EXAMENSARBETE

Control 4.0

Creating a vision for the future of industrial control rooms under Industry 4.0

Erik Sundström

Civilingenjör, Teknisk design
2019

Luleå tekniska universitet
Institutionen för ekonomi, teknik och samhälle

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Erik Sundström
Luleå 21st of May, 2019

Abstract

Today's industries are facing what some may call a new industrial revolution. Technological developments are heading towards more internet-based system solutions. This movement is often referred to as Industry 4.0 and is said to have the potential for more flexible, autonomous productions capable of managing themselves. With new technologies, however, there is also a demand for new competences and qualification requirements on the workforce. Furthermore, industries of today often have problems with recruiting new competent employees, especially younger people. Industries looking to implement Industry 4.0 would therefore have to manage the education and development of existing employees while also attracting new employees.

As part of a larger research project at Luleå University of Technology, this thesis project aims to describe how the control rooms in Swedish metallurgic industries will be affected by Industry 4.0. Furthermore, the project aims to describe what changes that are desirable for achieving a sustainable, effective and equal industry. To better achieve this goal, the project was done in collaboration with the metallurgic industry SSAB, specifically the steel production in Luleå. Through visits, interviews and observations at the control rooms in SSAB's steel production, the context of today's control room work was detailed. This context was compared to and analyzed using reviewed literature regarding future technologies under Industry 4.0 along with my own speculations on future possibilities. The analyses consists of my reflections on what problems that existed, what could be improved and what worked well in the control rooms. Furthermore, my analyses included the positive and negative effects that the implementation of Industry 4.0 technologies could have on the control room work. The analyses were utilized as the basis for creating a vision of how control rooms can develop under Industry 4.0, and the changes that are desirable.

The resulting vision compiled from my analyses consists of two scenarios; a dystopian and a utopian scenario. Each scenario depicts exaggerated depictions of the potential results of implementing Industry 4.0. The dystopian scenario depicts the few operators not made obsolete by an autonomous production and how they've been affected. They are constantly tracked and have their health monitored during their work, their equipment isn't designed with the user in mind and the job no longer feels like qualified work. As a contrast, the utopian operators instead utilize the increased capabilities for communication and data gathering from systems and machines to work with tests, development work and optimization. Furthermore, instead of constant monitoring, tracking sensors are instead used to notify emergency personnel if the operator hurts themselves while out working. With these scenarios I also included recommendations for how the utopian vision can be achieved and the dystopian one avoided. These recommendations include involving operators in development of work tasks and instructions to promote employee involvement and control. Furthermore, their involvement allows for the better utilization of their knowledge and experiences, while also potentially helping with making the control room work better adapted to the operators' needs. According to the results of this project, this will help improve and support efforts to create more attractive workplaces and promote qualifications development. By following the recommendations made, it is my hope that Swedish metallurgic industries like SSAB can better strive for an implementation of Industry 4.0 that is beneficial for both employer and employees.
Keywords: *Industry 4.0, Metallurgic Industries, Control Rooms, Attractive Work, Qualifications Development, Industrial Design Engineering*

Sammanfattning

Dagens industrier möter idag något som vissa kallar en ny industriell revolution. Inom teknikutvecklingen introduceras fler och fler internet-baserade systemlösningar. Denna utveckling namnges ofta som Industri 4.0 och ska kunna möjliggöra flexibla, autonoma produktionsflöden som kan drivas av sig själva. Med ny teknik kommer dock nya kunskapskrav och ett behov av nya kompetenser för arbetskraften. Vidare har dagens industrier ofta även problem med att rekrytera kompetent ny arbetskraft, speciellt bland yngre generationer. Industrier som vill implementera Industri 4.0 kommer därför att behöva hantera både kompetensutvecklingen och utbildningen av befintliga anställda, samt att attrahera nya anställda.

Som en del av ett större forskningsprojekt på Luleå tekniska universitet ämnar detta examensprojekt att beskriva hur kontrollrummen i svenska metallindustrier kommer att påverkas av Industri 4.0. Vidare ämnar projektet att beskriva vilka förändringar som är önskvärda med målet att uppnå en hållbar, effektiv och jämställd industri. För att bättre uppnå detta mål utfördes projektet i samarbete med stålindustrin SSAB i Luleå. Genom besök, intervjuer och observationer i deras produktions kontrollrum kunde det nuvarande kontrollrumsarbetet undersökas. Besöken analyserades genom att använda kvalitetsgranskad litteratur om framtida teknik och system under Industri 4.0, samt genom mina egna spekulationer om framtiden. Vidare inkluderade mina analyser vilka positiva och negativa effekter Industri 4.0 kan ha på kontrollrumsarbete. Analyserna användes som en grund för att skapa en vision hur kontrollrumsarbete kan utvecklas under Industri 4.0 samt vilka utvecklingar som är önskvärda.

Den resulterande visionen bestod av två scenarier; ett dystopiskt och ett utopiskt scenario. Varje scenario ger överdrivna beskrivningar av de potentiella följderna av en implementering av Industri 4.0. Det dystopiska scenariot beskriver det fåtal kvarvarande kontrollrumsoperatörerna som inte gjorts överflödiga av den autonoma produktionen och hur de påverkas. De spåras konstant i lokalen medan deras hälsa övervakas, samtidigt som deras utrustning inte anpassas efter deras behov och arbetet inte behöver någon vidare kompetens. Som kontrast till det använder den utopiske operatören de ökade möjligheterna för datainsamling från och kommunikation med system och maskiner för att arbeta mer med test, utvecklingsarbete och optimering. Vidare används spårningstekniken inte för konstant övervakning, utan meddelar istället akutpersonal om deras position och tillstånd om de skadar sig när de arbetar ute i lokalen. Med dessa två scenarier tog jag även upp rekommendationer för hur den utopiska visionen kan eftersträvas och den dystopiska undvikas. Rekommendationerna inkluderar att involvera operatörer i utvecklingen av nya arbetsuppgifter och instruktioner för att främja anställdas medverkan och kontroll över sitt arbete. Utöver det möjliggör deras medverkan att deras kunskap och erfarenheter utnyttjas och används, samtidigt som det potentiellt hjälper anpassa kontrollrumsarbetet bättre efter operatörernas behov. Det kommer att hjälpa förbättra och stödja arbetet med att skapa mer attraktiva arbetsplatser och främja kompetensutveckling. Genom att följa rekommendationerna hoppas jag att svenska metallindustrier som SSAB kan enklare arbeta mot en implementation av Industri 4.0 som är fördelaktig för både anställd och för företaget.

Nyckelord: *Industri 4.0, Metallindustri, Kontrollrum, Attraktivt Arbete, Kompetensutveckling, Teknisk Design*

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1 Introduction

This thesis project, written during the spring semester of 2019 at Luleå University of Technology, is part of the master programme in industrial design engineering. It is part of a larger research project at the university that aims to examine the impact of and create recommendations for the implementation of Industry 4.0 at the Swedish metallurgic industries. The goal is to promote attractive workplaces and develop the skills of the existing work force. The thesis project focuses on researching how the control rooms that manage the production systems of metallurgic industries can be changed and improved. This is done with the help of the Swedish steel industry SSAB, who is a partner of the larger research project and have assisted in fulfilling this goal.

1.1 BACKGROUND

Swedish metallurgic industries of today will soon face new challenges with the coming of Industry 4.0. It is a wave of new, more internet-based systems and technologies originating from the German government's industrial strategy *Industrie 4.0*. Industry 4.0 is, as described by Kagermann, Wolfgang, & Helbig (2013), the fourth stage of industrial revolutions. It entails utilizing cyber-physical systems (CPS) and the internet of things (IoT) to create systems where resources, information, objects and people are connected through networks and the internet. This would in turn allow industries where the machines, warehousing systems and production facilities communicate and coordinate with each other to organize and optimize the production. In addition, changes like these would also affect organizational structures, business models and other services as well.

Kagermann et al. (2013) present several improvements that will potentially be implemented with Industry 4.0. Examples include improved flexibility through interconnected production systems and the ability to better adapt to individual customer demands. Other improvements include more transparent information flows to optimize decision-making, removing the operators from dangerous working environments through remote control, and more. The new systems that are to be implemented with Industry 4.0 are horizontally and vertically structured. Horizontal systems share resources not only amongst people and machines within a company, but also between different companies. Vertical systems are used to exchange information and resources between different hierarchical levels. With a long list of possible improvements and descriptions of how the future of industries will change, the authors paint a very optimistic description of Industry 4.0 and its capabilities. However, while they do bring up subjects that would require further research and development, there are still potential problems with Industry 4.0 that aren't addressed in the article. For instance, with new technology requiring new competencies and knowledge from the employees, how should the reeducation of existing employees be handled?

The new systems and changes of Industry 4.0 would bring with them a shift in what knowledge and qualifications that are required of the employers and the employees if they want to stay competitive and attractive on the future market. Beyond that, metallurgic industries are also currently facing difficulties in finding new manpower with the right competences, especially from younger people. Metallurgic industries will thus need to manage both the challenge of attracting new employees while also developing competences of the existing employees.

Luleå University of Technology is conducting a research project that aims to find out how the sustainability, effectiveness and attractiveness of Swedish metallurgic industries can be improved through Industry 4.0. This is done by working together with the Swedish steel industry SSAB and the industrial union IF Metall. The results of the research will be presented through visions of how the different workplaces and groups at SSAB might be impacted by Industry 4.0. Furthermore, the research seeks to describe what changes that are desirable and which ones are not for metallurgic industries in general. However, not every system and technological solution from Industry 4.0 is worth implementing in every industry. Adapting to new technologies without a proper reason beyond following modern trends may cause more problems than what will be solved, such as increasing stress, creating more monotonous work and reducing the attractiveness of the workplace. The right changes and solutions must instead be identified and researched in order to determine how an attractive and sustainable industry can be created and supported with the help of Industry 4.0.

1.2 STAKEHOLDERS

The thesis project is done in cooperation with SSAB and IF Metall. The people at SSAB are the primary stakeholders in the thesis project due to the visions and recommendations created by this project. Since the recommendations are based on and would affect their control room workplaces if implemented, the operators will likely be the most affected. In addition, other personnel that interacts with the control rooms and their processes, such as maintenance personnel, may have their work affected the changes. The results are presented as universally applicable recommendations and visions for Swedish metallurgic industries. Secondary stakeholders thus include other industries and organizations that may find the results interesting without being directly involved in the project. The changes may also, if implemented, affect working and employment conditions, which makes unions like IF Metall secondary stakeholders.

1.3 OBJECTIVE AND AIMS

The aim of this thesis project is to map and identify how the technologies and systems gathered under the term Industry 4.0 can be utilized to create sustainable and effective control room workplaces at metallurgic industries. The work primarily focuses on the steel industries of SSAB but aims to be applicable in other industries and companies as well. These workplaces need to be beneficial to both the employers and the employees, while also providing equal opportunities to all employees.

The objective of the thesis project is to deliver a description of how Industry 4.0 can impact the work in control rooms, both positively and negatively. In addition, the new demands on the workplace, the workers and the organizations that may arise needs to be described. The questions that have served as goals and guidelines for the thesis project are:

- How can the workplace and the work tasks in the control rooms at SSAB be structured and adapted to changes in systems and technologies that Industry 4.0 could bring?
- How can existing personnel at SSAB be introduced effectively to the changes in their workplace that Industry 4.0 would bring, and what new qualifications will be required of them?
- What factors can increase the attractiveness of the workplaces at SSAB for new and current employees?
- What recommendations can be made to promote a vision of sustainable, effective and attractive future control room work, and how can the employees be involved in creating that vision?

1.4 PROJECT SCOPE

The thesis project has been done by one person during a time span of 20 weeks, meaning that the scope of the project is limited. The focus of this thesis project is the control rooms at SSAB, meaning that other work tasks and working environments will be excluded, unless they have some connection with or impact the control rooms. While establishing a context I have examined most of the control rooms along the steel slab production line. Each control room performs many different types of maintenance requiring different skills and tools. For that purpose, I have limited my study and analysis to the more general work tasks and circumstances that are present in most control rooms, which has helped make the results more applicable to control rooms in general.

The results of this thesis project are limited to delivering a vision of how to achieve a sustainable, effective and equal workplace. However, the results haven't included implementation strategies with steps on exactly how to achieve the vision. In addition, the economic impacts of the proposed solutions have been considered on a base level, but the thesis project hasn't included detailed investment calculations of costs and earnings. The main reason for these limitations is due to the time constraints and the fact that I am working on this thesis project alone.

1.5 THESIS OUTLINE

Chapter one of this thesis project serves as an introduction to the report, and the subjects it covers. This includes detailing background information of relevant subjects, objectives and aims and the scope of the project. Chapter two contains a description of the context of the thesis project, including an objective description of the steel production process at SSAB. Chapter three details the theoretical framework that the analysis of context and creation of the vision is based upon. Chapter four describes the different methods utilized to gather information, analyze the context, validate the results and more. In chapter five, based on the interview and observation results, the current state of the control room work is detailed, including the thoughts and remarks of the operators. This chapter includes more opinions and thoughts from myself and the control room operators regarding the work. Chapter six contains my analyses of the current state and the context, based on my own knowledge and on the literature I've reviewed. In chapter seven, I present the conclusion of my analysis; two scenarios depicting how control room work and metallurgic industries may be impacted, and a description of a balanced vision of the future. Chapter eight consists of a discussion and my reflections on my work and my results.

2 Context

This chapter describes the context of the thesis project. This includes a general description of the entire production process, a description of the control room work and a list of technologies and systems described in Industry 4.0-related literature that is seeing use today.

2.1 SSAB

The Swedish company SSAB is one of the metallurgic industries facing the challenge of working towards possibly implementing Industry 4.0. It is a steel manufacturing industry with main production facilities in Sweden, Finland and the US. The focus of the larger research project and this thesis project is the Swedish production facility located in Luleå. According to SSAB (2019a) the production facility in Luleå has around 1100 employees and while their primary products are steel slabs, they also produce and offer coke, crude iron, steel processing, continuous casting and more. The primary production process, the steel slab production, can be separated into several different sequential subprocesses: coke production, blast furnace melting, desulfurization, basic oxygen furnace (BOF) processing, steel processing, casting and cooling.

A part of SSAB's industry that will be affected by the implementation of the new technologies and systems of Industry 4.0 are the control rooms that oversee the production. In these control rooms, operators control different parts of the production process remotely and monitor the production systems. The operators rely mainly on different monitors and computers that show the status and progress of the machines in the production line and allows for the operators to manage the processes and machines. Each of the subprocesses of the steel slab production have their own control rooms that oversee them, where the work tasks vary depending on what part of the subprocess that is being monitored and controlled. In total, the steel production line is managed by eleven different control rooms. These control rooms are usually located right next to the process that it controls and manages. While all control rooms are part of the same steel production line, they are grouped together under different sections of the production. The four different sections are: the cokerie section including the coke production processes; the crude iron section including the blast furnace processes; the crude steel section including desulfurization and BOF processing; and the continuous casting section including steel processing, casting and cooling. An illustration of the steel production process can be seen in figure 1.

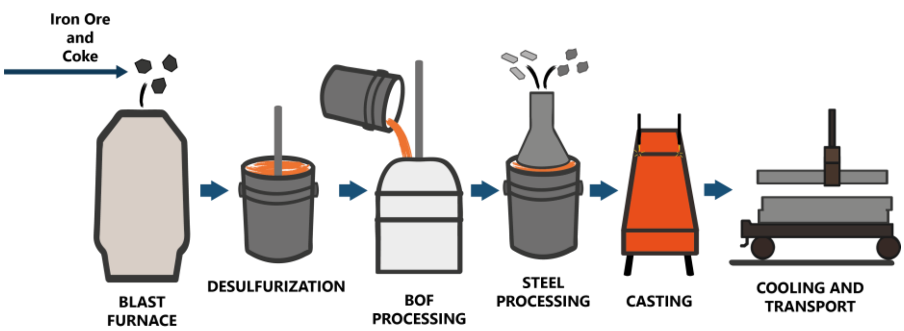

Figure 1: An illustration of the steel production process at SSAB in Luleå

The number of operators that work in the control rooms vary depending on the processes that are controlled. As an example, while the control room managing the alloying process only has two operators, one for each production line, the control room right after it in the production process has 12 operators, six for each production line. Something that every control room has in common is that they are manned by five different shift teams of employees. The shift teams work eight-hour shifts on weekdays and 12-hour shifts on weekends and rotate between the different shifts during the weeks. Each shift team at each section of the production, for instance the shift teams for the desulfurization and the BOF processing control rooms, share the same shift leaders. Furthermore, all the shift leaders in one section work under the same manager. An illustration detailing this hierarchy can be seen in figure 2.

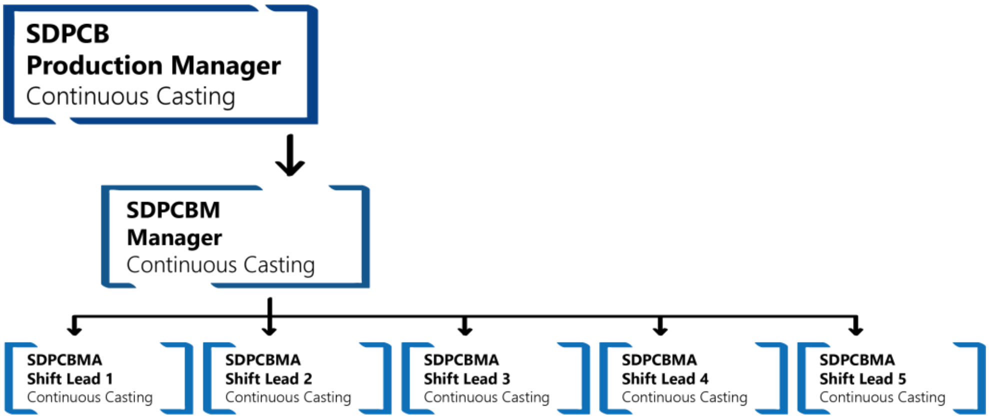

Figure 2: An illustration of the hierarchy in one of the sections of SSAB in Luleå, specifically the continuous casting section of the production

2.2 TECHNOLOGIES AND SYSTEMS

While Industry 4.0 includes innovative technologies and systems that have yet to reach a realistic implementation stage, there are some innovations that are already seeing use in todays' industries, albeit usually lacking certain features described in literature with visions of future industries.

One technology that has been associated with Industry 4.0 that is starting to see use in todays' industries is virtual reality technology, or VR technology. At SSAB, VR has been utilized in visualizing the production locales to allow people to explore and acquaint themselves with the workplaces without physically visiting them. For instance, the company is experimenting with using a virtual model of a steel mill walking beam furnace in Raahe, Finland to allow maintenance personnel to visit the maintenance area beforehand to identify potential safety issues (SSAB, 2019b). At the steel mill in Luleå, SSAB utilizes VR in training employees on how to operate certain equipment, but the implementation is still fairly limited. However, when interviewing the managers, one showed an interest in the potential of using VR technology as an educational tool. It could be used to train control room operators on how to handle problems that otherwise rarely occur or to familiarize them with the control rooms.

Another technology of Industry 4.0 is the increased monitoring and tracking of employees, which is something that is currently available. One company providing this service today is *indoo.rs*. They claim that monitoring the employees' environments and locations can help monitor excessive noise, air quality, notify employees that are exposing themselves to harmful environments and optimize work flows (Stein, 2018). This tracking technology isn't something present in SSAB's productions today, but certain control room operators have described an interest in it. The reason is that it would make leaving the control rooms to work alone in the production safer.

3 Theoretical framework

This chapter will describe the literature that has been reviewed and considered relevant to this project, including literature about industrial design engineering, Industry 4.0, attractive workplaces and more. This literature was used to analyze the information that I've gathered during my context studies of the control rooms and visits to SSAB.

3.1 INDUSTRIAL DESIGN ENGINEERING

Industrial design is described by the World Design Organization (WDO, 2019) as strategic problem-solving that aims to create innovative products, systems, services and more through a design process with a human-centric focus. Industrial design also requires consideration of how the interaction between the human, technology and the organization can be taken into account in the design process, as well as creating sustainable solutions and designs. These descriptions align with my understanding of the subject as an industrial design engineering student, and so I will be describing these subjects in more detail.

3.1.1 Human-centric design

Wikberg-Nilsson, Ericson and Törlind (2015) describes the main goal of human-centric design as fulfilling the needs and wants of the user. This entails complementing people's strengths and capabilities by adapting the workplaces, processes, equipment and organizations to the humans instead of the other way around. However, the authors claim that the term "user" is less straightforward than one might think. It can refer to the customer who purchases the product or service, the workers and employees who create or deliver it, or someone else involved in the process. It is therefore important to define who is the customer, that pays for goods and services; the operator, who operates the service or product; and the final customer, that utilizes the service. This is because they all have different needs and demands of the products and services. An example the authors give of this would be that a company might prioritize reducing costs, an operator may value ease of production or use, while a customer may want fast results. Designing with a human-centric focus would therefore require consideration of several different parties' needs from different perspectives. This would entail working to design systems and products that can produce good results for the final customer while providing operators comfort and ease of use, without becoming too expensive for the companies to realistically implement. It is at the same time important to identify and address the different needs and wants that individuals may have (Wikberg Nilsson et al. 2015). Examples include making sure people with varying strength can operate levers and lift items, making sure a system interface makes it obvious what different buttons do and preventing ergonomic problems by protecting workers from vibrations and loud sounds. Human-centric design is important in this thesis project for selecting solutions and systems to create the vision of future control room work. If the operators' needs and wants aren't taken into account, it may cause improvements to worsen the working conditions for the operators or complicate the implementation process.

3.1.2 Human – Technology – Organisation

While designing with humans in focus is important, it is also important to keep in mind how the systems and the organization will be impacted by the design choices made and what impact they will have themselves. One science that focuses on the relations between humans, technologies and organizations is the human-technology-organization (HTO) perspective. It has previously been described by Rollenhagen (1997) as the three areas of knowledge that are important to consider when working with improving workplace safety, and how they can impact each other. While HTO has progressed to being used in wider applications today, such as system performance and health issues, the areas of focus and the principles of HTO remains according to Karltun, Karltun, & Eklund (2014) mostly the same. Rollenhagen (1997) lists many different aspects of HTO that I find are relevant to the human-centric focus of industrial design. Examples of these subjects include accounting for human factors when designing systems, adapting information to optimize knowledge retention, the effects of stress and how to handle it, group dynamics and social norms, the organizations' role in handling information and safety, and the safety culture perspective.

While there are more subjects in HTO, many of them are relevant to industrial design, such as organizational structure and the focus on human factors, albeit with some differences. It is important to note, however, that Rollenhagens descriptions of the subjects of HTO are somewhat simplified and requires further research in order to ascertain how useful they are. In addition, seeing as the book is more than two decades old, it would be important to ensure the relevance of the subjects today, should they be implemented. Despite this I believe HTO is a relevant tool in industrial design engineering to ensure that the connection between humans, technologies and organizations is properly taken into consideration when creating effective and sustainable workplaces. Examples of utilizations of HTO is given by Karltun et al. (2014) when they describe their experiences from working with the concept as a systems perspective, with references to other literature regarding the way it's used. The examples of using HTO include investigating and analyzing the development of a mail distribution division, studying forklift drivers' working conditions, and as a tool to describe the complexity of planning and schedule work. I believe that these examples indicate that HTO is a fitting tool when mapping, analyzing, clarifying and improving working conditions.

3.1.3 Sustainable design

Sustainable design is according to the Ministry of Enterprise and Innovation (2016) an important subject for industries aiming to secure their competitiveness on the future market, increase resource effectiveness, reduce their ecological impact and satisfy the needs of their consumers. This subjects' relevance to the thesis project comes from promoting sustainable control room workplaces being one of the projects' aims. Without properly research of the subject, it can be difficult to define sustainability and to understand how it can be achieved. The term "sustainability" was according to Giddings, Hopwood, & O'Brien, (2002) first defined as "meeting the needs of present without compromising the ability of future generations to meet their needs". This term has been interpreted and translated in many different ways since its first use, and today the term sustainable design is often defined as being composed of three sectors: Economic, ecological and social sustainability.

A simplified description of economic and ecological sustainability is according to Giddings et al. (2002) that it requires effective resource management; to do as much as possible with as low natural and economical costs as possible. An example would be by using more recyclable or renewable natural resources that the company themselves can reuse. Social sustainability, however, is somewhat different and has more varied definitions. Dempsey, Bramley, Power, and Brown (2011) uses sustainable communities as examples of social sustainability. This example presents concepts that can be important for achieving social sustainability, such as addressing and satisfying peoples' needs, creating welcoming and inclusive environments, promoting participation and more.

According to Giddings et al. (2002), none of the sectors should be prioritized above the others, as they are all connected. Prioritizing one sector can lead to consequences in the others, which in turn can impact the prioritized sector negatively. For instance, if economic sustainability is prioritized by foregoing social sustainability and cutting costs from recreational activities, you may end up with unmotivated workers and thus a lowered efficiency.

3.1.4 Health and work environment

One factor that can greatly affect a person's performance is stress. A stressed worker may work less effectively and is at risk to make more mistakes that could endanger themselves or others. Furthermore, according to Thylefors (2015), high levels of stress can cause a number of health issues such as high blood pressure, chronic pain and hampered immune systems. For that purpose, creating and managing a psychologically healthy work environment can be just as important as a physically healthy one.

Thylefors (2015) describes how the concept of stress can be summarized as the negative consequences of several factors of a lacking psychological work environment. These factors are people having too demanding work, limited levels of decisions and control, and insufficient social support. To illustrate the relationship of these factors, the author refers to the *demand-control-support* model that is illustrated in figure 3, originally created by the sociologists Robert Karasek and Töres Theorell.

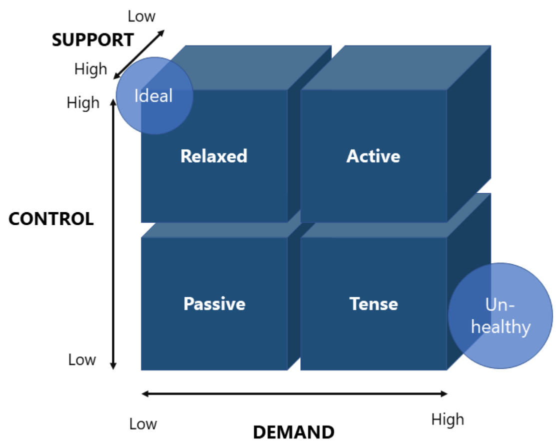

Figure 3: The Karasek demand-control-support model

According to Thylefors (2015), the level of control refers to how much freedom an employee has to make their own decisions, in addition to how many opportunities for learning, creativity, variation and development the work provides. Level of demand includes aspects such as work volume, difficulty level of tasks, and whether conflicts between roles or demands occur. Finally, the level of support refers to how much social support the work provides through practical and emotional help from managers and colleagues. If a work task or job offers low amounts of control and support while being very demanding work, placing it in the tense block of the figure, the employee's health and well-being may suffer. If the employee is instead properly supported and provided high levels of personal control, even very demanding work can be positively challenging and stimulating.

Another work-related health topic commonly studied in industrial design engineering is ergonomics. Ergonomics is defined by Hägg, Ericson, & Odenrick (2015) as humans' interaction with their surroundings. The impact of and the physical stress caused by aspects such as forces, moments and mechanical energy on humans is studied and analyzed in this subject. Ergonomic work studies often analyze the lifts, motions and exertions that are necessary to perform the work. In some cases, however, work can be ergonomically unhealthy despite not containing any heavy lifts or exertions. This is because uninterrupted sedentary work often causes posture problems and increase the risk for cardiovascular issues. The authors state that if the work lacks physical variance in its tasks, or if the forces and loads in the work aren't alleviated, it can damage and fatigue the people performing the work. For light physical work, such as sedentary work at a desk, the authors recommend regular physical exercise and opportunities to interrupt long periods of sitting down. To avoid ergonomic health issues, governmental authorities such as Arbetsmiljöverket (2011) in Sweden create rules and guidelines on how to assess and avoid ergonomic issues in the workplace. There they emphasize the importance of variation of work tasks, few and non-repetitive heavy loads, and few static work tasks. Furthermore, they emphasize the importance of motion and variance even in sedentary work, similar to what Hägg et al. (2015) describe.

3.2 **INDUSTRY 4.0**

As mentioned before, Industry 4.0 covers many improvements and changes to different organizational aspects by including a wide range of systems and technologies. In this part of the literature review, I will describe some of these concepts, systems and technologies more thoroughly.

3.2.1 Internet of Things and Cyber-physical systems

Internet of Things (IoT) has been defined by Gubbi, Buyya, Marusic, & Palaniswami (2013) as the act of providing actuating and sensing devices with a way to effectively share information. This is to be achieved through more universal sensor readings, data analytics and information representation by utilizing cloud-based computing. In other words, machines and systems will, through IoT: gather more information and data; have that data be analyzed and calculated by internet-connected computing; and present that data in an easy-to-read and comprehensive way. One prominently mentioned technology that according to Atzori, Iera, & Morabito (2010) enables IoT is Radio Frequency Identification tags, or RFID-tags. These tags are used today to identify products and machines, and to read their location data. This data from the RFID-tags could be shared amongst machines and products, so that the production systems can better keep track of individual parts throughout the process.

Atzori et al. (2010) state that location data isn't the only data that would be shared amongst systems and machines in the future. The vision for IoT is to have machines share more data from both physical and digital systems in order to optimize and increase the effectiveness of the processes. Examples given by the authors include vehicles sharing data with traffic control sites in order to better route traffic, real-time monitoring of almost every part of a production process, and remote identification and monitoring of patients at hospitals.

The greater amounts of data gathered through the IoT will according to Kagermann et al. (2013) be used in Industry 4.0 to create and enable *cyber-physical systems* (CPS). CPS are, according to Kagermann et al. (2013) and Brettel, Friederichsen, Keller, & Rosenberg (2014), defined as systems of smart machines, storage systems and production facilities with the ability to autonomously share information between themselves and communicate with people. The systems and machines are then able to act on this information to manage the production of goods, adjust to customer demands and plan orders and deliveries, all without the direct involvement of employees. An example of this would be a production process being able to adapt the physical production according to the digital data from customer orders autonomously. Production processes would be able to set production schedules in accordance with maintenance, readjust machines to customer orders and tell when more material needs to be delivered, all without the involvement of any employees. While it may sound somewhat unbelievable, I myself have seen customer order systems capable of planning and balancing production schedules autonomously based on the workload. Therefore, production systems with internet-based systems gaining more capabilities to communicate with suppliers and adapting to customer demands isn't something I see as too implausible.

3.2.2 Decentralization

Decentralization is according to Carvalho, Chaim, Cazarini, & Gerolamo (2018) described in Industry 4.0 as allowing local operators and machines to make more decisions themselves instead of relying on central computers and orders passed down hierarchically. With the increased demand for individualized products, the authors believe decentralization would entail increased flexibility needed to fulfill those demands. The production line would be able to adjust itself to the customers' demands with the smart machines and autonomous exchange of information from CPS, without needing operators to reprogram or adjust the machines. Instead, the authors claim that operators would only need to perform maintenance and intervene in case of errors or problems. Another example of decentralization given by Brettel, Friederichsen, Keller, & Rosenberg (2014) is how production systems could come to cooperate and work together with other production systems and supply chains autonomously. This would entail production systems sharing information on customer orders with material suppliers and their systems to order the correct amount of materials and prepare deliveries without the involvement of people. According to the authors, this would allow for more flexible allocation of production capacity in these value chains. However, it requires each participating actor to provide potentially sensitive information about their delivery and production capacities.

Autonomous production systems capable of adapting themselves aren't the only technologies attributed to decentralization under Industry 4.0. Lundmark (2019) describes how the digitalized and internet-based machines and productions would allow certain kinds of work to be performed remotely, away from the production itself. An example would be allowing the drivers of mining machines to control them from outside the mine itself. The operators would use VR technology to simulate sitting in the machine and interacting with its controls.

With more remote-controlled decentralized productions the author states that this may end up changing certain "blue-collar" professions into "white-collar" ones, which would impact employment and union conditions. Furthermore, it may allow the outsourcing of more tasks and duties to external actors, which according to Johansson et al. (2017) would provide companies with a more flexible workforce. However, it could also make them dependent on specific outsourcers, making them more vulnerable in price and service negotiations. For the employees, outsourcing can lead to the removal of dangerous working environments thanks to the remote-controlled technology. On the other hand, if decentralization leads to more outsourcing the employees may according to the authors find themselves replaced by an outsourced workforce. In addition, the outsourced employees may receive less support from the company themselves, compared to what ordinary employees would receive.

3.2.3 Operators of the future

In addition to the technologies aiming to improve the flexibility and effectiveness of production systems, there are also new technologies associated with Industry 4.0 that aims to assist the workforce. Romero, Bernus, Noran, Stahre, & Fast-Berglund (2016) uses the term "Operator 4.0" to define how operators will work with Industry 4.0 technologies. According to them, operators have progressed through several different generations, from mainly performing manual and dexterous work during the earlier years of industrialization into performing work assisted by machines. This progression continued into operators now cooperating with robots, machines and computers to perform their work. The authors claim that this progress will continue into the fourth generation of operators, who will perform work aided by machines that enhance their physical, sensorial and cognitive capabilities. Romero et al. (2016) categorize these different enhancing technologies according to how they can enhance operators, providing a list of aspects that the term Operator 4.0 is made up of.

One example of categories for enhancement technologies given by Romero et al. (2016) is called the healthy operator. This category refers to the use of different Industry 4.0 technologies to increase work efficiency and operator's well-being. The authors describe personnel trackers that will be available under Industry 4.0 as being able to track not only the positioning of operators, but also biometric data. This would allow the operators to plan and schedule their work based on health-related metrics, monitor physical and mental workloads, and set alerts for when exertion or stress levels are too high. Other examples of uses for this type of technology are given by Stein (2018), who claims that their tracking technology allows for specifying areas with health hazards and warning operators who stay for too long in these areas.

Another category of technologies given by Romero et al. (2016) is "the smarter operator". The authors describe how a "smarter operator" will be achieved by utilizing intelligent personal assistants, or IPAs. These IPAs are artificial intelligences or software agents developed to assist in interfacing with machines, systems and databases, as well as performing tasks or services. A main feature of IPAs is according to the authors that they can offer voice-based interaction technology, allowing operators to verbally request information and work with the assistant hands-free. Examples given by the authors of how this technology would work includes scheduling tasks, managing inventory statuses while out working with maintenance and receiving live help in finding where specific materials should be stored.

Other categories of future operators that Romero et al. (2016) describe are augmented operators and virtual operators. Augmented operators refer to the usage of *augmented reality* (AR) technology to provide operators with digital information and support in real time. According to Wu, Lee, Chang, & Liang (2013), AR technology is technology that provides three basic features: a combination of real and virtual worlds, real time interaction, and accurate 3D registration of virtual and real objects. An example of how this technology works would be a pair of glasses that can display different instructions, schematics and data to an operator depending on what machine that operator is looking at. Virtual operators, on the other hand, are described by Romero et al. (2016) as utilizing *virtual reality* (VR) technology to interact with simulated design, assembly or manufacturing environments. This is, according to Dangelmaier et al. (2005), done through 3D-rendered models that a person can explore by wearing special VR lenses and eyewear. These track the person's position and where they're looking, allowing them to walk around and examine the 3D environment "in person", so to speak. By also utilizing special controllers, the user can interact with the 3D-environment in real time through manual motions. One possible use for this technology is presented by SSAB (2019b) during trials at a production locale in Raahe, Finland. There, the company is experimenting with recreating the production through 3D simulations and familiarizing new maintenance personnel with the locale by using VR technology before visiting the physical location.

Romero et al.'s, (2016) theories on the future of operator work under Industry 4.0 continues with several more categories, including using exoskeleton technology to strengthen them. Many of his theories may at first seem to be very visionary and optimistic, while at the same time seeming to be futuristic and unrealistic today. However, there are already many examples of similar technology being implemented, such as the aforementioned exoskeletons that is according to Marinov (2017) seeing use in BMW production facilities. Another example includes trials of using VR at SSAB (2019b) in Raahe. These examples illustrate the validity of Romero et al.'s theories and shows that the future is not as distant as one might believe.

3.2.4 Big Data

Industry 4.0 contains many different ambitious examples of technologies and systems that could improve and change productions and industries greatly. However, a common denominator between these technologies is that they rely on a large amount of data to function. According to Chen, Mao, & Liu (2014) and Oussous, Benjelloun, Ait Lahcen, & Belfkih (2018), the term "Big Data" is used to describe the vast amounts of data that is regularly handled in todays' society that cannot be handled by traditional IT tools in a reasonable amount of time. Examples of big data sets given by the authors include personal location data, images and pictures uploaded to social media sites, industrial machine sensor data and data from RFID tags. The relationship between Industry 4.0 and big data lies in IoT. If IoT is implemented in a factory, the sensors and terminals that connect the machines, systems and operators would generate a large amount of data when measuring and analyzing the production. The big data from IoT sensors and terminals can then according to Wang, Wan, Zhang, Li, & Zhang (2016) be utilized by CPS to allow entire smart factories to coordinate their production lines according to a system-wide goal. This includes using data from customer orders to adjust products and machines autonomously. It could according to the authors also allow for a more detailed overview and management of the processes and systems by gathering greater amounts of feedback data from each part of the process.

3.3 ATTRACTIVE WORKPLACES

As one of the goals of the project relates to ensuring control rooms remain and can become more attractive workplaces, this subject serves to describe what exactly that entails. Attractive workplaces can, according to Hedlund (2007), be defined as a workplace where people want to work and where people wants to stay. While a job that doesn't look enticing to job applicants may still be attractive to the people who have the job, the author defines this as a hidden job instead of being attractive. Any variation of attractiveness where both the people "outside" and "inside" a workplace don't consider the job to be attractive is instead redefined as hidden, idealized or unattractive work, as seen in figure 4.

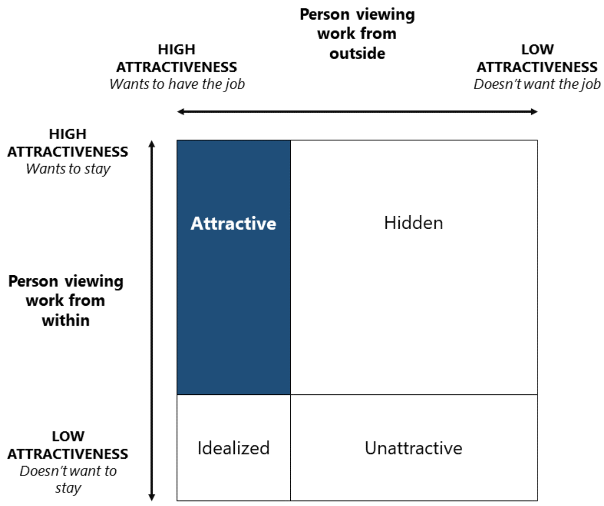

Figure 4: Hedlund's model on how the attractiveness of work is regarded from an internal and external position

As for the motivation for making work and workplaces attractive, Åteg, Hedlund, Pontén, & Arbetslivsinstitutet (2004) lists several possible reasons. These include employee retention, attracting new employees and improving the company's competitiveness and sustainability on the market.

The exact definition of what it is that makes work attractive, however, is a more varied and subjective topic. Hedlund (2007) lists different examples of reasons for a workplace being attractive to different people. These examples include fewer employee departures, status, career possibilities, salary, proximity to home, challenging work and more. In summary, the attractiveness for a job or a workplace can vary greatly depending on the person considering the position. That is not to say there aren't identifiable trends in what that is considered attractive by current or potential employees as they seem to vary with generation shifts. The author mentions how studies from 2003 showed a trend in that younger generations viewed flexibility, self-governing work, camaraderie and interesting work tasks as more attractive aspects. While these trends continue to shift and grow today, there are still some similarities to be found. This is shown in Bakker & Albrecht's (2018) study on work engagement, a factor that is affected by the willingness to stay from employees. They claim that employees today prefer flexible, customizable work tasks and an engaged, responsive management, similar to the studies that Hedlund presents.

A general model for attractive work was presented by Åteg et al. (2004), which consists of 22 different aspects of attractive work. These aspects are categorized under three different factors: attractive working conditions, attractive work content and work satisfaction, and can be seen in table 1.

Table 1: List of 22 aspects of attractive work, divided into three categories

Attractive working conditions	Attractive work content	Work satisfaction
Adequate equipment and tools	Familiarity	A demand for the person
Leadership	Freedom to act	Recognition
Localization	Physical activity	Results
Loyalty	Practical work	Status
Organization	Theoretical work	Stimulation
Physical work environment	Variation	
Relations	Work pace	
Social contact		
Wage		
Working hours		

This model is applicable to a variety of situations due to the it being universal in its descriptions. To summarize the categories that the authors present, attractive working conditions entails making sure the employees have the tools and assistance available to perform their job and that they receive enough social support from their colleagues and managers. Making the contents of the work attractive involves making sure the employees don't feel restrained in their work and have a healthy balance of physically active and non-strenuous work. Finally, the authors state that work satisfaction may come from having your contributions recognized, having employees feel needed, and by having stimulating work tasks that the employee feels satisfied completing.

The last aspect in particular, stimulation, can potentially be accomplished by making success challenging but achievable. While Åteg et al. (2004) defines these aspects based on their research in attractive work, they don't present explicit solutions to achieving these aspects. Work towards creating a more attractive workplace will require more in-depth research on how each aspect is achievable at that specific organization. However, this model gives a good idea of what aspects to keep in mind.

3.4 QUALIFICATIONS DEVELOPMENT

Industry 4.0 will according to Kagermann et al. (2013) bring with it a change in what knowledge that is required of the people working with its technologies and systems. It may require changes in the competences, specializations and general skills that employees and employers possess. At the same time, the employees' skills and knowledges may serve as important resources in the future when developing and changing the workplace. Therefore, this subject is included to provide context to the education and learning processes that people may face in the future, in addition to describing the importance of both employee and employer involvement in learning.

In any organization, the employees' knowledge and creativity is an important resource to utilize and develop. In order to do that, they must be provided an opportunity to expand their skills and competence through learning. Learning is defined by Abrahamsson et al. (2016) as the process of creating new knowledge and replacing old knowledge. When utilized in organizations, one of the goals is to develop employee competence. Competence is described by the authors as a person's knowledge in relation to a specific task. An employee with competence in a certain task is not only able to complete the task successfully but can also understand and work to develop that task. To achieve this, the authors state that employee must have room to reflect on the task, understand its context, and be able to combine their theoretical and practical knowledge of the task. In addition, the organization must provide opportunities for the employees to apply and share their knowledge to enable them to learn from one another, and possibly allowing the organization itself to learn.

Providing ample support for learning, room for reflection and for knowledge development in the employees' work can, according to the authors, have several benefits. These can include more effective and safer work, better communication between people within the organization, and employees that are more engaged in the development of their work. This is because people are often more positively inclined towards changes and processes that they had a hand in creating. However, learning isn't strictly a positive thing, as it can have negative aspects. For instance, as mentioned by Abrahamsson et al. (2016), people may develop other knowledge from their work that actively conflict with the intended purpose of learning processes.

As for methods of organizational learning, Abrahamsson et al. (2016) bring up dialogue as a useful learning tool as it can promote listening to one another, cooperation and inclusivity. For instance, democratic dialogues can be held in smaller groups where work experience can be used as a starting point for discussion and everyone's opinion can be taken into account. During these dialogues, people can learn new things and discuss their experiences.

Other methods are brought up by Kock (2010), who begins by categorizing learning processes as either formal or informal learning. Formal learning refers to conscious and intentional learning, often by holding internal or external courses for people to develop knowledge. It is generally more organized and planned than other methods of learning. Those other methods fall under the term informal learning, which is learning done during the daily work and reoccurring tasks and can in my opinion be defined as more subconscious learning. Examples of this include participation in development projects, meetings, job rotation and more. According to the author, it is important to note that neither of these types of learning are inherently better than the other. Informal learning can lead to more practical knowledge, but it needs to be compensated with formal learning, as gaps in knowledge may otherwise occur. Furthermore, participating in formal learning such as courses can help improve the amount of knowledge people absorb during informal learning. Therefore, the author recommends a combination of both formal and informal learning to optimize people's learning potential.

3.5 CHANGE IMPLEMENTATION

The implementation of Industry 4.0 would bring many changes to workplaces, organizations and work tasks with it. If these changes aren't handled properly, they may cause issues with or conflict with the employees present.

Organizational change is described by Jacobsen, Thorsvik, & Sandin (2002) as occurring when, in an organization: new elements are introduced; existing elements are connected or separated; or when existing elements are removed. These elements can be anything from departments and job positions to work tasks and locales. The authors continue describing that organizational change has several dimensions of classification. For example, changes can be evolutionary or revolutionary in that they can be the result of several incremental changes over time, or they can be spontaneous responses. The other dimensions include whether the change is proactive or reactive, in addition to whether the change affects the organization structurally or culturally, and whether the changes were planned or not. Depending on how the organizational change is classified, the procedure to manage and handle the change and the effects thereafter can vary.

3.5.1 Human resistance to change

When implementing organizational changes, it is according to Jacobsen et al. (2002) common that these changes face some resistance from the people affected by them. This resistance can according to Pieterse, Caniëls, & Homan (2012) take many different shapes and forms. Some examples of resistance include people willfully reducing their work pace, acting more withdrawn or actively sabotaging the change process. Other examples include striking to protest the change, or symbolic sabotage by going against company cultures. Jacobsen et al. (2002) list ten different possible reasons for people to be resistant to changes, which are detailed in table 2.

Table 2: A list of possible reasons for people to resist organizational change

Reason	Description
Fear of the unknown	Leaving a certain, secure state of work for a more unsure one
Psychological contracts	People may have unwritten expectations that may be broken by change
Loss of identity	People may have built a sense of importance for the work they do, which may be challenged by change
Symbolical order	Ex. An employee is reluctant to swap from an office they feel at home in for a new one
Authority relationships	People who perceive that their position of power will be threatened by the change may resist
Need for investments	People may be reluctant to invest time and resources into acquiring new skills and knowledge
Increased workload	Change often entails an increased workload, for a time, due to having to keep old activities going at the same time
Social connections	People may be reluctant to lose the ability to work with people they like, or to work with those they don't like
Personal loss	Changes may have economic consequences for individuals, or affect their career possibilities
Stability for external actors	External actors such as customers, suppliers and entrepreneurs may be affected by changes within an organization

While resistance can hinder the implementation of changes, Sveningsson & Sörgärde (2015) describes how it also has the potential to be constructive. There are few change implementation processes that go through precisely according to plan. When presented with change, it is seen as natural that the suggestion may be picked apart, criticized and reimagined by the people that will be receiving the change. Some may see this as those people working against and opposing the person driving the change implementation. However, the authors describe that it is important to try and understand the reason for resistance instead of trying to eliminate it. The people resisting a change often view it from a different perspective than the one driving it. The differing perspectives should according to the authors be utilized through dialogue and discussion in order to better shape the proposed change to better fit both parties. Trying to dismiss or refute the perceived resistance may instead incite real systematic resistance from the ones giving feedback.

3.5.2 Non-human resistance to change

People aren't the only possible sources of resistance in organizations. As Langstrand & Elg (2012) describes it, organizational changes can be met with non-human resistance. This resistance can come from existing systems, organizational structures, parts of the change being unsuited for the situation and more. The authors define four types of non-human resistance: preexisting anti-programs, latent anti-programs, inadvertent creation of anti-programs and ineffective non-humans. The first type includes existing systems and procedures effectively opposing the planned changes. The example by the authors is an existing accounting system that bases financial results on the number of producing hours conflicting the implementation of a production pace based on completing customer orders just in time. The second type of resistance, latent anti-programs, includes situations where changes are made based upon current conditions. While these changes can be beneficial at the time they can, according to the authors, result in future changes disrupting the entire system. The third type of resistance comes from changes inadvertently hindering themselves, for example by changes meant to save time introducing steps and procedures that ultimately take more time than before. The final type of non-human resistance that Langstrand & Elg (2012) includes parts of a change that don't contribute to the goal of the change. An example of this would be implementing checklists and whiteboards to allow for more effective planning, only to have those resources be abandoned or used for other purposes.

4 Methods and Implementation

The following chapter describes the methods I have used and the processes I have followed to gather information, analyze contexts and more. In addition, I also describe why and how I utilized these methods. The chapter ends with my reflections on how I utilized the methods and what I might have done differently.

4.1 PROCESS

The process of this thesis project progressed between several steps. The first step focused on preliminary planning of the project, in addition to setting up deadlines. The second step consisted of surveying SSAB and the control rooms there. While working with this step, I performed several visits to the company, during which observations of the workplace and interviews with different people related to the control rooms took place. In the third step, research was done on different subjects and sciences relating to the current state and relevant to the aims and goals of the thesis project. Afterwards, the next step involved analyzing the results of the survey to draw conclusions on the current state, existing problems and possible future solutions. The fifth steps covered the development of the vision and detail how a sustainable, effective, equal and attractive workplace can be achieved in control rooms. This step included feedback interviews with operators and shift leads in order to better assess what changes would suit the control rooms. The final step consisted of working to validate the results of the vision development by comparing it with other examples of similar implementation, and by presenting the results to the operators and managers at SSAB for feedback.

While the steps detail the general order of what the thesis project focused on, the actual work process followed a more iterative design by going through several phases. According to Wikberg Nilsson et al. (2015), an iterative process doesn't follow a normal process structure where the work is focused on one phase at a time and previous steps are considered to be finished. It instead repeats the work process of planning, analyzing and so on while the work overall is focused more on different subjects during each phase. In this thesis project, each step in the work process wasn't necessarily done in every phase if the step wasn't relevant to the phase itself. The steps of the project's work process included planning of deadlines and meetings, diagnosing and mapping the current state, researching solutions and literature, developing the vision of future control room work, and confirming the relevancy of the vision. An illustration of how I worked with iterative processes can be seen in figure 5.

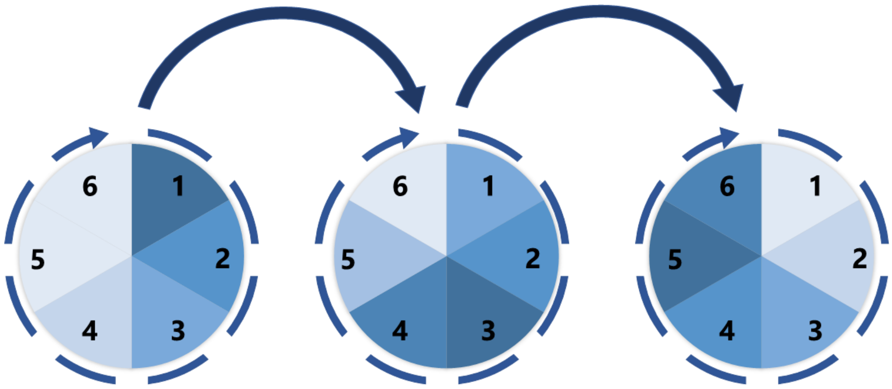

Figure 5: An illustrative example of my iterative work process. The circles represent different phases. The numbered steps are, in order 1-6: planning, mapping, literature review, analysis, vision development and validation.

The circles in the figure illustrate the phases of the project, with each number representing a step in a standard work process such as planning, mapping, analysis, development and more. The colors indicate how much focus that I put on that step in each phase, with darker colors indicating a greater focus. Thus, the illustration shows how each phase shifted the focus of my work. For instance, in the earlier phases I put more focus on planning visits and setting deadlines, as indicated by a darker color in step 1. In later phases my focus shifted towards mapping the current state, analyzing the context using literature, working on creating concepts of a vision and more. While I was moving forward in the project, I still worked with the other steps in the process, albeit spending less time on them if compared to another phase.

This iterative work process was chosen for this thesis project to more effectively manage my time and focus, in addition to allow me to return to and, if needed, rework the previous steps and phases of the project. For instance, I returned to perform more literature reviews when encountering an interesting and relevant subject during the analysis phase.

4.2 PROJECT PLANNING

The first step of planning the thesis project was to examine the available timeframe in order to better plan the work. The phases of the project were then determined using the project description from the larger research project, in addition to getting inspiration from the lifecycle of a system or product (Osvalder, Rose, Karlsson, Eklund, & Odenrick, 2015). The lifecycle includes stages such as need-finding, planning, conceptual design and so forth, which can be likened to the stages of a project. The order of and the focus of each phase of the project was chosen by taking inspiration from the steps of a system's lifecycle. Additional planning was be done at the beginning of each phase, where more precise deadlines for meetings and visits were set, and important dates were recorded. This was based on the project planning method described by Wikberg Nilsson et al. (2015), along with the mindset of the plan not being static by continually updating it throughout the project.

4.3 CONTEXT MAPPING

In order to learn more of the context of the control room work at SSAB, and to map the differences and similarities between the different workplaces, four visits to the industry in Luleå were performed. The first three visits focused on different sections of the steel production process. The three sections visited were the continuous casting section, the crude iron processing section, and the blast furnace section. A total of seven control rooms were visited, where three of them were located in the continuous casting section of the production process, two were in the crude iron section while the last two were in the blast furnace section. During each visit, a manager or shift lead of the section accompanied me to the different control rooms where I observed the workplaces and interviewed the managers, shift leaders and the operators of the control rooms. The focus of these visits was to build an understanding of the current state. The fourth visit was done near the end of the project and focused on gathering feedback from the control room operators and shift leads of the continuous casting section on the progress and conclusions that I'd made.

The managers and shift leaders who accompanied me, listed in table 1 were recommended by my contact person at SSAB. They were recommended for their knowledge and experience of the different sectors to help me get a clear understanding of the work processes and conditions of the different sectors. The table also includes where the operators who participated in interviews worked

Table 3: A list of the occupation of the guides for the visits to the different sections of the production, and the sections where the operators involved in direct interviews worked

Visit	Occupation	Section
1	Manager	Continuous casting
1	Operator	Continuous casting
1	Operator	Continuous casting
1	Operator	Continuous casting
2	Manager	Blast furnace
3	Shift lead	Crude iron processing
3	Operator	Crude iron processing
4	Shift lead	Continuous casting
4	Operator	Continuous casting

4.3.1 Interviews

Interviews are, according to Wikberg Nilsson et al. (2015), meetings with a user or a subject of interest in order to gather information about experiences, opinions, attitudes, behavior and more. Interviews can be performed at varying levels of structure. The authors describe more structured interviews to have more precise framing of questions and answers while less structured interviews are more open-ended and have less strict questions, acting more like conversations with the interviewed person to learn more about a subject. Regardless of the level of structure, the authors recommend creating an interview guide, which is a list of goals for the interview: questions you want answered, subjects you want clarified and more.

I used interviews to gather information about the control rooms work from the control room operators, shift leaders and managers in the production. This method was chosen in order to gain a better understanding of the control rooms by relying on the experiences and expertise of those who have worked in them. The interviews were done during the four visits to the steel production, where the first three focused on gaining an understanding of the production processes, the control room work, working conditions, training and more. The fourth visit focused on gathering feedback on the results I had at that time from the operators. The interviews were semi-structured, where I had predetermined questions and subjects that I needed information about. The questions were mostly open-ended, in order to avoid directing answers and to learn as much as possible about the control rooms. All but one of the interviews took place primarily in the control rooms, where both managers, bosses and operators were asked and answered questions. The interviews done were both open and direct interviews. In the open interviews, most if not all of the operators present engaged in answering questions, creating open discussions. In the direct interviews, one or a few operators were asked questions, rather than involving everyone in the control room. During the direct interviews, I sat down with the interviewee at their workstation and asked them to clarify how their duties were done, if there were parts of the job they wanted to change, in what way, and more. The answers and information I received were documented in writing by taking notes. The list of subjects and questions that I had sought to clarify can be seen in appendix 1.

4.3.2 Observations

Observations are, according to Osvalder, Rose, & Karlsson (2015), a method to gain an understanding of a situation without affecting the ongoing process by observing how people react and act in a given real situation. Observations can be conducted directly by having the observer present on site or indirectly by recording the subjects without being present. Furthermore, the authors describe that observations can be systematic or unsystematic, wherein the observer in unsystematic observations record everything of interest without seeking out any information in particular. Systematic observations follow a more defined schedule, where the observer often knows what events or processes that will deliver useful data.

During this thesis project, I performed unsystematic, direct observations during three visits to the steel production. By visiting the control rooms and observing them myself, I gained a better understanding of them than I would've gotten from second-hand descriptions of the workplaces. The goal with the observations was to, in each control room, observe and note the differences and similarities between computer systems, working environments, the perceived attitude of the operators to their work and the interactions between employees. In addition, I noted how the working environments around the control rooms looked like and worked while I was being guided by the shift leaders or managers. Since the observations of the control rooms were performed during the same visits as the interviews, they focused on noting how the operators other than the interviewee worked while I was there. Any notable observations were recorded by way of handwritten notes.

4.4 LITERATURE REVIEW

My primary method of searching for and acquiring literature to review was to utilize online databases of articles. The databases used were Google Scholar, Web of Science, the LTU database and Scopus. In order to find relevant results, I filtered my searches using search terms related to the subject at hand. Examples of these terms include "sustainability", "production", "augmented reality", "steel production" and more. As reading every potentially useful article wasn't feasible, and in order to help validate the articles, I made my selection for reading and consideration based on their date of publishing and the amount of citations they had. An article being widely cited lends credence to its validity, while accounting for the publishing date helps avoiding potentially outdated and irrelevant information.

In addition to searching through databases, I also utilized the varied course literature that I've acquired during my studies in human work science and production design. Furthermore, I also acquired literature based on recommendations from other members of the larger research project that this thesis project is a part of.

4.5 ANALYSIS OF CONTEXT

The first step of my analysis involved categorizing problems and aspects of the control room work that I identified during my context mapping according to different themes. This was done according to the method of thematic analysis, as described by Braun & Clarke (2006), with the purpose of organizing my analysis and finding common problems and aspects between different control rooms. Thematic analysis entails identifying themes in gathered data in order to gather information under different categories. The themes I categorized according to were areas where I believed technologies and systems, including those from Industry 4.0, could provide solutions or improvements.

Once categorized, the analysis of the current state of the control room work was done primarily through comparing the gathered documentation and information with reviewed literature. This included comparing the situations and problems of control room work with solutions and systems presented by literature, primarily those related to Industry 4.0. I also looked at the current state to identify positive systems and areas in order to analyze how they would be impacted if the proposed changes were to be implemented. Comparing aspects and problems of the current state with literature allowed me to find inspiration in potential improvements, while also helping me identify potential problems the implementation may cause beforehand.

4.6 CREATION AND VERIFICATION OF SOLUTIONS

With my analyses in hand, I started examining and theorizing how the changes and improvements that I'd developed to see how to adapt them for implementation in the current control room work. This included studying which changes that could be combined with others, and how that combination could be designed. The selection of changes was primarily based on my own interpretations and analyses, however I also discussed the implementations together with my colleagues from the larger research project. This helped me validate and reflect on the solutions and changes that I had chosen for my vision.

In order to verify the ideas and solutions included in the vision for future control room work, the ideas were presented to the operators and managers for feedback. Since the operators and I possess different knowledge and experience of the context, *boundary objects* such as storyboards were used to present identified problems and ideas. Boundary objects are described by Dempsey et al. (2011) as methods or objects that can be utilized to provide a shared understanding and bridge gaps between different groups and parties. There are three characteristics of a boundary object described by the authors:

- It must establish a shared language that individuals can use to represent their knowledge.
- It must provide the means for the individuals to learn about their differences.
- It must facilitate a process for the individuals to jointly transform their knowledge.

The boundary objects were used in this project during meetings with the operators, where they helped make my thoughts and ideas easier to convey to the operators, while also making their feedback easier for me to understand. They were also used when I presented my work to colleagues when looking for feedback and input.

4.6.1 Storyboard

Storyboards are, according to van der Lelie (2006), a way to communicate aspects of design to multiple people from different backgrounds by visualizing a theoretical scenario or experience. Storyboards are made by creating several illustrated panels, each describing an event in a theoretical situation, with the goal of visually explaining strategies, work processes and more. By describing the chain of events in the theoretical scenario visually, it is according to the authors made easier to identify potential problems and understand the described process beforehand. This method is similar to the scenario method described by Wikberg Nilsson et al. (2015), where a story of a user utilizing a product is created to identify potential problems and evaluate concepts. The addition of the illustrative element to storyboards allows the scenario to be more easily understood by parties not involved in the creative process.

Storyboards were used in this thesis project as a method to describe and illustrate potential problems that may occur, and efficiently describe how certain proposed solutions would work. They were designed by first using sketches to try out designs and stories that I could use, after which the storyboards were recreated digitally. The illustration style of the storyboards was made somewhat undetailed, for example using simple stick figures to represent people. This was done so that the proposed solution wouldn't be perceived as a "finished" solution that didn't need changing, which would discourage any feedback more ambitious than "change the color". A simpler design made it easier for people to give more impacting feedback. Using storyboards also made presenting and explaining my ideas and analyses to others easier. Creating these storyboards allowed me to better reflect and focus on the problems and solutions that I applied this method to when creating the illustrations.

4.6.2 Scenario-based evaluation

Stories and scenarios are useful in demonstrating a function or solution and explaining how it would work. However, speculating about future developments in technology always runs the risk of the things developing in a different way than what you'd have thought. In order to speculate on and evaluate these alternate outcomes for the changes and solutions that I'd brought forward, I was inspired by the scenario-based evaluation method presented by Wikberg Nilsson et al. (2015). In this method, a product or concept is evaluated not only according to the base specifications, but also according to new and modified specifications. For instance, while a product may have been designed to sustain the daily use for one person, what would happen if two people used it each day? The purpose of this method is according to the authors to better create products and solutions that fulfil the needs and wants of a more varied userbase.

The scenario-based evaluation method inspired me to view and analyze the solutions and changes from Industry 4.0 that I had deemed useful from other perspectives. I did this by looking at a technology or system that could be beneficial and tried to imagine scenarios where that technology could be misused or cause more problems than it solved. This was done primarily by imagining the best and the worst outcome of implementing a change, which allowed me to better identify faults and problems that would need addressing for a successful implementation. Material based on the scenarios that I created were utilized during my final feedback-oriented visit to the SSAB control rooms. By bringing visualizations of and presenting my positive and negative outcomes of Industry 4.0 to the operators and shift leads, I was able to better explain my reasonings and theories to them. The visualizations used can be found in appendix 2.

4.7 CREATING THE VISION

In order to present the vision more effectively, the vision was inspired by the scenario- and the scenario-based evaluation methods. As described by Wikberg Nilsson et al. (2015), scenarios are stories of a user utilizing a product or service, with the purpose of identifying faults, problems and alternatives. Creating scenarios to describe the vision helped illustrate benefits of the changes I'd imagined. However, future speculations can be uncertain, and changes may not have the effect or may be utilized in a different way than how you expected them to be. During my analyses I kept that fact in mind and, inspired by the scenario-based evaluation method, tried to imagine different outcomes or effects that any changes might have. In order to better illustrate how varied the implementation of Industry 4.0 can be, I used those different outcomes to create different scenarios. Each scenario depicted different potential outcomes of implementing Industry 4.0, where one or more aspects were exaggerated to more effectively convey the differences between scenarios.

4.8 REFLECTIONS ON MY METHODS

Visiting several different control rooms at SSAB helped me get a better overview and understanding of the general control room work. Observing the working environments gave me a better understanding of the work, but I found that the interviews were more effective in gathering information. This was likely because I performed the observations while performing interviews, meaning I focused mostly on asking questions and documenting responses. There is a possibility that there was more that I could have learned had I performed visits focused on observations, but I feel that the information I did gather is still adequate. There were clear similarities in the structure of work tasks even between control rooms with more practical tasks out in the production and those where the operators rarely left. Furthermore, visiting several control rooms helped emphasize the existing differences that I did find, while interviewing both operators and managers gave me a better sense of perspective over the control room work. During my visits to the different sections, I always had a manager or shift lead in that section accompanying me to the control rooms and through the production. This was necessary for my safety's sake, and so that I would find my way, but I have considered whether the presence of a manager may have affected the answers that the operators gave me during my interviews.

While the interviews I performed gave me a good amount of information and context to work with, I believe the contents could have been worked on more. In my interviews, I didn't put as much emphasis on the attractiveness of the work as I now wished that I'd had. I could have asked questions such as why they worked there, what parts of the work that they liked and what changes that they would dislike. While I believe the work with the project still went well, my recommendations and analyses could have better taken into account their opinions had I focused on that earlier. Instead, my earlier questions focused more on understanding the control room work and structure in general. Furthermore, as my interviews followed a semi-structured design, the focus of each interview varied from person to person. This did give me a wider picture of the control room, making me feel that it was the right choice. However, I could have arranged more structured interviews later in the project to focus more on subjects such as attractiveness and future challenges to complement my semi-structured interviews. As it is now, I feel that I lack some operator feedback on what that is attractive about the work and what changes to go for and which to avoid to keep it attractive.

One potential effort to gather context information that I initially planned but passed up on was benchmarking other industries. This would have been useful in possibly getting a better picture of control room work, or in gathering ideas for improvements and changes. However, given the timeframe and that this project is done by me alone, I decided to omit that method and settle for the results that I've gathered without it. Another method I had originally planned for, but ultimately replaced, was to perform a workshop with the operators to gather feedback on my conclusions and solutions. Due to having difficulty in planning a workshop meeting with the operators due to scheduling, I decided to instead perform a similar visit to my previous ones. The results from that visit were still very useful, so I feel that a lack of a workshop didn't greatly affect the project.

5 Analysis

This chapter begins with a description of the current state of control room work at SSAB that is based upon information from interviews with the operators and observations of the working environments. It includes a summary of the visits to the control rooms in addition to descriptions of how training takes place and what planned or desired changes that existed among the employees. In relation to the context description, this chapter includes more subjective opinions and reflections from the control room operators and from myself.

The chapter continues by detailing the results of my analyses of the information gathered of the context and current state of the control room work at SSAB. These analyses consist of my personal understandings of the context, comparisons to literature and my recommendations for improvements and solutions. They are based on the literature gathered and presented in this thesis project, and on theories learned during my studies.

The solutions and suggestions that I've detailed in this chapter are based on the identified and categorized potential issues. My choices of solutions are also based on examples of technologies and systems that I believe would improve the control room work, without necessarily solving existing problems.

5.1 SUMMARY OF THE CONTROL ROOM WORK

A common factor for all control room work that I deduced from observations and interviews is that it can entail a lot of waiting, since the job isn't very active outside of addressing problems. Many parts of the subprocesses don't require more interaction by the operators beyond pushing the correct buttons and inserting the correct values. At the same time, addressing problems can require the operators to quickly figure out a solution, which may entail manually working on the machines and leaving the control rooms. This means that the job could be very static in one moment, while being active and hectic in the next. During the more static moments of the control room work, the operators were observed to spend that downtime monitoring the computer systems and socializing with the other operators. According to operators in some of the more active control rooms, many new transfers move to other positions in the company after a short time working there due to the stressful working environment. The sources of stress in the control rooms can vary depending on the working environment and what process that is being monitored. As an example, at the control room called CAS-OB, the operators control the process of adding alloys to the steel and adjusting the temperature of the molten metal. Adding the wrong amount of alloy to the steel can render the batch unusable by the customer which can make the process more stressful for the operator, especially if you're new and uncertain in the role. A more senior operator of the CAS-OB that was interviewed also described how the instructions of alloying from the computer systems aren't very precise, meaning they must often estimate what amounts of the different materials they need to add. Furthermore, in control rooms where the operators must regularly leave to perform maintenance or other duties out in the production, those operators described some duties that take place in very remote locations where few employees pass by. This is coupled with the fact that long absences from the control rooms aren't always very uncommon, which may cause operators performing those tasks to go unnoticed for quite some time in case of an accident. Understanding that risk of danger is thus another possible cause of stress, according to the operators.

The level of detail of the information that the systems in the control rooms present about their respective processes requires operators to be able to manage a lot of information at once. Potential problems need to be quickly identified and the operators must quickly assess what solutions are needed. The operators interviewed stated that this may lead to new operators reacting slower, having more trouble finding the right solution or being more uncertain than their more experienced colleagues. Perhaps because of this, certain control rooms in the different production processes were deemed to be "more advanced" than others by both operators and shift leaders. These advanced rooms often manage the more crucial parts of the steel production process, such as the alloying at CAS-OB control room and the carbon reduction process at what was called the LD control room. When bringing in new operators to the control rooms, it is very rare to see them start working at an advanced control room. Instead, they get to start working in other control rooms in order to, according to the operators, get a better understanding and feel of control room work in general. The operators who have gained more experience and undergone certain educational programs can then apply to work in the more advanced control rooms.

When taking in and training new operators, all shift leaders and managers described having standardised educational programs for subjects required for the job like chemistry, metallurgy, workplace safety and more, which take place in locales dedicated for the educations. When it comes learning the workplace and how the control rooms work, the operators and bosses stated that all new operators are tasked with accompanying an existing operator and to learn from them. While there exist written instructions for how to perform certain tasks, most of the education consists of learning from experience. According to a manager, they also bring in former employees that are now retired to act as teachers for new operators. Regarding the length of the educational period, it was described to have taken the different operators anywhere between a few weeks to several months before they felt comfortable in their role. However, they also stated that they don't feel fully trained even after years of experience from working in the control rooms. This was explained to be because there are many problems that occur so infrequently that several years may pass between each occurrence, making it difficult to learn how these rare situations are to be handled only from experience. In addition, the shift-based organization of the control rooms mean that even if a rare problem occurs, only one of five shift teams will gain the experience of working with the problem.

5.2 PLANNED AND DESIRED CHANGES

From the interviews with the operators and shift leaders and the observations of the control rooms, several examples of planned or desired changes were identified. The operators and shift leaders at the crude iron processing section described how SSAB was currently working with automating the overhead cranes that the control room operators manually control today. This would effectively remove a step of the work process in those control rooms. The automation of work was something the operators in the control rooms had varying opinions of. Some control room operators managing the overhead cranes wanted for the work to be more remote controllable so they could work from home.

When asked about automation, some operators felt that the more menial tasks such as pouring in cooling agents into the casting process should be automated. However, automating critical tasks like managing casting temperatures could according to them lead to prolonging operators' reaction times in case of accidents or issues. This would be due to building up the assumption that automated systems rarely need intervention. When asked about the challenges with changes in the future, one shift lead pointed to knowledge development being a potential hurdle when they move towards a more digital production. They saw such changes under Industry 4.0 as inevitable, but worried about how many of today's employees were according to them more practically suited than digitally. Teaching them in handling a more digital production may be difficult.

Some managers described how they planned on increasing the number of operators in certain control rooms. The purpose of this was to make it easier to fit in the training of new operators in those control rooms without disturbing the production process too much. This was something that the operators of certain control rooms, specifically the CAS-OB, desired as well. They argued that the work of today would fit three operators better than only two, since the two production lines needed managing at the same time as work needed to be done outside the control room.

5.3 A WORKPLACE WITH POTENTIAL FOR IMPROVEMENT

During my visits and interviews at SSAB, there were several different aspects of the control room work that I saw a possibility for improvement. These aspects have been summarized and categorized into four possible areas of improvement: stress, training and learning, working environment, and ergonomics.

5.3.1 Potentially stressful work

After comparing the interviews with the control room operators, it seemed that certain control rooms have more problems with stress than others. Most operators claimed the work wasn't stressful until a problem occurred that needed to be solved quickly. The CAS-OB operators, however, gave other examples of possible sources of stress in their work. These sources included greater responsibility, a concern for injuries and the low number of operators. They were also the only ones that pointed out how people had transferred from the position after working for a few months, claiming the work was too stressful. This stressful work may also be negatively impacting the attractiveness of the control room for newer operators, since the application queue for working in the CAS-OB was fairly short, possibly showing a reluctance to work there. Of course, this may also be because working in the CAS-OB control room requires the operators to build an understanding of all systems in the continuous casting process, which can take years to build up.

The greater responsibility factor was explained as the reliance on the operator's knowledge in alloying the molten steel properly and on their knowledge of all the systems around them. Knowing that a wrong mixture may ruin the entire batch may cause stress for newer operators. The concern for a low number of operators in the CAS-OB control room was based on when the operators had to leave to perform maintenance. Since there are only two operators and two production lines, one operator leaving means the remaining operator must manage two production lines at once. Similarly connected to the maintenance work the operators perform, some operators have expressed concerns for working out in remote locations. The maintenance work is sometimes located where people seldom pass by, meaning an operator that injures themselves during that work may not be found for a long time.

5.3.2 Preparing for the unexpected: Learning and training

Something that all the control rooms at SSAB had in common was that training of new operators was mainly done by them accompanying a more experienced operator in order to "learn-by-doing". Additionally, the company occasionally brings in retired previous employees to educate the current staff. While these can be a very effective methods of learning, there are many parts of the control room work where the documented instructions are lacking in comparison to the employees' knowledge. As mentioned by Kock (2010), a combination of formal and informal learning may be more effective. The prioritization of informal learning today also leads to operators having to rely on the more experienced personnel and their availability. On the other hand, knowledge learned from those experienced personnel may vary depending on what tasks they have performed and how. This may in the worst cases lead to inconsistent competences between newer operators. In addition, this makes SSAB very dependent on those experienced personnel. If those experienced personnel have come up with more effective ways to perform tasks, that knowledge may be lost if they leave the company or transfer to another production section without documenting that knowledge. This, along with the "learning-by-doing" method, can also lead to issues regarding seldom reoccurring problems. Among the tasks that the operators of the control rooms must address are certain problems that can take several years for them to occur again. While there exist written instructions for some of the more severe of these rare problems, the operators may be unprepared for dealing with them due to lack of training and experience. Adding to the fact is that all control rooms work in shifts, which means that even if a rare problem were to occur, only a few operators are going to gain experience from working with that problem.

5.3.3 Working as an operator

During my visits to the control rooms I compiled a general understanding of the working environment in the steel production process through my observations and interviews. The environments that the operators work in when leaving the control rooms, like most large-scale productions, are vast and filled with heavy machinery. While there are many safety measures available, such as railings and protective equipment, there still exists the possibility of dangerous accidents. In addition, the maintenance work done by the operators often takes place in remote locations, where personnel may seldom pass by. The production locales were also loud, warm and dirty, however that is to be expected of a metallurgic industry.

In addition to the physical conditions in the control rooms, I also took note on the social working environments. With each control room having at least two operators assigned to them, no operator seemed to have to work and manage the production systems alone. However, in the smaller control rooms the operators would be left on their own if the others needed to go out to perform maintenance. This could become a problem if, for example, one of the operators were new and relied on the other's expertise, which is how their training usually works. They would seemingly either need to both leave the control room or have the inexperienced operator work alone for a time. Furthermore, working in the smaller control rooms may seem less attractive for operators than working in the larger ones, in that you don't have as many coworkers to socialize with while working.

As was previously mentioned, the locales that the control room operators visit when performing maintenance often have the potential to be dangerous. By working in remote environments away from others, an injury from an accident like a fall or incorrect machine handling may result in the operator remaining unnoticed for a long time. This can be caused by no other personnel visiting that area for work, and by the maintenance work often being expected to take a long time, making operators absence from the control room a common occurrence. However, while the operators in the CAS-OB control room were vocal with their worry for accidents happening and them remaining unnoticed, there weren't many recent examples of such accidents occurring. Nevertheless, it is a potential risk that may both avoid accidents and alleviate some stress for the operators were it to be solved.

5.3.4 Ergonomic concerns

The last category, while currently not a major problem, covers the potential ergonomic problems I had observed in the control rooms. While the maintenance tasks performed by the operators may require them to leave the control rooms, the majority of the control room work is done sitting at monitors and computers. Sitting down for long periods of time during work can have consequences for the operators health according to Arbetsmiljöverket (2011) and Hägg et al. (2015), who recommends that work tasks should be designed to break up these long periods of inactivity.

5.4 IDEAS FOR IMPROVING THE CONTROL ROOM WORK

When studying and reviewing literature on the technologies and systems of Industry 4.0, I came across several concepts that I believe could be useful in improving the aspects mentioned before. As mentioned by Rollenhagen (1997) and Karltun et al., changes for the person often requires changes in technologies and organizations. Most of these changes would require extensive development of digital and physical systems in the production processes at SSAB. While I generally haven't taken the exact implementation into account when selecting these changes, I have based my choices how realistic I believe the implementation of the changes are.

5.4.1 Improving the learning process

Regarding the issue with seldom reoccurring problems, one of the greater issues that I see is the difficulty to gain experience in dealing with them. Not only do some problems take years for them to occur again, but when they do only a few of all the operators of the control rooms will get to experience working with the problem, due to the shift-based schedule. A solution would then be to give operators the opportunity to practice these problems beforehand, something I believe VR technology may be very suitable for. VR technology is something that SSAB has already started investigating when training and preparing their employees, as is the case in the VR trials in Raahe (SSAB, 2019b). This utilization could be expanded upon, creating interactable virtual environments of the control rooms, machinery and production locales. The seldom reoccurring problems could then be recreated through simulations, which would allow operators to practice solving these problems in advance. Since the control room work often has periods of downtime, this practice could be done while the production is running smoothly. This allows for operators to train for these seldom reoccurring problems beforehand, which could help alleviate stress in critical situations. In addition, creating training material gives an opportunity to utilize the knowledge of the operators and let them take a greater part in shaping their routines.

The procedure for training new operators today relies on them following and learning from experienced operators, who sit on a lot of knowledge that isn't readily available to SSAB. Including them in the process of designing and creating the simulations for the work tasks could help with assuring their authenticity and accuracy. This would make it easier to design the simulations to take the operators' needs and wants into account, as mentioned by Wikberg Nilsson et al. (2015). Furthermore, the operators may be more inclined to use and accept this new form of training if they can take part in shaping it.

However, since there are many examples of problems and maintenance work that are seldom reoccurring, it may be unrealistic to try to prepare operators for every possible scenario. I believe improving the data collecting capabilities of the machines in the production can help in identifying upcoming maintenance and potential problems, so that operators can go through relevant training in response to upcoming problems. As Wang et al.(2016) describes, data-gathering capabilities of production systems and machines are expanding and should in the future allow for the collection and usage of more types of data. With this, I am certain it would be possible to analyze patterns and predict if a problem was likely to occur, thus allowing operators to know what maintenance that needs be done and what problems to prepare for.

5.4.2 Safer working environments

Some very suitable technologies under Industry 4.0 that could alleviate the issues with unsafe working environments are the ones associated with the Operator 4.0, more specifically the tracking technology categorized under the name "the healthy operator". By tracking the operators' location, their coworkers can more easily keep track of where they are if they need to find them or if an accident occurs. Tracking their health and biometric data as Romero et al. (2016) describes could allow for emergency personnel to be automatically contacted if the operator suffers an accident. An example of how this could work is presented in figure 6.

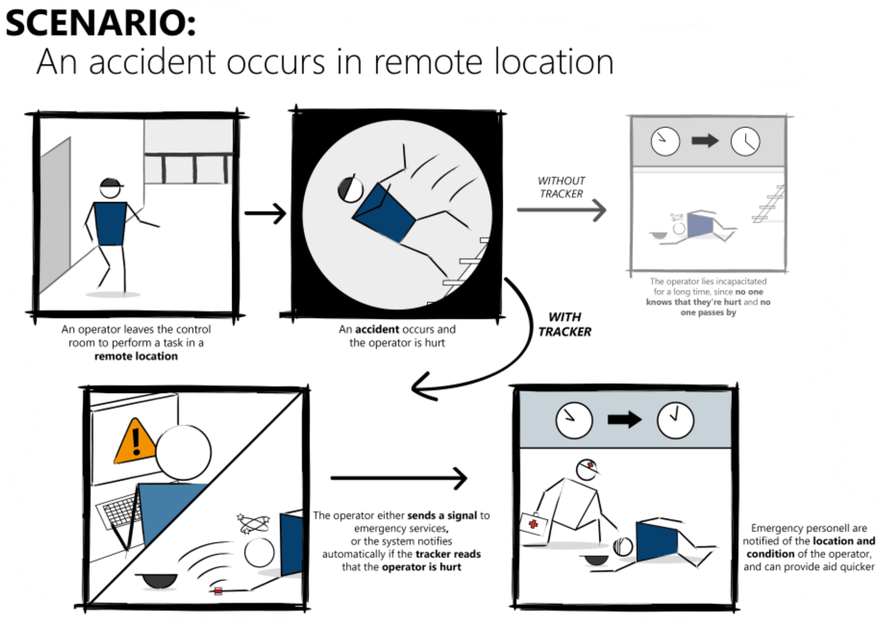

Figure 6: A storyboard describing how tracking technology can alleviate accidents at remote locations

Furthermore, the ability to warn operators who enter loud or hazardous areas, as described by Stein (2018), could serve as a reminder of what safety equipment to use and where. However, while this type of technology has many possible benefits, it can also lead to conflicts regarding the operators' privacy. Having your employer be able to track exactly where you are, how long you've been there, how hard you are working and more could cause stress from being under constant supervision.

5.4.3 Operator control capabilities

As mentioned before, most of the work in the control rooms is done sitting down, with operators only having to get up to go out and perform maintenance or solve problems. If the technologies under Industry 4.0 introduces more automation and self-adjusting machines, operators may see even fewer opportunities to leave the control rooms. People need physical variation and activity in their work to avoid static ergonomic problems according to Hägg et al. (2015). If the production is made more autonomous, in that it can readjust and manage itself according to customer orders as Kagermann et al. (2013) describes it, operators could be left with fewer active work tasks. Waiting for maintenance to be needed and problems to occur while supervising the system would be their main work tasks, meaning even more inactive periods of downtime. As mentioned by some of the control room operators, these kinds of automations weren't entirely desired by them. What they did desire were instead for more mundane tasks such as adding cooling agents to the casting process to be automated. The maintenance work and control of the process would, however, be left to the operators.

A technology that could make the current static work more mobile can potentially be found in the intelligent personal assistants (IPAs) that Romero et al. (2016) describe. The control room monitoring work could be made more mobile by allowing access to control room systems remotely through an IPA. Operators would no longer be bound to the control rooms to manage the production line or direct machinery. This could help provide more physical variance in their work, to avoid them spending too much time with sedentary work and avoiding the risks mentioned by Hägg et al. (2015). An IPA would also improve an operator's communicational capabilities, both with coworkers and with the production itself. For example, if an operator is performing maintenance and needs instructions, the IPA could help with contacting a more experienced operator for help, while also bringing up an error log from the machine itself. The IPA could also be combined with the AR technology mentioned by Wu et al. (2013) to manage the information shown on-screen. An operator could tell the IPA to display work instructions if they're unsure how to perform a task.

With the development of decentralized technologies as described by Johansson et al. (2017) and Lundmark (2019), employees would be able to manage tasks and machines remotely. While it promotes more static work, this could reduce or eliminate the exposure to potentially risky or unhealthy environments. It's not as realistic in the near future due to equipment costs, but it could allow employees to control machines without even being present in the production.

There are, however, some concerns to be raised regarding outsourcing. Outsourcing is prevalent in many industries, where parts of the production and different necessary services, such as cleaning or hiring, are left to another company to manage. If the technology for remote controlled productions are made readily available, would it lead to these jobs being outsourced and the current operators being let go? On the other hand, remote, VR controlled productions could help make the occupation more accessible. Industries would be able to more easily establish themselves away from the larger cities if a part of their workforce can work from another city. Furthermore, it could help make the job more attractive to people who don't enjoy working in loud or dirty environments like steel industries.

5.5 FURTHER IMPACTS OF INDUSTRY 4.0

Beyond the areas mentioned above, there are technologies under Industry 4.0 that would impact other parts of the control room work and the steel production in general.

An autonomous production has great potential to increase the efficiency and capacity of production systems, if Kagermann et al. (2013) is to be believed. This would make it attractive for SSAB, as self-managing systems could reduce material costs and make them more attractive to customers through adaptability. Industry 4.0 would, however, entail a great deal of effort to implement; new sensors need to be installed, new systems to handle more data and control the production need implementation, and the reeducation of their employees. For the operators of the control rooms, I believe it could also have both positive and negative implications. An autonomous production can reduce the amount of processes the operators need to manage and control at the same time, alleviating potential stress from multitasking. In addition, increasing the accuracy of and the amount of data gathered by the production could help reduce the reliance on individual operators' knowledge and experience. Certain processes of todays' control rooms, such as alloying the steel in the CAS-OB, would no longer need to rely on the operators' estimations. However, these changes would result in less operator control over the process. The work could become more monotonous for the operators, which in turn could impact their motivation and their attentiveness. Certain operators raised concerns about this during my interviews, where they spoke of how automated systems could potentially lead operators to not manage and monitor the processes as carefully. If the operators feel that the automated systems "work well on their own", they may not pay enough attention to the monitoring systems to react quickly in case of errors.

Improvements and changes in systems and machines will, in time, reduce the amounts of problems and errors that occur. However, the move towards more automation could make those errors more complicated to deal with, as they may require maintenance of both digital and physical systems as opposed to the more mechanical problems of today. This requires the control room operators' competences to change and evolve. Otherwise, the control rooms would have to continuously rely on external personnel to solve emerging problems, which would reduce efficiency. However, teaching new and existing operators who may not be technologically inclined will be challenging. It will require proper and continuous support during and after the learning process for the employees.

Beyond changing the pace of the control room work, the technologies under Industry 4.0 would more than likely entail a change of focus in the operators' work. Kagermann et al. (2013) mentions how employees will move away from routine tasks and will instead focus on value-adding and creative activities. This could contribute to making the work more attractive. Hedlund (2007) and Bakker & Albrecht (2018) mentioned how self-governing, flexible and customizable work is more attractive to younger generations. Adding more creative tasks to the control room can help make the work more varied and provide operators with a better sense of control, as their contributions shape the processes and work.

The work in general will likely become more digitally focused, requiring different competences than today's work. This, I feel, will entail a great need for knowledge development efforts for the operators at SSAB. The company needs to make sure that they don't leave their current employees behind when implementing the changes of Industry 4.0. It may be easier to train new employees in how to manage the new technologies and systems than it would be to reeducate existing personnel, but the current operators can be invaluable when it comes to shaping and implementing the changes. The experienced operators may have a good idea of appropriate changes if they can and are motivated to contribute. Including them in the development and implementation process can make designing according to their needs and wants easier. Another possible effect of changing the control room work could come from automating the physical tasks that operators perform today. Automation of reoccurring heavy or hazardous maintenance tasks could reduce ergonomic strain and risks for the operators. However, automating the tasks that take the operators out into the production may lead to newer operators becoming less accustomed with the physical production and the machines in it. This could be detrimental during large-scale problems, due to a lack of understanding of how the productions' parts work and relate to one another.

One aspect included in Industry 4.0 that can potentially have both positive and negative effects is the increased ability to gather data on the status of the different parts of a production system. As mentioned by Kagermann et al. (2013) and Wang et al. (2016), an increased data-gathering capability would allow for, among other things, the tracking of where a product is, who has worked on it, who it is supposed to go to and more. One outcome from this technology that can be both positive and negative would be the ability to track what steps each product has gone through and how well that was done. The positive side of this would be that it makes it easier to find a step in the process that needs improving, making it easier to improve and make the process more effective. A negative outcome would be it being easier to track *who* that performed a step in order to punish those whose performance is lacking. As with most of the technologies under Industry 4.0, however, I feel that the utilization of big data being a positive or negative thing relies more on how it is used, rather than the technology itself being responsible.

Finally, as with all organizational changes, the implementation of Industry 4.0 will more than likely face some resistance, both from human and non-human sources. I believe that the implementation will likely be more evolutionary, which according to Jacobsen, Thorsvik, & Sandin (2002) entails slower, incremental changes. This is because Industry 4.0 will likely require expensive new machines and digital systems to work properly. The large investments required to replace the entire production are likely not reasonable to handle all at once and will instead be done incrementally. However, this is where the non-human resistance comes in. I believe existing physical and digital systems will lack the capabilities to handle and manage the autonomous, data-gathering new machines and systems that Industry 4.0 requires. Thus, the implementation will face preexisting anti-programs, as mentioned by Langstrand & El (2012). Either the current systems would need to be adapted to the new autonomous networks, or the new machines and systems would need to be backwards compatible with the older systems. Between the two, I believe the latter solution would prove easier. The human resistance will likely come from the need for operators to change and develop their competences and knowledge in order to properly manage the new digital solutions and technologies. One shift lead mentioned during interviews that some operators lacked computer experience outside the monitoring systems. This would mean that the more digital interfaces, systems and equipment may be harder for some to adapt to. Other human resistance factors mentioned by Jacobsen, Thorsvik, & Sandin (2002) that may affect the implementation might be a fear of the unknown, loss of identity, or loss of social connections from downscaling due to automation. SSAB needs to be transparent in their changes, and provide sufficient support to existing and new personnel, in order to handle this resistance.

6 The resulting vision

Industry 4.0 is a very diverse and uncertain movement in the industry. With the amount of new technologies and systems that it brings, it also brings uncertainty in how those changes will be implemented. As discussed in the previous chapter, most technologies can have wildly varying impact on the work itself, the working environment and the employees. In order to demonstrate how different the many possibilities of Industry 4.0 are, I've formulated two scenarios; one depicting a dystopian future and one a utopian future. This chapter contains a description of these two scenarios, while also including my recommendations for how to work towards the utopian vision. These scenarios illustrate what I believe to be some of the worse and better possible outcomes of implementing Industry 4.0 in regard to the sustainability, effectiveness and attractiveness of the control room work. Some parts of the visions have been exaggerated in order to better illustrate the differences between the outcomes. I've primarily based the scenarios on my own reflections and speculations of what the potential positive and negative effects of Industry 4.0 on control room work. I also based them on the thoughts of the control room operators gathered from interviews, and on discussions with my colleagues from the larger research project.

6.1 A DYSTOPIAN FUTURE

This section will describe my dystopian scenario of the work at SSAB after the implementation of Industry 4.0. This scenario is based on the potential for misuse of the capabilities of the new technology and a disregard for employees' needs and wants. It was created based on the question "How could changes and new technology be implemented that would be detrimental to the control room work?".

In future dystopian steel productions, almost everything is automated and run by robots. While allowing for a more effective production, the control room operators who previously managed the production lines now only perform maintenance every now and then on the machines. As such, many of them have been let go, leading to the remaining operators not having many coworkers left to socialize with. Others have quit on their own accord, as they feel like the job no longer takes their needs and viewpoints into account. When maintenance needs doing, repeated strenuous and heavy work tasks are excused as the operators are equipped with exoskeletons. However, this equipment isn't adjustable to the user, meaning many operators smaller or larger than average cannot comfortably wear them. Beyond the maintenance work, the operators don't do much other than wait for more maintenance, since the automated systems and machines takes care of any monitoring tasks. If there are any tasks left beyond maintenance that require manual control of machinery or tools, they are remotely controlled by outsourced personnel from countries with cheaper labor costs.

The work that the remaining operators perform follow strict instructions and steps. The operators must wear AR-goggles that show them how they are supposed to perform their tasks, offering no room for creative problem-solving. As such, the work, and the operator role in general, feels unsatisfying and is no longer seen as qualified work. The instructions themselves are designed by the manufacturer of the machines and often contain steps that are unsuitable for specific workplaces and to the operators. Examples include unergonomic working positions and a lack of space to work in. The operators aren't provided any opportunity or possibility to voice concerns over or come with suggestions for improving these instructions.

When the operators arrive at work, they must equip work clothes equipped with tracking sensors. These sensors can monitor their location, health and biometric data. With this, the operators' bosses keep track of whether the operators take too many breaks, spends too much time in one place, or isn't working hard enough. Furthermore, with the increased number of sensors gathering more data, it is possible to monitor the progress of any product going through the production at any time. Management can, for example, track exactly who that was responsible for the maintenance of a robot that malfunctioned. This is demoralizing for the operators, as they work in constant fear that any error made will cause them problems with their bosses.

A summary of some of the main aspects of this dystopian vision can be seen in figure 7.

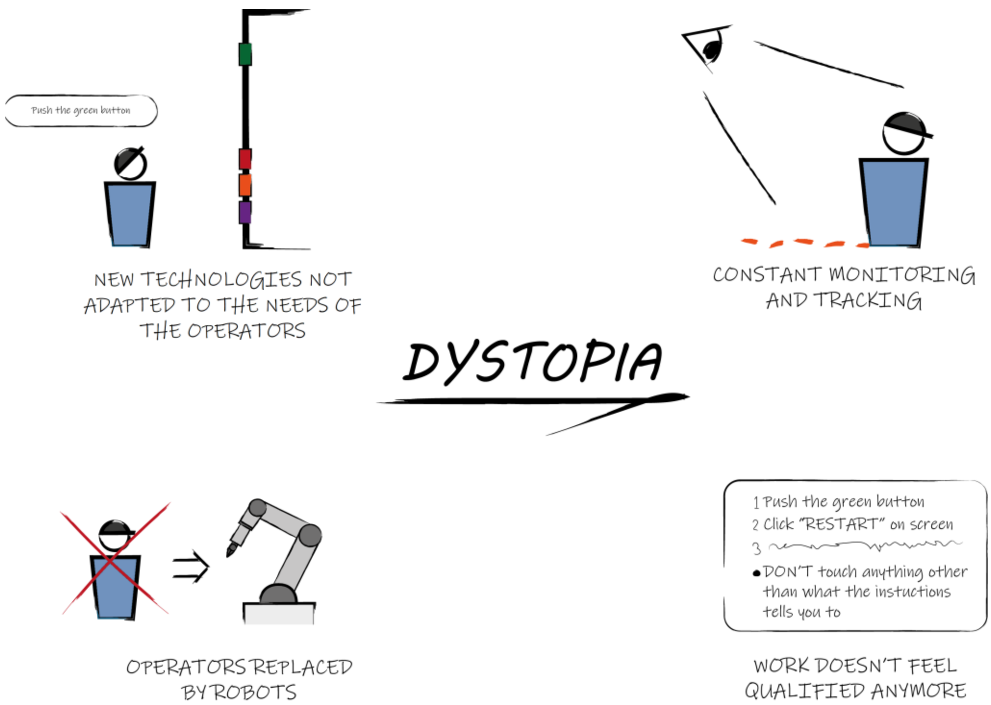

Figure 7: A summary of the negative potential outcomes of Industry 4.0 for control room work

6.2 AN UTOPIAN OUTLOOK

While the dystopian scenario predicts a bleak future for control room operators, the utopian scenario presents a future where the new technologies and systems under Industry 4.0 are implemented and utilized differently. This vision of future work was based on the question "How can changes and new technologies be implemented to improve or bring positive change to the control room work?". The positive changes and improvements were determined from operator feedback and from reviewed literature on the properties of a good working environment.

Instead of replacing employees altogether, automated robots and systems perform the more monotonous tasks for the operators. The operators now spend less time in potentially dangerous environments and perform fewer heavy work tasks. They instead work more with tests, evaluations, development work and maintenance, allowing them to improve the effectiveness, efficiency and quality of the production. When changes are to be made, they now have a hand in developing and implementing them. With this, they have more control of and responsibility for the work they do and the machines and systems they use.

Operators are now provided with new learning material in the form of simulations and VR. With them, the operators can practice working with the machines and train with handling seldom reoccurring problems, in case they occur in the future. The more formal learning methods, such as simulations, courses and written instructions, are still combined with informal methods such as learning from and discussing with coworkers. All training and learning material are now created with the feedback from the operators in order to help make them more accurate, relevant and useful for the users.

The control room work has been made more mobile through the use of IPAs and AR displays. By communicating with the IPA, the operators can monitor data from the control rooms, control machines remotely and be warned when entering potentially dangerous areas while out working. For operators that need instructions, the IPA can be used to display and manage instructions shown on the AR display, or it can be used to easily contact a coworker for guidance. The AR display can also highlight places and parts of a machine that the operator is looking for or need to interact with.

To ensure the operators' safety when out working, they are equipped with sensors that can track where they are in the production locales. This helps the IPA provide accurate directions when needed, while also allowing coworkers to locate each other, provided they willingly share their locations. Furthermore, the location tracker also lets the IPA warn operators who are nearing potentially dangerous areas. Examples include locations where eyewear or ear protection is needed, or if maintenance is being done and large machinery is being operated in the area. The sensors also allow for monitoring the operators' health values, should the operator be willing to share that information. If an operator is hurt or incapacitated while out working, the trackers can send a signal to emergency personnel detailing current status, position and how long they've been there.

An illustrative summary of the main aspects of the utopian vision can be seen in figure 8.

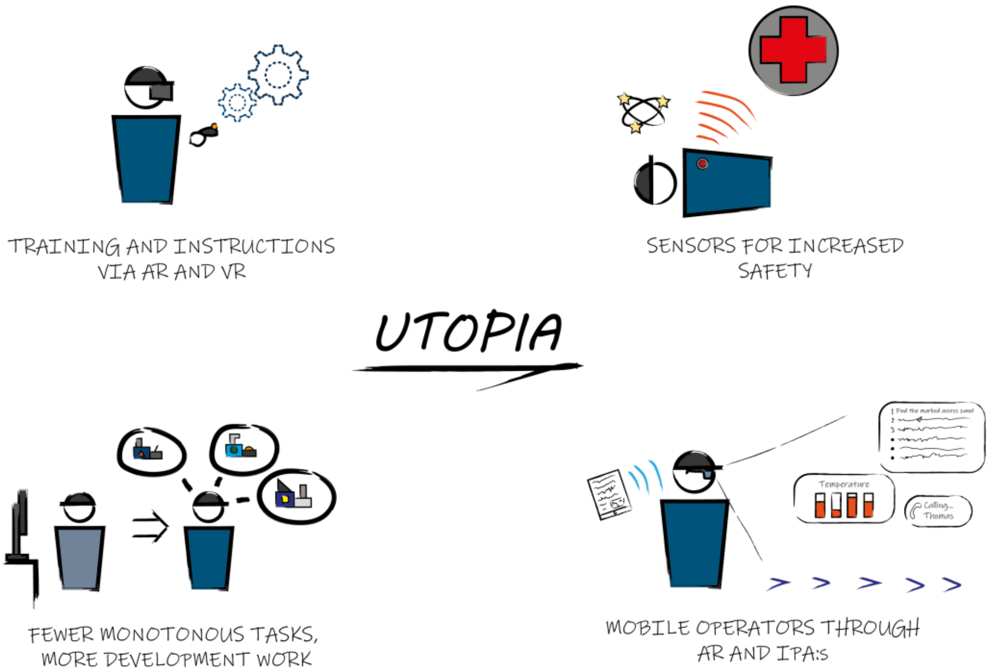

Figure 8: A summary of the positive potential outcomes of Industry 4.0 for control room work

6.3 MOVING TOWARDS UTOPIA

As exaggerated as the dystopian and utopian scenarios are, my hope is that they illustrate a clear point: Industry 4.0 has the capability to bring both positive and negative change. How good or bad the changes are depends much on how they are implemented and utilized. Primarily, the responsibility to properly adapt and implement the technologies and systems of Industry 4.0 falls on the organization and managers at SSAB. They need to make sure the operators' needs and wants aren't cast aside when implementing changes, while also providing ample support during these changes to help operators adapt. However, this also requires that the operators are actively involved and committed to help with adapting and changing their workplace and work tasks. Below I've summarized the efforts I believe are needed to succeed in implementing Industry 4.0 at SSAB and work towards the utopian vision.

- An implementation of Industry 4.0 would bring changes to and impact the control room work. Thus, I believe it is important that the operators are given an opportunity to review and affect these changes and how they are implemented. Representatives from the operators can be included in the groups responsible for designing change implementation for the production. This would allow for them to better control and impact the implementation, and better ensure that their needs and wants are taken into account when designing the future control room work. Furthermore, their addition could allow them to bring valuable experience and a different perspective on potential changes. In addition, it can allow for more operator control and involvement in shaping their work. This can according to Hedlund (2007) and Bakker & Albrecht (2018) improve the attractiveness of the work and promote work engagement.
- It's difficult to guarantee someone's engagement to participate, and even more so to implement changes that won't face any resistance. Furthermore, according to Sveningsson & Sörgärde (2015) the ones driving a change implementation will often view it from a different perspective than the ones who will be affected by it. They may see problems with the change that weren't apparent to the ones designing it. Clearly communicating future changes to the operators can help bring forward concerns and ideas for improvements. Questioning management decisions can be seen as resistance, but according to Sveningsson & Sörgärde (2015) even criticism from the operators can be constructive if the change implementers are open to feedback. Operators may also be less inclined to resist changes, whether intentionally or not, if they can better understand and impact them.
- Implementation of further automation of the steel production is bound to happen eventually, as is evident in current industry trends and current efforts at SSAB. I believe it will likely result in a lower number of operators needed in the production, as there will be fewer work tasks to perform. It also has the potential to greatly improve its efficiency, especially if a more autonomous production is achieved as described by Kagermann et al. (2013). However, it was evident from my interviews that the employees often possess a lot of individual experience and knowledge that isn't documented. In addition, they often possess an understanding of the entire steel production process and know how the different steps of the process relate and affect each other. Rather than laying off existing employees that are made redundant, it may be better to work with reeducating them so that their competences aren't lost.

- Beyond the obvious challenge of replacing the physical production and its machines, SSAB will also need to handle the new demand for more data. According to Wang et al. (2016), many of the technologies and systems under Industry 4.0 rely on vast quantities and types of data that I believe either isn't gathered or isn't utilized today. Thus, I believe it would be wise to document and categorize the data required for the desired future production to work beforehand. It would allow for better planning of what data that needs gathering and where it would be utilized.
- The changes in technologies and systems requires control room operator competences to change and evolve. In order to make learning more effective, SSAB should continue providing opportunities for operators to learn from each other, as there are many things that are difficult to learn through formal methods. Furthermore, formal instructions often focus on one task or process at a time. When following and observing their coworkers, new operators can learn not only of how a specific task is performed, but also how the task interacts with other processes and experience the working environment. However, as mentioned by Kock (2010), formal instructions and learning material is still needed. Involving operators in the creation and design of their work instructions and training material helps utilize their knowledge of the work and gives them opportunities to impact and control it as well. They can provide feedback on the design of the material and its contents, while possibly identifying aspects that may otherwise be overlooked.
- The control room operators need knowledge in how to manage and maintain the new digital systems that Industry 4.0 would entail and require. This would help avoid having to rely on external personnel to solve problems, while also giving operators a better opportunity to understand and control the systems they work with. Employee control is according to Thylefors (2015) important to promote a good working environment. Thus, ensuring employees possess the required digital literacy and providing education and training for the new systems can help.
- Utilizing simulations and VR as tools for learning is already something SSAB (2019) is working with. Based on this, and on the thoughts of both myself and managers at SSAB, I recommend that this type of learning is expanded. VR simulations could allow training for seldom reoccurring problems and for operators to familiarize themselves with the machines.

Most of my recommendations relate to involving the operators in the implementation, development and maintenance of the new technologies and systems under Industry 4.0. Part of this is in order to ensure that their needs and wants are taken into account when designing and implementing changes, the importance of which is described by Wikberg Nilsson et al. (2015). However, it is mainly because the shift in competence and knowledge requirements may be one of the greater obstacles that SSAB will face. The road towards implementing Industry 4.0 will be long, but I believe that the results show that it is a manageable and worthwhile goal to strive for.

7 Discussion

This chapter contains my reflections on the outcomes of the thesis project and critical analyses of the results I've achieved. The chapter begins with a discussion on the validity and relevance of the results. The following parts of the chapter consist of the conclusions that I've drawn, how the results compare to the objectives and aims of this project, and my recommendations for continued studies.

7.1 RELEVANCE

During my work with this project, I've tried to base as much of my analyses and results on reviewed literature. This includes my evaluations of the current state, the technologies and systems I've deemed applicable at SSAB, and the effects of the implementation of the changes. The primary purpose of this was to ensure the validity of my claims and reflections that I made during my analyses, while also providing me with a better idea of how different technologies and systems would work in practice. For example, learning the extent of the capabilities of modern tracking equipment from Romero et al. (2016) and Stein (2018) allowed me to more accurately speculate on future implementations. In addition, the literature on subjects such as human-centric design, qualifications development and attractiveness helped validate and shape my arguments for ensuring the operators have control and understanding of their work. This, I feel, helps make my scenarios of outcomes of an Industry 4.0 implementation, and my recommendations on how to move towards the better scenario, more credible.

The literature on work attractiveness, qualifications development and the technologies under Industry 4.0 I found were very useful when creating my analyses and visions. Some literature has acted more as ways to inspire and shape my way of thinking during analyses and haven't been directly referenced as much, such as change implementation in my future recommendations. However, there are a few subjects, such as HTO, that hasn't been utilized as much in general. Instead of researching and interpreting these subjects, I feel that I could have focused my efforts on other, more useful subjects. Other subjects, such as sustainability and its role in control room work, could have used more research.

Many of the recommendations I presented as the results of my studies included operator involvement and learning as important aspects to enable Industry 4.0 in SSAB. These are aspects I believe are important when trying to achieve an implementation of Industry 4.0 that is more sustainable, effective and attractive for both the company and the operators. The main argument for increased sustainability lies in the employee participation leading to a workplace with a greater social sustainability. Social sustainability can according to Dempsey et al. (2011) be improved by addressing and satisfying peoples' needs, and by promoting participation, which my results do. Furthermore, a more autonomous production capable of adjusting and managing itself can result in a more efficient and profitable industry according to Kagermann et al. (2013). This could make the results more attractive for industries.

The argument for an increased attractiveness to operators lies in the utopian control room work providing the operators with more control over their work. In addition, a utopian operator's work would be safer with more varied work that requires expertise to complete thanks to the technologies gathered by Romero et al. (2016) under the term "Operator 4.0". With more autonomous productions, the work would also consist of fewer menial tasks.

One of the main arguments for this project being relevant to SSAB is that it can help the company in remaining competitive on the market in the future. As is evident from examining the industrial strategies of Sweden and other countries, Industry 4.0 is something many are willing to invest in and strive towards. As a company, I believe SSAB will have a better opportunity to compete with other companies on the market, should they adapt to Industry 4.0. While SSAB is an established company, the global market of today means that they have more competitors that may be capable of surpassing them in quality and effectiveness. Further arguments for working towards Industry 4.0 lies in the concept's rising popularity. A company that is up to date with the latest technologies and organizational trends may seem more attractive to customers and future employees alike. The recommendations I've provided regarding operator inclusion, control and learning can help make the control room work at SSAB more attractive for existing personnel to stay in and future employees to seek out. This would be due to them having more control, introduce more varied and interesting work tasks, while also providing a better mix of practical maintenance tasks and theoretical development and optimization tasks. These are amongst the aspects that Åteg et al.(2004) and Hedlund (2007) believe can make a workplace more attractive. Finally, regarding attracting new younger employees, I believe that the control room work would be made more attractive with the recommended changes. The involvement in learning and development of work allows for a sense of adaptability and control over the work. Having management be engaged and responsive in the development work could further help with making the work attractive. These are amongst the aspects of work that younger generations according to Bakker & Albrecht (2018) and Hedlund (2007) are more attracted to.

7.2 CONCLUSIONS

One of the goals of this thesis project was to research what changes under Industry 4.0 that were desirable to implement in metallurgic industries' control rooms. By delivering a vision of how future control room work could look like, detailing both positive and negative outcomes, that goal has been fulfilled. With the recommendations, the project also delivers guidelines to better work towards and achieve the desirable vision. While much of the work was based on the steel industry of SSAB, I believe that the recommendations are applicable enough to be adaptable to other metallurgic industries as well.

7.2.1 Objectives and aims

The aim of this thesis project was to identify and detail how Industry 4.0 can be utilized to create sustainable and effective metallurgic industry control rooms. These control rooms also needed to be beneficial to both employee and employer, while also providing equal opportunities to all employees. I believe this aim has been fulfilled with the recommendations for achieving the utopian vision. The utopian vision of Industry 4.0 promises a more efficient and value-adding production through autonomous manufacturing and smart operators equipped to handle the digitalized production. However, before achieving that vision there are several obstacles to overcome, such as the physical and digital replacement of the current machines and

systems, or the change in required competences and knowledge. These obstacles are what I hope my vision and recommendations help prepare for. Furthermore, I believe that my recommendations to include and account for the operators and their needs can help achieve a workplace benefitting both employers and employees.
Creating more extensive learning material through the involvement of the operators would also help provide more equal opportunities to learn and improve for new operators. Lastly, while based on and sometimes addressing the SSAB industry, I believe the results are still general enough to retain an applicability in other metallurgic industries.

As for the objectives of this project, the vision was able to deliver a description of Industry 4.0's potential positive and negative impact on control room work through the scenarios. The new demands on the employees, the workplace and the organization for new knowledge and technology also needed describing. In addition, the method of how to achieve sustainable and effective control rooms needed describing through a vision. I believe my analyses and the resulting scenarios and recommendations have achieved what I sought to achieve. Throughout my analyses, examining the positive and negative potential of the technologies under Industry 4.0 allowed me to create the utopian and dystopian scenarios. These help with more clearly illustrating the potential benefits and disadvantages that Industry 4.0 may bring, depending on its implementation. The utopian scenario serves as my vision of how Industry 4.0 should be implemented, while my recommendations are a description of what changes are needed to achieve that vision.

7.2.2 Answering the research questions

Throughout my work with this project, I set up several research questions to serve as guidelines and goals for my work. Below are my reasonings and answers for those questions.

- **How can the workplace and the work tasks in the control rooms at SSAB be structured and adapted to changes in systems and technologies that Industry 4.0 could bring?**

To answer this question, the principle aspects and technologies of Industry 4.0 needed to be clarified. This was done by researching the origin of Industry 4.0, a strategic effort by the German government to support the development of their industries called *Industrie 4.0*. By detailing the principles of this strategy, I could apply it to control room work and theorize the effects it would have. Industry 4.0 would bring significant changes to the control room. The production would work more autonomously with menial tasks and not require as much operator control. Meanwhile, the operator work tasks would become more focused on designing improvements, testing and maintenance. When they need to enter the production, they are supported by IPAs, AR goggles and health sensors to support them and make the work more efficient and safer. This would require a refurbishing of the physical and digital aspects of the production, while the operators need to develop new competences. Designing the new work tasks together with the operators and implementing new supportive technologies such as VR training and IPAs could help with making the transition easier and more effective.

One question that remains is how the control rooms should be structured. As the operators would be more mobile and have easier access to instructions and communication, would individual control rooms be unnecessary? A possible future could lie in centralizing parts of the control room work. The operators would be called in from a central office to go where they are needed instead of being distributed across the production. This would potentially reduce the downtime of the operators, making their job more active and varied. It would, however, require them to learn and familiarize themselves with larger parts of the production. Keeping the smaller control rooms would mean that the operators may have more downtime, but that would allow more time for the development and optimization work. A potential solution would be rotating operators between centralized and local control room work. As an autonomous production may create a surplus of operators in the control rooms, that surplus could move toward a centralized maintenance role. In the meantime, the remaining local operators could focus on the development and monitoring work of specific processes in the production. This way, the control room work could balance centralization and decentralization.

- **How can existing personnel at SSAB be introduced effectively to the changes in their workplace that Industry 4.0 would bring, and what new qualifications will be required of them?**

Changes in the workplace and in organizations often causes some form of resistance to them, whether human or non-human. Existing personnel could, according to Jacobsen et al. (2002), potentially be less willing to leave a currently stable state of work for an uncertain future, or they might have built a sense of pride and identity in their current work tasks. In order to tackle such resistances, I believe it is important that these changes are made transparent. Employees shouldn't be made to guess how their job might change or whether they even have a job after new changes are implemented. By clearly explaining how the work will change and discussing the implementation, the current employees who are initially resistant can better be made to understand and impact the changes. Regarding new competences, Industry 4.0 may require operators to interact with more digital systems and change their focus to more process development. A change in the contents and focus of their work could cause operators to complain about and resist these changes. However, by providing ample opportunities and support for learning, I believe it is a surmountable challenge.

- **What factors can increase the attractiveness of the workplaces at SSAB for new and current employees?**

This question served as a reminder to keep the operators' needs and wants, both current and new, in mind when analyzing and recommending changes. The attractiveness of a workplace can be very subjective. There are, however, some more general factors for attractive work that I believe aren't specifically connected to the implementation of Industry 4.0. These include adequate equipment and tools, good wages, recognition and more. The factors are listed by Åteg et al. (2004) and while they are generally applicable to most workplaces, they are still important for keeping a job attractive to current and new personnel. Other general factors for attractiveness may be more affected by and related to implementing Industry 4.0. For example, if autonomous productions reduce the number of operators needed, they could feel like they're losing social contacts. In addition, the work could become more static by autonomous machines taking over physical tasks if proper variation and physical activity isn't included. These more general factors for attractive work need to be kept in mind when planning any changes.

Additional important factors are those relating to current trends amongst the younger generation. Flexibility, self-governing work and a responsive management are factors that are according to literature considered attractive today. By working to implement more operator control of task design and more development work, control room work could become more attractive to potential new employees. There are other, more subjective factors that may also make the control room work attractive to a person. It is reasonable to believe that a workplace following modern trends and implementing new innovations could be more attractive to some. It would, however, be impossible to create a workplace which everyone found to their liking, so perhaps the best course of action would be to ensure the job retains a clear identity. No employee should find that the work is vastly different than what has been advertised and presented. Further efforts to make the work attractive to new and existing operators could be ensuring the operators' control over the work is apparent. Knowing that your feedback and experience are valuable resources for improvement work can be very motivating.

- **Which recommendations can be made to promote a vision of sustainable, effective and equal future control room work, and how can the employees be involved in creating that vision?**

The recommendations I presented in my results aim to help achieve the utopian vision of control room work under Industry 4.0. The utopian and dystopian visions themselves help with making it clear how polarizing the implementations of Industry 4.0 can be. When it comes to promoting sustainability, a more autonomous production has the potential to produce more efficiently and manage itself more effectively. This would give it the potential to improve both the economic and ecological sustainability. My recommendations for changing the control room work also has the potential for improving those types of sustainability. That potential comes from the recommended increased involvement of operators in process development and design. If properly utilized, I believe that the operators' experience and competence regarding the systems can help with future optimization and improvement projects. The social sustainability of the control rooms relies on the operators' involvement in designing work tasks and creating learning material. Their involvement could help make it better adjusted to their own needs and wants.

As for creating the vision, the operators' involvement lies in using methods similar to the interviews I did and feedback they gave that allow them to explain and discuss their thoughts of, needs and experience with the work. Without the operators, it would be more difficult to assess all aspects of the work that would be affected by future changes. I therefore believe that it is critical to involve operators in establishing a context, and to not rely only on information from managers and documentations. Despite not performing a workshop during this project, I believe that operator involvement in creating and selecting changes for the control room work would be beneficial. That way, they can be more directly involved and influence the change implementation design instead of only providing information that is left for others to interpret. However, while I only attempted to involve a shift team from one of the control rooms, it may be easier to arrange a workshop with operators from different control rooms. This has the added benefit of potentially revealing problems and ideas that only some types of control rooms have. When involving the operators, utilizing boundary objects can make explaining technologies or solutions easier, while also allowing for feedback that is easier to understand.

Beyond helping establish a context, I also believe that the operators' experience with the control room work will prove necessary when realizing the vision. Without their input, creating an implementation that accounts for their needs and wants will be more difficult. Their involvement also provides them an opportunity to control and shape their own work, provided that they are included in development groups and are given opportunities to provide feedback. Furthermore, by helping implement changes, they can potentially become more familiar with the changes and how they work ahead of their implementation.

7.2.3 Further reflections

While I am satisfied with the results of my project, there are some questions and future outcomes that I haven't brought up yet but would like to discuss.

The implementation of the technologies and changes from Industry 4.0 raise a few questions regarding the structure of the control room work. If the operators no longer need to enter the production to perform menial tasks, will the work become more sedentary? Much of today's control room work is already spent sitting in front of monitors, so a removal of the menial tasks may increase the risks of cardiovascular issues and other consequences of sitting still. Fewer reasons to visit the control rooms would, however, entail safer operator work. They wouldn't have to visit the loud, dirty and potentially dangerous production locales, meaning potentially fewer ergonomic issues other than from the sedentary work. The question then lies in how to balance the sedentary work with physical work should an autonomous production be achieved. I believe that the ergonomically negative aspects of a mobile operator could be rectified by cleaning up and securing the production locales. It could possibly be done by investigating and implementing "Operator 4.0"-technologies described by Romero et al. (2016). For example, IPAs could warn operators that are out in the production when they are nearing an area where certain protective gear is needed. The exact solution, however, is something that I won't investigate further in this project.

From the start of this project, I have worked with an implementation of Industry 4.0 in mind due to the objectives from the larger research project. However, it is possible that the future of control rooms doesn't involve the strategy to the degree that is assumed and theorized in this project. Instead, perhaps individual parts of the strategy will see implementation at SSAB and other industries, while the rest of it is discarded. Industry 4.0 is, after all, but one of many organizational concepts. Although they have promised great benefits and changes, it is in my experience rare to see an organizational concept be implemented in its entirety. I can imagine that completely autonomous production systems capable of adjusting themselves may require too big of an investment to see implementation in the future. However, I don't believe it is reasonable that Industry 4.0 will be completely excluded in the future. The strategy has seen a lot of traction in many different organizations across the world and more of the technologies described in it have been emerging on the market. Indeed, there are already implementations at SSAB, such as the VR utilization in Raahe, that are similar to the potential of Industry 4.0 described by Romero et al. (2016) and Kagermann et al. (2013).

7.3 RECOMMENDATIONS FOR CONTINUED RESEARCH

As there is still much work left to be done in regard to designing and preparing for an implementation of Industry 4.0 at SSAB, I've compiled some recommendations for continued research.

Regarding the literature subjects studied during this project, more research should be done on sustainability's role in control rooms. While I have included some literature regarding that subject, I believe there is still more to it that is relevant for the project. Another subject that was exempted was the impact of gender balance in the control rooms. I decided to omit that subject near the end of the project, as I hadn't had time to research it properly. However, I still believe it is an important subject to research in regard to change implementation, as disproportionate gender balances can have a hindering impact. Furthermore, gender differences are important to consider when working with changes towards a more widely accommodating workplace.

Naturally, there would need to be more thorough investigations into each of the technologies that I recommend, as the more difficult task of designing these changes still remain. This would include detailing the exact implementations, planning and developing material. In addition, additional studies at the control rooms at SSAB are necessary to gather more feedback on subjects such as what that makes control room work attractive. As only a few shift teams out of all available were interviewed, there are surely more valuable ideas and opinions to gather.

More detailed studies should be done to customize and adapt the suggested solutions to the needs and wants of the control room operators. I do believe this project has taken their opinions and thoughts regarding the general work into consideration. However, I haven't investigated the specific demands of the control room operators' different work tasks beyond the monitoring role. Investigating those tasks could have brought other common work tasks between the different control rooms forward. I also believe further studies of control rooms from other metallurgic industries' control rooms could be useful in benchmarking and inspirational purposes. Control rooms in industries other than SSAB may have different circumstances and needs. This must be considered in order to properly create a universal strategy for the effects of Industry 4.0 on control room work.

In its current state, I find my work on this thesis project to be satisfactory. There are naturally parts that can be further developed, but I believe the project works well as a preliminary study into the control rooms of tomorrow. My hope is that the results of this study, while not being concrete instructions to implementing Industry 4.0, can work as guidelines for what subjects to further research and develop. With the use of these guidelines, metallurgic industries can be better prepared for implementing and better utilize future technologies and systems.

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9 Appendix

MAPPING

Structure

- How many employees are included in a team in the control rooms?
    - **Varies between control rooms; anywhere between 2-12 operators per room.**
- How do different shift teams communicate?
    - **Leaving notes, communication through intranet, during shift change.**
- How does the control rooms communicate?
    - **Outdated phone equipment.**
- Do operators shift regularly between control rooms or do you work in only one of them at a time?
    - **Operators work in one control room at a time.**
- Do operators rotate between control room work and other roles?
    - **Operators only work as control room operators. Depending on the control room they can be the ones who perform most of the tasks in the production surrounding the room.**
- How long is a shift in a control room?
    - **Shifts are eight hours long, three shifts per day on weekdays. 12 hours long with two shifts per day on weekends. The shift teams rotate on weekly schedules.**
- Is the same computer system used in every control room?
    - **A similar computer system is used in every control room, but it's contents are adjusted to the part of the process the control room oversees.**

Competence

- How are new operators trained?
    - Courses? **Operators go on internal and external courses to learn subjects like chemistry or metallurgy.**
    - Following an employee? **The work tasks are often taught by a more senior operator, whom the new operator follows during their work.**
    - Written instructions? **Written instructions exist**
- How long does it usually take until a new operator ”gets used to” the work and no longer needs as much help or training?
    - **Operators "never really finishes training", as there are many problems and maintenance tasks which occur rarely. Always something new to learn.**

- Do the operators rotate between different tasks in the control room or are you relegated to a certain role?
    - **The operators can rotate to different tasks. While some tasks require specific education, operators are commonly able to swap tasks in the middle of their shift.**
- Are there ”beginners tasks” that new operators start with?
    - **Yes. There are certain tasks that are more appropriate for newer operators to start with. Certain control rooms in some section are deemed more advanced than others, meaning they require operators to have years of work experience before working there.**

Operator retention

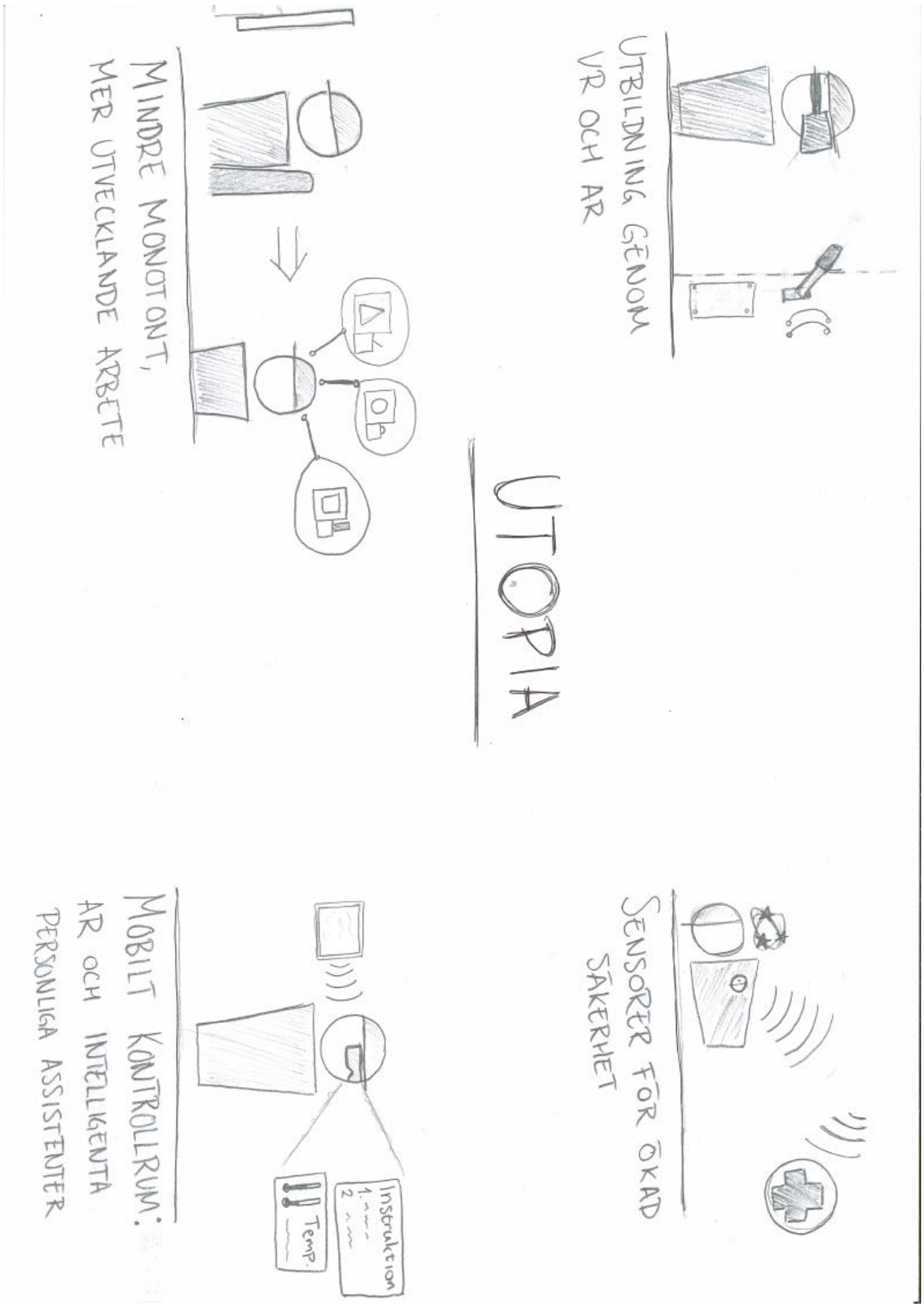
- How many new operators come to the control rooms/how often?
    - **About one new operator per year per shift team**
- How long do operators usually work in one control room?
    - **Depends on the person. Some younger people are more inclined to change careers than their older coworkers. Some older operators have worked at their control room for 15-20 years.**
    - Where do operators go when they leave the control rooms: to another control room, to another role entirely, or do they quit or retire? **Most people leaving the control rooms retire, some quit or more to other control rooms if they feel that they aren't suited for the work.**

Risks

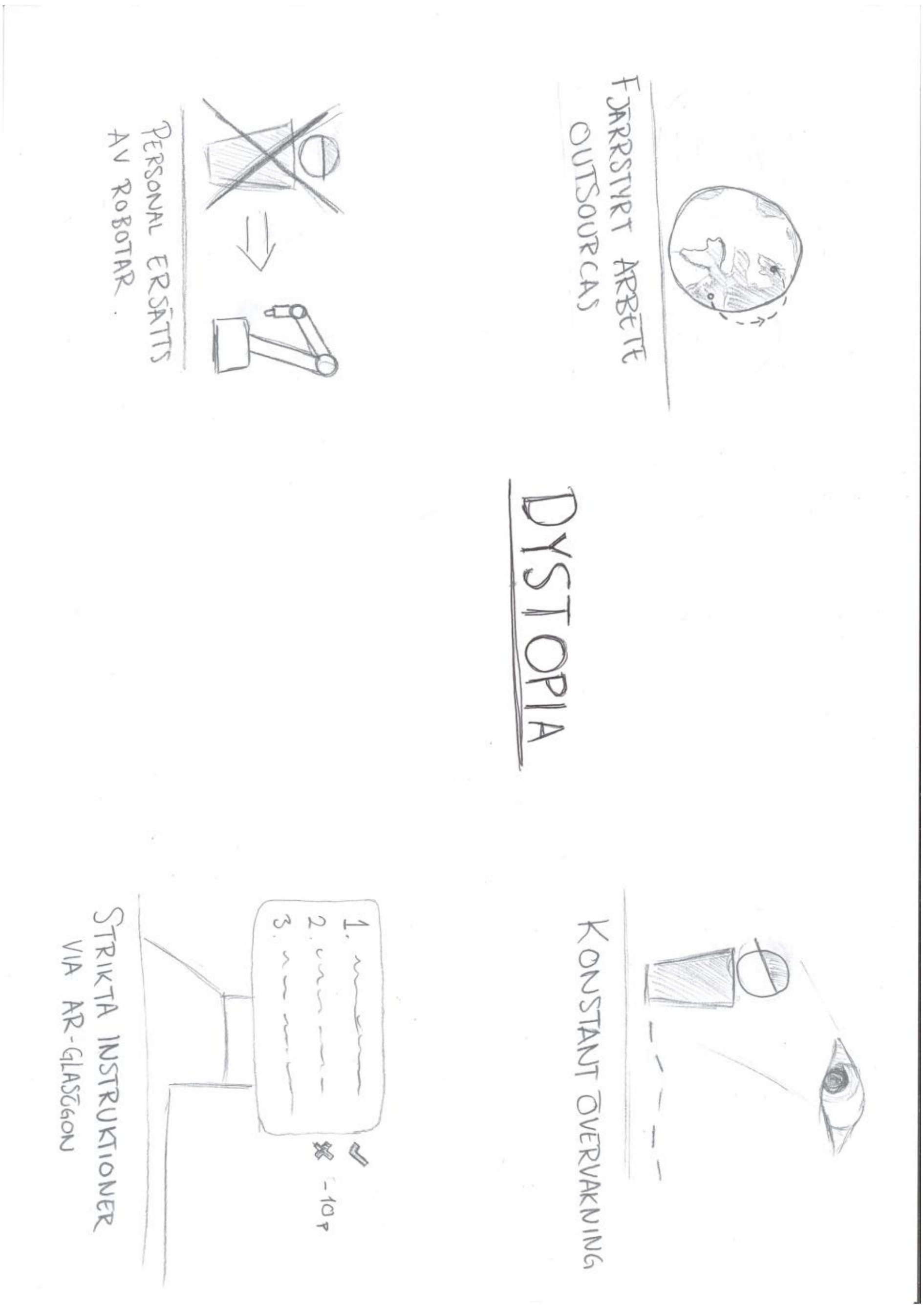
- What risks are the the operators exposed to during their work?
    - Physical risks such as ergonomic damage? **Individual maintenance tasks have different conditions. Some have heavy lifts, some take place in very warm environments, handling molten steel. Some tasks take the operator far away from others, to places where people rarely walk past otherwise.**

Future technology

- What do the operators and bosses think needs improvement in the control rooms?
  - Certain tools and machines don't work well.
  - Simulations for learning: There are many seldom reoccurring problems that are hard to prepare for. Difficult to learn from someone else, as they may be in another shift, and it can take years between occurrences
- What do the operators and bosses think works well today in the control rooms?
  - More automation may make work more static. It might also make operators always assume the system works well on its own and react slower in cases where it doesn't.
  - Operators have participated in designing the look of the computer system.
  - People are needed in the workplace, can't automate everything



Appendix 2A: Images used to give visual examples of the utopian scenario. From top left to bottom right: *Education through VR and AR, Sensors for increased safety, Less monotonous, more developing work, Mobile control room: AR and Intelligent Personal Assistants*



Appendix 2B: Images to visualize examples of the dystopian scenarios, used during feedback. From top left to bottom right: *Remote controlled work is outsourced, Constant monitoring and tracking, Personnel are replaced by autonomous robots, Strict instructions via AR-goggles*