation was often experienced as burdensome. When employees were expected to rotate across many tasks or roles, the work was described as less predictable and more difficult to manage. The interviewees associated broad rotation with weaker continuity in everyday work, greater difficulty in staying up to date in each position, and a reduced sense of control over demanding tasks. In this sense, the burden of job rotation was not related only to the number of tasks itself, but also to the difficulty of maintaining sufficient familiarity and confidence across a wide range of responsibilities.

Interviewees working as supervisors emphasized the importance of individual-centered development in terms of job rotation. Characteristics of employees were highlighted as an important factor in affecting the capacity to handle many roles. This included, for example, the personality, age, motivation, skills and activity of individuals. It was noted that some structure is worthy to have, but instead of forcing everyone to fit into same frame, the job rotation and expertise in many work tasks should focus more on individuals than groups.

Therefore, the interview material suggests that the job rotation cannot be evaluated only in general terms. Its effects appear to depend on the balance between scope and continuity.

While limited rotation supports flexibility and makes work more meaningful, too extensive rotation structure reduces employees' sense of mastery and makes every day work more demanding. This makes the job rotation an important organizational issue, as it influences both the distribution of skills between roles and employees' experience of how manageable their work is.

4.2.3 Perceived weakening of the deep expertise

A third theme identified in the interviews was the perceived weakening of deep expertise. This theme was closely connected to broad job rotation, which was discussed in chapter 4.3.2 above and to the increasing number of different tasks that employees were expected to handle. The interviewees described, that when the range of responsibilities became too wide, it was more difficult to maintain strong role-specific competence.

Broad rotation was perceived to weaken deep expertise in several ways by both personnel groups of production operators and supervisors. First, long periods between performing the same task reduced routine and confidence. Some interviewees described situations, where they might return to a task only after a long break, which made the work feel less familiar than before. Long periods between working on a single task weakens routines and increases uncertainty, which highlights especially in more demanding tasks, such as A1, C1 and D1, which were considered in many interviews as most difficult task mostly because of that reason. This was perceived as increasing the cognitive load associated with remembering and mastering task-specific details and reorienting to role-specific demands. The weakening of deep expertise was also linked to perceived mental strain. In more demanding tasks, uncertainty about individuals own competence increased the cognitive burden of the work. Instead of relying on strong routine and familiar ways of working, employees have to spend more effort on remembering details, checking on how tasks should be done especially in the rare situations and reorienting themselves to the role.

Common experience was that demanding tasks were not given enough repetitions or time to master them and perform in those positions in the way the work requires or the individual wants. This was especially a concern across all departments for newer or more inexperienced employees, who are expected to learn and master tasks at a very fast pace without the opportunity to develop deeper expertise. Also, asking from the colleagues increased, which

was perceived as burdensome, as it increases the workload of the person being asked constantly. In some situations, a more experienced employee must watch and advise a more inexperienced employee, who has not been much in that position or has been having a long break being in other tasks, which is also perceived as burdensome, given also the increased workload generally.

Furthermore, interviewees suggested that very broad job rotation could reduce employees' sense of ownership and dedication over a specific task area. When there was little focus on one role for a longer period of time, there was also less opportunities or motivation to develop that area further. The findings suggest in this sense, that while extensive job rotation can improve task coverage, it also reduces the depth of expertise needed to perform tasks confidently and smoothly. It was also noted that dedication to tasks was reduced when the job rotation was extensive.

4.2.4 Increasing workload

Fourth identified theme in the interviews was the perception of increasing workload. Across the interview material, employees described a general development in which the amount of work had increased over time. This was not linked into one single change, but to a gradual increase in tasks and responsibilities in production work.

Central concern raised by interviewees was that some task positions had been reduced, while the work itself had not decreased accordingly. As a result, duties and tasks that had previously been shared by larger group, are now handled by fewer number of employees. This appeared especially in Departments B and D and somehow in Department C. The interviewees described this as making everyday work more demanding, especially during shifts where several responsibilities and tasks had to be managed at the same time.

The perception of increasing workload was also related to the broader division of labour in the production environment. According to the interviewees, production personnel have gradually been given more tasks such as various inspection rounds and sampling, expanding their scope of work. However, these expanded responsibilities did not appear in every role. This was perceived to be development direction, that reduces the time what is available for main production tasks and makes the shifts feel more intensive. It was also closely related

to the amount of time maintenance-expertise employees spend in their maintenance tasks during production, which is later discussed more in chapter 4.3.5.

Another issue that came up is that personnel often operate understaffed, which automatically leads to increased workload of other employees. This was a concern especially in Department A, where the operating understaffed particularly burdens Task A1. It was also noted that it leads to situations, where it becomes almost impossible to maintenance-specialists to perform maintenance tasks if there are any, as there are not enough employees to perform production tasks. Increased workload was closely related to the amount of time maintenance-specialists spend on their maintenance tasks, with increased working hours.

Same issue raised up in Departments C and D also. In Department E, it was noticed, that when the department is operating understaffed, many of the work tasks that needs to be done in the field is not done, as the department requires constant presence for process monitoring and controlling. This also increases the cognitive load, as the supervisory-control of process is continuous without any variation in work tasks. Usually this happens when one of the two employees is on maintenance-specialist and doing maintenance tasks.

Few interviews also noticed maintenance shutdowns as more demanding and burdening situations. Shutdowns can be scheduled or unplanned situations, often with time-pressure. Usually shutdowns require rarely done tasks, and uncertainty or inexperience performing those tasks leads to increasing workload.

The interview material suggests that the increasing workload is not only experienced as an increase in workload, but also as managing a wider mix of tasks within the same shift, as a result of increased work tasks and a small number of personnel in production line. Therefore, the workload is experienced as increasing because the same teams are expected to handle more responsibilities with decreasing personnel and without corresponding increase in time.

4.2.5 Maintenance-related matters

A fifth theme emerged from the interviews is maintenance-related matters. This theme did not focus primarily on equipment failures themselves, but on the everyday relationship between production work and maintenance-related responsibilities. Interviewees described maintenance as an important part of the production environment.

One issue that was raised in the interviews was the extensive use of operators with maintenance-expertise in maintenance tasks during the shifts. These employees are often taken away from the production line duties to handle maintenance work, which means that their production role have to be covered by other employees. Thus, maintenance-related work affects a lot into how production work is organized in practice.

The interviewees also suggested that frequent and lot of time taking involvement in maintenance-related tasks could weaken deep expertise in production tasks. When employees spend a large amount of time in maintenance tasks, they have fewer opportunities to remain fully engaged in their regular production tasks. This was described as a challenge particularly in environments, where operators were expected to maintain competence in several production tasks at the same time. At the same time, it was described that this issue does not appear when maintenance tasks are performed in their own departments, instead it was seen as strengthening the expertise.

Another highlighted issue was preventive maintenance, which has become a new task for operators with maintenance-expertise. However, due to the personnel resources, carrying out preventive maintenance has been found to be challenging, as it is time-consuming and operators have their own production tasks and often other maintenance tasks during the shift. Interviewees described that there is no time or opportunity to carry out preventive maintenance tasks.

In addition, the interview material from the maintenance-specialists indicates that the practical conditions for maintenance work are not always seen as satisfactory. Problems related to the availability of tools and spare parts were mentioned as factors that complicated maintenance-related activities and reduced the smoothness of work, thus increasing the time that was used in the maintenance tasks sometimes with hours. Another thing which was experienced as a challenge was the maintenance tasks in the departments or with the equipment that were not familiar and again, it increased the time-use a lot.

At the same time, the presence of a shift maintenance engineer was described in positive terms, suggesting that accessible technical support was seen as a clear and strong resource in everyday work, which also reduces the time used in maintenance tasks. It was also perceived as supporting part of the supervisors' daily work.

Another emerged maintenance-related issue was communication and organization of work between shift and day maintenance team. Interviewees described that the maintenance-expertise operators were meant to handle troubleshooting tasks during the shifts, although this was not the original intention. The support and help from day maintenance remained limited, but there were also differences between departments. In the current situation the maintenance-expertise operators are used more and more in the maintenance shutdowns sometimes across the departments and in the equipment failure situations, what belonged before to the care of day maintenance teams, despite having their own production tasks and maintenance-related duties during the shifts. This is perceived to increase the workload of everyone working on the production line and to cause problems in maintenance work.

In overall the findings suggests that maintenance-related matters form an important theme, because of the close connection between maintenance and production creates practical challenges for the continuity of the roles, maintaining the competence in tasks and the daily organization of work.

4.2.6 Equipment failures and disturbances

A sixth theme that emerged from the interviews concerned equipment failures and disturbances. Unlike the previous maintenance-related theme in chapter 4.3.5, the focus here is not on the division of labour between production and maintenance, but on the direct effects of technical problems and process disturbances on daily work. These situations were described as an important part of the reality of production work.

The interview material shows that equipment failures were seen as disrupting normal work and making it more difficult to perform tasks as intended. When the equipment does not function properly, operators have to shift attention from routine work to problem identification, coordination and corrective action. Sometimes it means bigger changes such as shutdown of production line, which causes more action, time-use and demanding work. Same happens when disturbances occur in the process or the quality of the product. Thus, disturbances interrupt the expected flow of the work and change the nature of the shift.

Disturbances and equipment failures also are experienced as increasing workload. This was not described as general increase in the amount of work, but as situational intensification of

task demands. Disturbance situations require quick responds, managing the uncertainty and making practical decisions, sometimes under unstable conditions and pressure. These indicators make such situations more demanding than routine and stable work.

Interviewees also highlighted the personnel resource shortages of day-time maintenance employees. As they are not usually available to do reactive maintenance tasks, disturbances and equipment failures are most often and increasingly handled by shifts maintenance-expertise operators, which in turn increases the workload of operators and production tasks.

General impression of the interviewees was that the equipment failures have increased. Some suggested that an important factor causing that could be a lack of preventive maintenance. Another problem raised was that some equipment faults last for long periods, sometimes months, without being fixed and you just have to live with them. This automatically leads to a large increase in workload and sometimes production challenges. Some of the equipment problems were described as turning from a failure into the new normal.

At the same time, interviewees highlighted the importance of maintenance in preventing and resolving these kinds of situations. This suggests that the importance of maintenance is reflected not only in planned maintenance tasks but also in the ability of the production lines to cope with technical failures and restore the normal operating conditions. This matter highlighted the importance of operators with maintenance-expertise and their ability to resolve technical disruptions and equipment failures to keep production running. Used time was perceived to be related a lot to the current situation they are handling. Different skills, especially in electrical and automation specialists, were highlighted also, as some of the disturbance situations demand special skills. In this matter it was also emphasized that external companies can have a big role also in resolving challenging problems by cooperating with production operators, operators with maintenance-expertise and supervisors.

These findings suggest that equipment failures and disturbances are important because they are exposed to how strongly daily production work depends on technical reliability. When that reliability is disrupted, the work becomes more fragmented, more reactive and more demanding for the operators.

4.3 Summary of empirical findings

The empirical findings show, that if the production work in the case company is observed only through separate task lists or interview themes, it gives a limited view on the production roles. Instead, the findings describe production work as a work system in which task structures, operator roles, process information, technologies and organizational support conditions are closely related. From the perspective of Work System Theory, the findings can therefore be summarized through the relationship between processes and activities, participants, information, technologies, infrastructure and the organizational environment.

From the perspective of processes and activities, the findings show that production work consists of several partly overlapping task categories. The task classifications and time allocation data show that production work consists of different task profiles. Some roles are primarily supervisory-control oriented, some are more strongly machine-paced and some combine both characteristics. The time allocation data showed that process monitoring accounted for the largest share of working time in the examined task groups. However, this does not mean that machine-paced tasks have only a minor role in the work system. Even when their direct execution time is relatively limited, recurring machine-paced tasks structure the whole shift by requiring timely presence, preparation and readiness to act at correct time.

From the perspective of participants, the findings highlight the importance of role-specific competence, teamwork and job rotation. Team spirit appears as an important resource in daily work, especially when operators need support in abnormal or demanding situations. At the same time, job rotation supports flexibility but also makes it more challenging to maintain deep role-specific expertise, when the rotation is too wide. Limited rotation was generally perceived as positive, because it supports task variation and flexibility, whereas broader rotation is associated with weaker role-specific deep expertise, reduced confidence to act and greater difficulty in staying up to date across multiple task areas. However, the importance of individuals skills, abilities and motivation was highlighted.

From the perspective of information and technologies, production work is strongly dependent on process monitoring, interpretation of information and timely response to deviations. Supervisory-control tasks require operators to maintain awareness of the process state and to recognize when intervention is needed. Equipment failures and disturbances

make this dependency especially visible. During disturbances, work shifts from planned task execution toward diagnosis, coordination and corrective actions. Therefore, technical reliability and availability of relevant process information are central conditions for smooth production work.

From the perspective of customers and products, the findings show that production work is ultimately connected to maintaining reliable output, product quality and continuity of production. Although customers are not directly present in the daily production work, the customer requirements and feedback are reflected indirectly through quality expectations, production priorities and the need to ensure stable process performance. The product itself is also closely connected to the organization of work, because quality-related tasks, monitoring, disturbances and timely field-based activities all influence the ability to produce consistent output.

From the perspective of infrastructure and organizational environment, the findings show that production work is shaped by personnel, maintenance support, tools, spare parts and the practical organization of shift work. Maintenance-related matters are not separate from production work, because process operators with maintenance-expertise are often needed for maintenance tasks during the shift. This affects task coverage, workload and the possibilities for performing proactive work. When personnel are limited, or maintenance-related work increased, the same work system have to absorb additional responsibilities with fewer available resources.

From the perspective of strategies, the findings demonstrate that production work depends on how key support functions, such as maintenance, competence development and shift-level resource allocation, are organized to support daily operations. The organization of maintenance task and duties are strategically important, because maintenance support, preventive maintenance practices and the availability of employees with maintenance-related expertise directly affect production continuity, workload and the ability to respond to disturbances. The future work organization should be based on an understanding of both task content and the wider work system conditions that support operational reliability, continuity and employee well-being, as the findings suggests.

Table 21 below summarizes the key empirical findings from the perspective of Work System Theory and the supporting theoretical perspectives used in this thesis. It shows that the key

findings are connected to several elements of the work system rather than only to isolated tasks.

Table 21. Summary of key empirical findings from the perspective of the Work System Theory and the supporting theoretical perspectives.

Key empirical finding	WST perspective	Supporting perspective
Team spirit supports operators work	Participants / environment	Workload
Job rotation supports flexibility and is pleasant, but increases demands if too broad	Participants / activities / strategy	Cognitive demands / competence
Importance of deep role-specific expertise affecting confidence, routines and process understanding	Participants / information	Situation awareness / competence
Workload increases when tasks overlap, disruptions occur, or responsibilities become fragmented.	Activities / participants	Workload / cognitive demands
Maintenance-related responsibilities affect how production roles can be performed in practice	Activities / infrastructure / strategy	Coordination / work system alignment
Equipment failures and disturbances make work more reactive and reduce opportunities for proactive work	Technologies / activities	Workload / situation awareness
Sustainable work organization depends on alignment between tasks,	Whole work system	Work system alignment

competence, information, technologies and resources.		

Overall, the empirical findings suggest that sustainable work organization depends on alignment between task structures, operator competence, process information, production technologies and supporting resources. The central issue is not only how individual tasks are divided between roles, but how the production work system enables operators to manage routine work, monitoring, field-based tasks, disturbances, maintenance-related responsibilities and development of competence in a balanced way. These findings provide the basis for the following discussion chapter, where the implications for workload, autonomy, proactive work and sustainable work organization are examined in relation to the theoretical framework.

5 Discussion

This chapter discusses the empirical findings in relation to the theoretical framework and the research questions of the thesis. The purpose is not to repeat the empirical results presented in Chapter 4, but to interpret what they indicate about the nature of production work, workload, autonomy and sustainable work organization in a continuous process industrial environment. The discussion focuses on how machine-paced tasks and supervisory-control work co-exist in production roles, how this affects the practical possibilities for monitoring and proactive work, and how the organization of work can support a more sustainable division of work.

5.1 Interpreting production work between machine-paced and supervisory-control work

The empirical findings show that production work in the case company cannot be interpreted as a simple division between machine-paced tasks and supervisory-control tasks. Instead,

the examined roles form different combinations of these two dimensions. Some roles are primarily monitoring-oriented, some are strongly tied to the physical rhythm of the production process, while some combine both characteristics. From the perspective of Work System Theory, this means that the nature of production work cannot be understood by examining individual tasks separately. The tasks must be interpreted as part of a broader work system in which processes and activities, participants, information and technologies interact with each other.

The task mapping and time allocation results indicate that process monitoring forms a central part of production work across the examined departments. However, monitoring does not appear as a passive activity. Rather, it is connected to the operator's responsibility to follow process information, maintain awareness of the production situation and remain ready to intervene when deviations occur. Therefore, supervisory-control work can be interpreted in WST terms as an activity structure in which participants rely heavily on information and technologies to maintain the continuity of the production process. This supports the theoretical view that automation does not remove operator work but changes its nature by shifting the emphasis from direct manual control towards monitoring, interpretation and intervention readiness (Bainbridge, 1983, p. 775; Pütz et al., 2024, pp. 801–802).

At the same time, the findings show that machine-paced and field-based tasks continue to shape production work even when they do not represent the largest share of total working time. Some tasks require physical presence, timely execution and coordination with the rhythm of the production process. Therefore, their significance should not be evaluated only by the duration of performed task. A task with a relatively limited time share might still strongly affect the work system if it restricts the operator's ability to leave the workstation, allocate attention to monitoring or perform proactive work. This finding highlights the importance of analysing not only how much time tasks require, but also how they structure the relationship between participants, activities and technologies.

The central issue from a WST perspective is therefore not whether a role is purely machine-paced or purely monitoring-based. Rather than that, the important question is how different task types are combined within each role and how this combination affects the functioning of the work system overall. Roles with high monitoring intensity are strongly dependent on information flows, automation systems and process displays. Roles with high machine-paced intensity are more directly tied to physical tasks, material flows and the temporal rhythm of

production. The most demanding roles appear to be those that combine both dimensions, because they require operators to maintain process awareness while also performing time-bound physical activities.

From the perspective of situation awareness, the monitoring-oriented roles are not passive even when visible manual activity is limited. Operators must perceive relevant process information, understand its meaning and anticipate how the process may develop. This makes supervisory-control work cognitively demanding, particularly when disturbances, product changes or abnormal situations occur. The findings are therefore consistent with the idea that operator work in automated systems depends on maintaining situation awareness over time rather than merely reacting to individual alarms or performing predefined tasks (Endsley, 1995, pp. 36–37).

This interpretation also shows why production work cannot be fully understood through formal job descriptions alone. Formal role descriptions indicate what operators are responsible for, but they do not necessarily show how work is actually performed in interaction with process conditions, technologies and other participants. The empirical findings suggest that the practical content of production work emerges from the alignment between activities, human participants, information and technological systems. When this alignment is strong, operators are better able to monitor the process, coordinate with others and respond to deviations. When the alignment is weaker, work may become more fragmented, reactive and dependent on individual experience.

Thus, the findings refine the distinction between machine-paced and supervisory-control work. In the studied production environment, these categories should not be treated as separate types of work, but as interrelated dimensions of the same work system. Supervisory-control work describes the dominant monitoring and interpretation responsibility of many roles, whereas machine-paced tasks describe the physical and temporal constraints that continue to structure the work. This provides a more accurate basis for discussing workload, autonomy and proactive work in the following section.

5.2 Implications for workload, autonomy and proactive work

The findings suggest that workload, autonomy and possibilities for proactive work should be interpreted as outcomes of the work system, rather than as characteristics of individual tasks alone. Perspective from WST shows that these issues emerge from the interaction between processes and activities, participants, information, technologies and the organizational environment and strategy. Therefore, the workload experienced in production work is shaped by how different tasks and responsibilities are combined within the same shift, how work is distributed between roles, and how disturbances, maintenance-related responsibilities and technical reliability affect the continuity of work. Same perspective is supported by the perspective of WST; the workload is not only a matter of task quantity or duration, but it is shaped by alignment between activities, participants and organizational support, especially when maintenance-related responsibilities, disturbances and reduced personnel require operators to manage several overlapping demands within the same shift.

Workload in production work is also influenced by both monitoring-based tasks and time-bound activities performed in the field. Although process monitoring formed a large part of the observed time allocation as the data shows, the interviews showed that machine-paced tasks, disturbances, maintenance-related issues and product changes might create uneven and situation-dependent workload. This means that workload is not evenly distributed over time. Routine operation may include periods of relatively stable monitoring, while disturbances or concurrent tasks might increase both physical and cognitive demands for operators. Thus, workload is connected to the temporal structure of the work system: how tasks occur, overlap and interrupt each other during the shift.

Autonomy is similarly affected by the structure of the WST. In roles where the operator must remain physically close to the workstation or respond to production rhythm, practical autonomy is limited even if the total amount of active manual work is not high. In the other hand, roles with more flexible task structures might allow operators to allocate attention to observation, preparation or improvement activities more easily. Autonomy, however, in this context does not mean independence from the production process. It refers to the operators practical possibility to decide when and how attention can be moved between monitoring, field tasks, communication and proactive actions without weakening production continuity.

The role of participants is central. The findings related to job rotation and perceived weakening of deep expertise show that workload is partly connected to competence and role familiarity. Job rotation might support flexibility and shared understanding between roles, but it may also increase cognitive demands if operators are required to maintain competence across several positions with different task structures, technologies and process responsibilities. From a WST perspective, this indicates that this alignment between participants knowledge, skills and assigned activities is an important condition for sustainable workload. If the work system requires broad flexibility but does not sufficiently support the development and maintenance of role-specific expertise, the burden falls on individual operators. Thus, it can be seen also as a problem in organizations' chosen strategy.

Information and technologies further shape both workload and autonomy. Monitoring-oriented work depends on process data, alarms, control systems and other information sources such as quality values, that supports situation awareness and decision-making. When these information flows are clear and timely, they can support proactive work by helping operators detect deviations early, anticipate upcoming tasks and coordinate their actions with others. However, if information is fragmented, delayed or difficult to interpret, supervisory-control work might become more reactive. This situation reduces operators' autonomy, because attention is directed towards responding to immediate problems rather than planning or preventing them.

The possibility for proactive work depends on more than the availability of time. Proactive work requires that operators have sufficient process awareness, access to relevant information, practical freedom to leave immediate routine tasks when needed and coordination with other roles in the production line. The findings suggests, that disturbances, maintenance-related issues and machine-paced tasks reduces these possibilities by tying operators to immediate production demands. At the same time, strong team spirit and shared practical knowledge can function as resources that helps maintain production continuity and create space for anticipatory actions.

Overall, the findings show that workload, autonomy and proactive work are closely connected to the alignment of the work system. If activities, roles, information flows and technologies support each other, operators have better possibilities to maintain situation awareness, coordinate work and act proactively. If this alignment is weak, work becomes

more reactive and dependent on individual experience. This interpretation provides the basis for discussing sustainable work organization in the following section.

5.3 Implications for sustainable work organization

The findings discussed in sections 5.1 and 5.2 indicate three critical lessons for sustainable work organization in continuous process production. First, time allocation does not fully show how demanding or restrictive a task is. Some tasks take relatively little time but strongly affects the shift because they require immediate response, physical presence or preparation at a specific moment. Secondly, monitoring capacity is easily underestimated if it is interpreted as an available time for additional work. In this study, monitoring appeared as an active responsibility that requires attention, interpretation and readiness to intervene. Thirdly, the sustainable work organization depends on strongly how disturbances, maintenance-related responsibilities and development of competence are handled within the same whole work system. From the perspective of Work System Theory, these findings show that the sustainable work organization is not only a question of task redistribution, but of how activities, participants, information, technologies and organizational conditions support each other in daily production work (Alter, 2013). In the context of this thesis, this means that the division of work should be evaluated through its effects on monitoring capacity, role-specific competence, autonomy, disturbance handling and opportunities for proactive work, rather than solely through the tasks performed or the time required.

First implication concerns the use of time allocation data in work design. The empirical findings show that time allocation provides an important basis for understanding production work, but it does not alone explain the practical demands of different roles. Some performed tasks require only a limited share of total working time, but still strongly structure the shift because they require timely presence, preparation or immediate response. Therefore, sustainable work organization should consider both the amount of time spent on different task categories and how these tasks limit the operator’s attention and movement during the shift. This is especially important in tasks where monitoring responsibility and machine-paced or field-based tasks overlap.

Second implication is that monitoring and supervisory-control work should be recognized as work in itself. In continuous process production, monitoring is not simply waiting or passive observation. It involves maintaining situation awareness, interpreting process information, following production conditions and remaining ready to intervene when deviations occur. If monitoring-oriented time is interpreted as available time for additional tasks, the cognitive and operational importance of supervisory-control work might be underestimated. For sustainable work organization, this means that the division of work should leave sufficient capacity for observation, anticipation and early responses, not only for visible manual task execution.

Third implication concerns proactive work. The findings indicate that proactive work depends on more than the formal availability of time. It requires sufficient personnel, clarity on roles, access to relevant information, practical freedom to move between task areas and a work rhythm that allows operators to act before problems develop into disturbances. When operators are tied to immediate production demands, maintenance-related tasks or disturbance handling, it makes proactive work more difficult. Therefore, sustainable work organization should not treat proactive work as an additional activity that can simply be added to existing responsibilities, instead it should be understood as an outcome of a work system that provides enough practical capacity, competence and coordination for anticipatory action.

Fourth implication relates to job rotation and competence. The empirical findings show that job rotation can support flexibility, task variation and shared understanding and knowledge between roles. However, broad job rotation may also weaken deep role-specific expertise, if operators do not spend enough time in particular positions to maintain confidence, routine and detailed process knowledge. From the perspective of sustainable work organization, job rotation should therefore be designed as a balance between flexibility and expertise. Limited and well-structured rotation might function as a resource, whereas overly broad rotation may increase cognitive demands and reduce the development of ownership over specific task areas. However, it is important to note that operators should be evaluated as individuals, and everyone has their own abilities and capacity to absorb tasks, skills and competence.

Fifth implication concerns the relationship between production and maintenance. Maintenance-related responsibilities and disturbances appear as important factors that shape the actual organization of production work. When operators with maintenance-expertise are

frequently required to handle maintenance-related tasks, their regular production roles must be covered by others or left with reduced attention. This affects workload, task continuity and the possibilities for proactive work. Therefore, maintenance should not be treated as an external support function that is separate from production work. Instead, the production-maintenance interface should be understood as part of the same work system, because technical reliability, maintenance support and disturbance handling directly affect the functioning of the production roles.

The findings also suggest that technical reliability is a central condition for sustainable work organization. Equipment failures and disturbances make work more fragmented, reactive and demanding. In such situations, operators are forced to shift attention from routine monitoring or planned tasks to diagnosis, coordination and corrective actions. This indicates that sustainable work organization should be understood through the ability of technical and organizational infrastructure to support stable production, rather than solely through the allocation of tasks between employees. Preventive maintenance, availability of tools and spare parts and accessible technical support can therefore be interpreted as resources that support the equipment reliability and sustainability of production work.

From the perspective of customers and products, sustainable work organization is also connected to maintaining production continuity and product quality. Although customers are not directly present in the daily production work, their requirements are reflected through quality expectations, production priorities and the need for stable output. This means that the organization of work should support both internal sustainability and external performance. If workload becomes too reactive or the role-specific competence weakens, the effects may not remain limited to employee well-being but might also influence production stability, quality control and responsiveness to deviations.

Safety emerges also from the findings, although it was not examined as a separate research question. Several findings are closely connected to the conditions that enable safe work. Sufficient monitoring capacity, role-specific competence, clear coordination between roles, technical reliability and opportunities for proactive work all support the operator’s ability to maintain situation awareness and respond to deviations. In the other hand, increasing workload, fragmented responsibilities, disturbances and weakened deep expertise may reduce the practical capacity to observe, anticipate and intervene in time. Therefore, sustainable work organization should also be understood as a foundation for safe work: when

the work system supports stable production, clear responsibilities and proactive action, it also strengthens the conditions for maintaining safety in daily operations.

These same conditions also support product quality and production continuity. Stable production, sufficient monitoring capacity and timely responses to deviations help prevent quality-related problems before they affect the final product. Similarly, production continuity depends on the work system's ability to support operators in monitoring the process, identifying deviations and responding to disturbances in a timely manner. In this thesis, safety, product quality and production continuity are therefore interpreted as context-specific outcome dimensions of a well-functioning production work system. They do not replace Alter's (2013) original Work System Theory framework but specifies what the outcomes of supportive work system means in the context of continuous process production. Figure 6 illustrates the outcomes of WST.

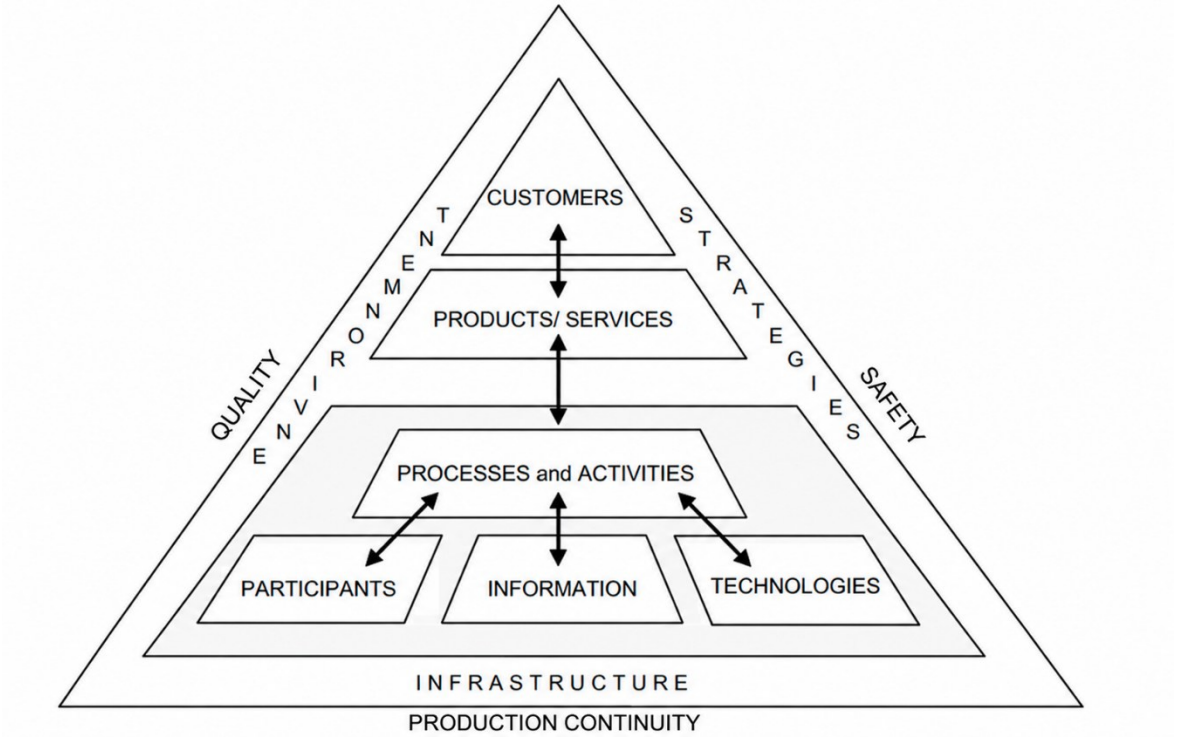

Figure 6. Work System Theory framework and added key outcomes supported by a well-functioning work system in the context of this thesis.

The theoretical implication is that when Work System Theory is used in continuous process production, the outcomes of the work system should be defined more broadly. In this thesis, safety, product quality and production continuity are interpreted as important outcomes of a well-functioning production work system. In this setting, the relevant outcomes of the work

system are not limited to immediate product or service but also include the conditions through which the production system remains safe, stable and quality-oriented. This does not challenge the original WST framework but shows how its outcome logic can be made more explicit in safety-critical and continuity-dependent production environments.

Overall, the findings suggest that sustainable work organization should be based on the alignment of the whole work system rather than on isolated task redistribution. The key issue is whether task redistribution results in a work system that supports monitoring, competence, coordination, technical reliability and proactive work, rather than merely whether individual tasks can be moved between roles. This interpretation provides a basis for answering the research questions in the conclusion chapter, where the empirical findings and theoretical discussion are synthesized into the main conclusions of the thesis.

5.4 Limitations of the study

This thesis has several limitations that should be considered when interpreting the findings. The first limitation concerns the scope of the empirical setting. The thesis was conducted in one process industrial site and focused on production work within the specific organizational and technological context of the case organization. Therefore, the findings should not be interpreted as statistically generalizable to all process industrial environments. The contribution of the study is analytical, as it provides a structured interpretation of how production work, time allocation and work organization can be examined in a continuous process production context. Furthermore, although the thesis included most of the production roles in the interviews, the number of participants representing each role was limited, which restricts the depth of role-specific interpretation. Findings related to job rotation it is also worth noting that the job rotation itself is fairly new thing in case company. In some departments it has been operating for a longer time and in others it is still in progress. Changes in personnel has also been affected to the progress of job rotation.

Second limitation is the nature of the time allocation data. The task mapping and time allocation analysis provides an important overview of how production work is distributed between different task categories. However, the data does not cover all short-term variations,

interruptions or unexpected situations occurring during the shifts. In continuous processes, workload might rapidly change depending on disturbances, product changes, maintenance needs and other situational factors such as production line shutdowns. Therefore, the time allocation results should be interpreted as a general representation of task structure rather than as an exact measurement of every moment of work.

Third limitation relates to the interview data. The interviews provided valuable insights into how operators and supervisors perceive workload, job rotation, maintenance-related issues and the current division of work. However, interview data is based on participants' experiences and interpretations, and the number of interviewees per each production role was limited. Therefore, the role-specific findings should be interpreted with caution, as they do not provide the full variation of experience within each task or department. The findings are most useful for identifying recurring themes and work system-level implications rather than making strong conclusions about every individual role. In addition, it does not directly measure mental workload, situation awareness or physiological strain. As a result, the findings concerning workload and proactive work should be understood as perceived and work system -related implications, rather than as objective measurements of individual cognitive load.

Fourth limitation concerns the level of analysis. This thesis intentionally examines production work at the level of tasks, roles and work organization. It does not evaluate individual performance or make claims on personnel-related optimization. This is also deliberate limitation of the study, because the purpose was to understand the structure and nature of production work, and not to assess individuals. Consequently, the findings are most useful for discussing principles of sustainable work organization.

Fifth limitation is connected to the theoretical framework. Work System Theory provides an useful structure for interpreting production work as an interaction between processes, activities, participants, information, technologies and organizational conditions. However, WST itself does not provide detailed measures for the workload, situation awareness or human performance. For this reason, the theoretical interpretation was supported by concepts of human factors, supervisory-control work and situation awareness The use of WST should therefore be understood as an analytical framework for structuring the discussion, not as a complete explanatory model for all cognitive and organizational aspects of production work.

Finally, the thesis is cross-sectional in nature. The findings describe the production work and perceived organizational conditions at the time of data collection. Since production environments, technologies, personnel practices and maintenance arrangements might change over time, future research could benefit from longitudinal data or repeated analysis after organizational or technological changes. Such research could provide a deeper understanding of how changes in work organization affect workload, competence development, monitoring capacity and opportunities for proactive work.

6 Conclusions

This thesis examined the nature and time allocation of production work in a continuous process industrial site. The aim was to analyse how production tasks are distributed across different roles and how working time is divided between machine-paced tasks and process monitoring activities. The thesis examined how this information can support the development of sustainable work organization. It focused on tasks, roles and work organization, not to individual performance or personnel optimization.

The main finding of the study is that production work in the examined process industrial site cannot be understood through simple division between machine-paced work and supervisory-control work. Instead, the production roles combine these dimensions in different ways. Some roles are more strongly tied to machine-paced and field-based tasks, while others are more monitoring-oriented. However, even roles with a high share of monitoring work may include time-bound physical tasks, disturbance handling and coordination responsibilities. Similarly, tasks that represent a relatively small number of total working time might still have a strong effect on the operator's autonomy and ability to perform proactive work if they require immediate response or physical presence at specific moments.

The first research question asked how production tasks in the process industrial site are divided between machine-paced tasks and process monitoring activities. Based on the findings, machine-paced tasks and process monitoring activities should not be understood as two clearly separate categories, because several production roles combine both types of

work. Process monitoring forms a central part of production work across several roles, but it is closely connected with physical task execution, quality-related activities, maintenance-related responsibilities and disturbance handling. Machine-paced tasks are especially significant because they structure the timing of work and might limit the operator's ability to move attention to other tasks. Supervisory-control in the other hand, is not passive observation, but involves maintaining situation awareness, interpreting process information and remaining ready to intervene when production situation changes. Therefore, the distinction between machine-paced and monitoring-based work should be understood as a continuum and not as two separate categories.

The second research question asked how this information can be used to support sustainable work organization. The study shows that task and time allocation data can provide a useful foundation for work design, but it should not be used alone. Sustainable work organization requires understanding how tasks affect monitoring capacity, role-specific competence, autonomy, disturbance handling and opportunities for proactive work. This means that the development of work organization should consider not only what tasks are performed, but also how tasks are sequenced, how they overlap, how they interrupt other responsibilities and how they influence the operator's ability to maintain process awareness. In this sense, the results support a broader view of work organization in which task redistribution is evaluated through its effects on the whole work system.

The sub-questions further specified these findings. The central production tasks included process monitoring, field-based production tasks, quality-related checks, disturbance handling, maintenance-related responsibilities and coordination within the shift. Time allocation was mainly monitoring-oriented, but machine-paced and physically bound tasks remained important because they structured the timing and autonomy of work. Temporary disengagement from immediate tasks was possible mainly in stable monitoring-oriented situations, whereas machine-paced, disturbance-related and maintenance-related tasks required physical presence and timely action. The interview findings showed that the current division of work was supported by team spirit and limited job rotation, but challenged by increasing workload, broad rotation, maintenance-related responsibilities and equipment failures. Based on these findings, future work organization should support monitoring capacity, role-specific competence, proactive work, technical reliability and clear coordination between production and maintenance.

The theoretical contribution of the thesis is modest but relevant to the academic discussion on production work in automated process industrial environments. Earlier research on automation, supervisory-control work, situation awareness and workload has shown that operator work increasingly involves monitoring, interpretation, anticipation and intervention. However, this earlier research often emphasizes the operator–automation relationship or cognitive demands, while less attention is given to how these demands are shaped by the everyday organization of production work at the level of roles, tasks and time allocation. This thesis contributes to this gap by combining task- and time-allocation analysis with Work System Theory. The findings show that workload, autonomy and proactive work are not determined only by task duration or task frequency, but by the alignment between work roles, production activities, technical reliability, information flows, competence and organizational support. In this way, the thesis connects human factors perspectives with Work System Theory and shows that production work in continuous process industry should be analysed as a sociotechnical work system rather than as a collection of isolated tasks.

From a managerial perspective, the thesis demonstrates how Work System Theory can support structured discussions about production work by connecting task-level findings with broader questions of work organization, such as role design, competence, coordination, technical reliability and opportunities for proactive work.

The findings also contribute to the perspective of human factors on process industrial work, which is consistent with earlier research on automation and supervisory-control work, where operator work has been shown to shift toward monitoring, interpretation and intervention rather than disappearing (Bainbridge, 1983; Strauch, 2018; Pütz et al., 2024). The results support the view that automation and process control do not eliminate operator work but change its nature. In automated and semi-automated production environments, operators are required to monitor, interpret, anticipate and intervene. This makes situation awareness and readiness for action central parts of production work, which connects the findings on Endsley's (1995) work. The research also shows that workload should be understood as more than the amount of visible manual activity. Workload might increase when operators must manage overlapping responsibilities, disturbances, maintenance-related issues or broad job rotation requirements within the same shift.

The practical contribution of the thesis is that it provides a structured and fact-based way to discuss production work and division of work in the case organization. The study offers an

overview of how production tasks are distributed across departments and roles, how time is allocated between task categories and what kinds of themes operators and supervisors associate with the current organization of work. This information can support future discussions about work design without reducing the issue to individual performance or personnel numbers. The findings suggest that sustainable work organization should preserve sufficient capacity for monitoring, support the development and maintenance of role-specific expertise keeping in mind individuals' abilities, motivation and skills, clarify the relationship between production and maintenance responsibilities and create practical conditions for proactive work.

The thesis also highlights the job rotation. Job rotation can function as a resource by increasing task variety, flexibility and shared understanding and knowledge between roles. However, if rotation becomes too broad or if operators do not spend enough time in specific roles, it may weaken deep expertise and increase cognitive demands. Therefore, job rotation should be designed carefully as part of the overall work system. A sustainable model should balance flexibility with the need for role-specific competence, confidence and process knowledge.

Future research could deepen the findings by collecting longitudinal data on how production work changes after organizational or technological modifications. Further studies could also combine task and time allocation analysis with more detailed observation, workload assessment or situation awareness measures. Another useful direction would be to examine the production-maintenance interface more closely, because the findings of this study suggest that maintenance-related responsibilities and technical reliability have a significant effect on the continuity and sustainability of production work.

Overall, the thesis shows that sustainable work organization in continuous process industry requires a systemic understanding of production work. Machine-paced tasks, monitoring responsibilities, competence requirements, disturbances, maintenance-related work and technological conditions are interdependent parts of the same work system. Therefore, the development of work organization should be based on how the whole work system supports stable production, operators' situation awareness, role-specific competence and proactive work. This provides a foundation for improving the division of work in a way that supports both operational performance and employee well-being.

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Appendix 1. Interview questions for the operators

1. Role and practical execution of work
Describe your own work shift in practice.
Which tasks take most of your time?
How does your work correspond to the official role description?
Are there tasks or responsibilities in your work that are not clearly documented?
Which tasks are most central for the functioning of the process?

2. Time use and division of work
How would you estimate your working time to be divided between the following: Physical task execution / Process monitoring / Handling disturbances?
How do active task execution and monitoring work vary during the shift?
How much does the nature of work vary between shifts in your role?
Which factors shift the work from "monitoring" toward "active task execution"?
When is a monitoring period passive, and when is it active monitoring? How can this be recognized?
What explains the largest differences, if using of time varies between shifts?
Which factors explain why the same task may sometimes take more or less time?

3. Situation awareness and cognitive workload
What information do you continuously follow in your work?
How do you recognize that the process is operating normally?
In what kinds of situations does the work feel mentally demanding? How about physically?
How quickly do you usually need to react to deviations?
Are there situations where you need to anticipate future events?
Which factors make it easier and which more difficult to perform well at work?
When you perform several work roles, what is most difficult thing when switching from one role to another?
Are there situations where you need to act with incomplete information? How do you act in those situations?

4. Meaning of the work role in the process system
In which situations is your role especially important for the process?
Is the meaning of your role the same in normal situations and disturbance situations?
What are the core responsibilities of your role in normal situations and deviations?
In what kinds of situations do your responsibilities become especially important?
How is your work role connected to the other roles?
Are the role boundaries in your work clear or flexible?
When flexible role boundaries are helpful, and when they are challenging?

5. Automation and changes in work
How much of the process operates automatically in your work role?
In what aspects does automation help the most and in what makes it more difficult?
When does automation "hide" the state of the process, meaning that it becomes more

difficult to understand what is actually happening?
In which situations do you need to intervene in the process?
Has the work changed in recent years? If so, in what direction?
Do you experience the work more as active task execution or as monitoring?
How do you maintain your competence in situations where disturbances occur only rarely?

6. Disturbances and critical moments
Describe the most recent significant disturbance situation.
How did you recognize the situation?
How did you decide what to do?
Who participated in solving the situation?
What was the most difficult aspect of the situation?

Closing questions
What makes work flow smoothly in your department and shift?
What most often prevents smooth work?
If you could change one thing in everyday work, what would it be and why?

Appendix 2. Interview questions for the supervisors

1. Production work
What currently challenges production work the most?
Which of these challenges are most visible in everyday work?
Are the challenges more continuous or situation-specific?
Do they become more emphasized in certain roles or situations?

2. Job rotation
How do you evaluate the current job rotation in your area from the perspective of production functionality?
In what ways does job rotation work well and support production?
In what situations can it increase workload or make work management more difficult?
Does the current arrangement sufficiently support the development of deep expertise?
Is there a risk in some roles that competence remains too superficial?

3. Workload factors
The employee interviews indicated an experience of increasing workload. From your perspective, what explains this?
Which factors currently create the most workload in production work in your area of responsibility?
Is the workload mainly related to: amount of work / interruptions in work / disturbances / competence requirements / something else?
Has workload changed in recent years?
In which roles or situations workload is especially emphasized?

4. Disturbances and maintenance
What kinds of disturbances, equipment failures or maintenance-related situations affect the smoothness of the work most?
In which situations do the interface between maintenance and production work well?
In which situations are there problems or additional workload related to this interface?
Where would development be needed?

5. Anticipation and development of work
To what extent does the current division of work enable a proactive way of working rather than only continuous reacting?
Do employees have sufficient opportunities for observation and anticipation?
In which roles does this work best?
In which roles or situations does the work easily become reactive?
What changes would best support a sustainable division of work?

6. Closing questions
If the current division or organization of work should be developed first, what would you change?
What would be the most important single change?

What would be a realistic development target in the short term?
What would improve both work smoothness and work sustainability?
Is there something important related to this topic that I did not ask about?