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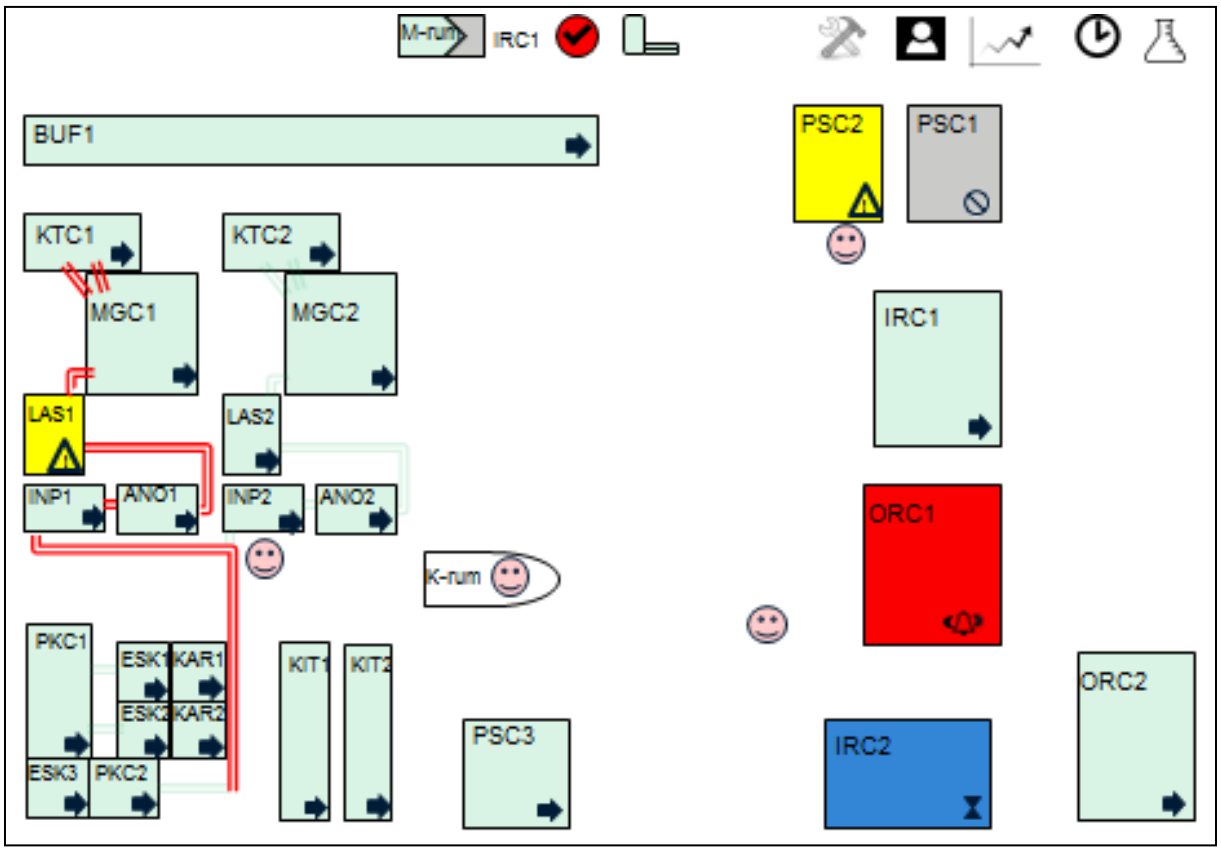

Information concept for a production system control room at SKF

Master thesis in Production Engineering

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Gothenburg, Sweden 2016

MASTER THESIS IN PRODUCTION ENGINEERING

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Cover: The machine park overview screen display showing the present state of the production system

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Abstract

When SKF decided to build a new production system they identified a need for gathering information from the production system in order to operate it effectively. Therefore, a decision was made to gather information and control systems of the production system, secondary users' computer, screens and tablets and the operators' mobiles in a control room. The purpose of this master thesis was to aid SKF in reducing their production system losses through information sharing and control possibilities of the new production system. The goal was to identify which information and control the operators and operational managers needed in the control room to operate the new production system and to present a conceptual visual suggestion of the screen displays in the control room.

Data was gathered through interviews, observations and company visits. The data was then analysed by system mapping, functional tree analysis and hierarchical task analysis. The visual suggestion of the interface was designed with the help of design guidelines. The result was evaluated through reviews with operators and the process development team and a walkthrough of the interface with the operators.

The result of this master thesis shows that the users of the control room need seven main screen displays for the information and control necessary to make decisions in their daily work. The users need a calendar screen for future and past activities in the production system in order to plan their work and make analyses to improve the production system and the work procedures. The present state of the production system connected to alarm and warning texts but also with possibilities to reach deeper information about the production system was also identified as a requirement. Information about material supply and what they should produce at what time is needed. The need for different communication methods to share information between users was identified. The users also needed prioritizing help for deciding what to do and when. The users need to control the material ordering for the automated guided vehicles, block and order out products from the buffer and order consumables from the control room.

Key words: Control room, manufacturing industry, processing industry, information architecture, SKF, LCHO, information concept, production system

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My warmest thanks goes to all operators, operational managers, tool technicians, supply chain personnel, process media personnel, maintenance personnel, production technicians, the process development team, the channel group manager, quality personnel, the method and production system manager and the factory manager who has been willing to share their thoughts and ideas with me and ultimately make this thesis possible.

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Linda Nordström
Gothenburg, 2016

Table of content

Nomenclature

ACRONYM	DEFINITION
AGV	**A**utomated **G**uided **V**ehicles
HMI	**H**uman **M**achine **I**nteraction
LCHO	**L**ow **C**ost **H**igh **O**utput, a strategy SKF has developed
OEE	**O**verall **E**quipment **E**ffectiveness
PLC	**P**rogrammable **L**ogic **C**ontroller
SAP	German software manufacturer
HTA	**H**ierarchical **T**ask **A**nalysis

1. Introduction

This chapter describes the background, the purpose, the limitations, the research questions and the report structure of the thesis.

1.1 Background

Spherical roller bearings with outer diameters between 160 and 360 millimetres are today manufactured in the d-factory at SKF in Gothenburg. The machine park consists of a mix of older and newer machines, automation cells and transport systems. The present production system has too low availability. SKF's analysis showed that the machines can handle the management requirements of availability, but that all the material handling and truck driving draws down the ratio. SKF is therefore in the phase of rescheduling its production system. Some changes have already been implemented while others are still in the planning phase. A new storage system will be introduced, which will be controlled by a parent resource planning system, SAP. An automated guided vehicle transport system will be used to connect the storage system to different automation cells with robots and machines. The previously manual assembly and packaging will now be done automatically.

When creating this new production system a need to gather and present the plant's status to its personnel has been identified. The information should be used for decision support in real-time for primarily operational managers and machine operators in their daily work. SKF has decided to gather the information in a control room, but some of the information will also be presented visually around the plant, on mobiles, tablets, computer and screen displays.

1.2 Purpose and goal

The purpose of this master thesis is to aid SKF in reducing their production system losses through information sharing and control possibilities of the new production system. The goal is to identify which information and controls the operators and operational managers need in the control room in order to operate the new production system. The second goal is to present a conceptual suggestion of the interface between the user and the information system, describing which information and controls the users need and secondary how the data should be grouped and presented on the screen displays in the control room. This report will be used by SKF when they are communicating with possible suppliers of the control room. SKF have the intent to use the final report as a base for future control rooms in plants with similar manufacturing environment.

1.3 Limitations

One limitation that has been made is that this master thesis will not result in a complete control room, but only in a requirement specification of which data and controls are needed for the users and a conceptual suggestion of the user interface.

It was decided not to study the physical workplace of the control room, such as table height, lightning, temperature, ventilation, sound etcetera.

Another limitation was not to investigate which subsystems will handle all the different information, because of lack of knowledge for both the researcher and the process development team at the time of the thesis work. This resulted in that no consideration was taken whether it will be possible to have information from several sources on a screen display.

The designed interface is showing the information the users should have access to in an ideal situation.

The thesis focuses on the primary users of the control room, operational managers and machine operators. Further limitation has been made to focus on which information should be presented, how the information should be presented, to whom and at what time.

The interface that was developed is in no way the finished screen displays but rather a description of what data the users need access to and a conceptual suggestion of how it can be presented.

1.4 Research questions

The research questions in this thesis were:

- Which information is critical for the primary users of the control room to help them make decisions in their daily work?
- How must information and control be organized in the control room interface to best support the operators' tasks?

1.5 Thesis outline

The thesis outline in the form of its chapters and their content is described in Table 1.

Table 1: The thesis outline

Chapter	Content
Chapter 1 Introduction	The chapter describes the background, the purpose, the limitations, the research questions and the report structure of the thesis.
Chapter 2 Theory	This chapter describes an interface, how humans process information in their heads and design guidelines to create an interface that support human information processing.
Chapter 3 Method	This chapter is divided into two parts; the first part describes theory about the methods that were used. The second part defines the work process and why and how the methods were implemented in this thesis.
Chapter 4 Result	In this chapter the results from the work process are described. Also the main problem that the control room is supposed to solve and the wanted effects. The produced product, its process and the new production system are described. The primary and secondary users are set and described. There is a summary of interviews with the users, a description of the outcome from the observations with operational managers, a system description, an analysis of tasks performed in the control room, a function analysis, the outcome from company visits and the designed conceptual interface are described together with the results from the evaluation of the conceptual interface by reviews of the interface and a walkthrough with the operators which are also included.
Chapter 5 Discussion	In this chapter the factors that have affected the results are discussed and analysed. The chapter ends with recommendations to SKF and possible future research.
Chapter 6 Conclusion	In this chapter the conclusions of the thesis are described.

2. Theory

This chapter describes an interface, how humans process information in their heads and design guidelines to create an interface that support human information processing.

2.1 Interface

Industries today have a high demand of always improving the effective use of the technical and human resources. One important step for improving the efficiency is to create technological solutions that support both the user by having a user-friendly interface and functionality (Bligård et. al., 2008). User-friendly means that the user knows how the new technology should be handled, while functionality means that the technology can solve the task.

With the increased level of automation and the decreased level of personnel in industry, the users are facing an increasing amount of information. The information is not only increasing, it is also getting more difficult to understand and more complex to handle since the process and its connection and supply chain is harder to overview (Bligård et. al., 2008). The interaction between the machine and the user has as a consequence become a central quality aspect of process and product development and improvement.

A control room is a form of interface between the machine and the user. The definition of a control room is according to ISO (2001) "a core functional entity, and its associated physical structure, where operators are stationed to carry out centralized control, monitoring and administrative responsibilities".

A user interface should help the operator with relevant data, which facilitates mental processing, decision making but also gives clues of how the product and system should be handled and controlled (Osvalder et. al., 2010). According to Osvalder et.al. 60 to 80 % of all accidents in complex technical systems are caused by the human factor. Investigations shows that accident where the human is blamed for making an error often have a connection to poor technology design, often not customized to the task, situation and user (Ibid.). In other words the reason for the human error is often the incomplete and flawed interface.

2.2 Human information processing

Cognitive theories about information processing are the base for human's interpretation, processing, decision making and actions (Osvalder et.al., 2010). The human is fed information from its surrounding via the senses; vision, hearing, smell, taste and touch. In the perception a screening of the information is done. The screening is done on an unaware level by the human interests, the intensity the information have, which need we have for the information, what news value the information have and how much effort the human have to put in, in order to get the information. The human makes decisions and chooses responses by using its mental models. The source of the mental models is the databases of information that we have in our long-term memory and the working memory. Rasmussen (1983) argues in his SRK-model that the human then executes the chosen response either completely automatic without thinking by using rules or by trial and error. The senses give the human response of the outcome from the execution. Figure 1 shows Wickens' model of human information processing. All parts in the cognition are active both parallel and serial. This means that the human can perceive information at the same time as information is processed and as decisions are made.

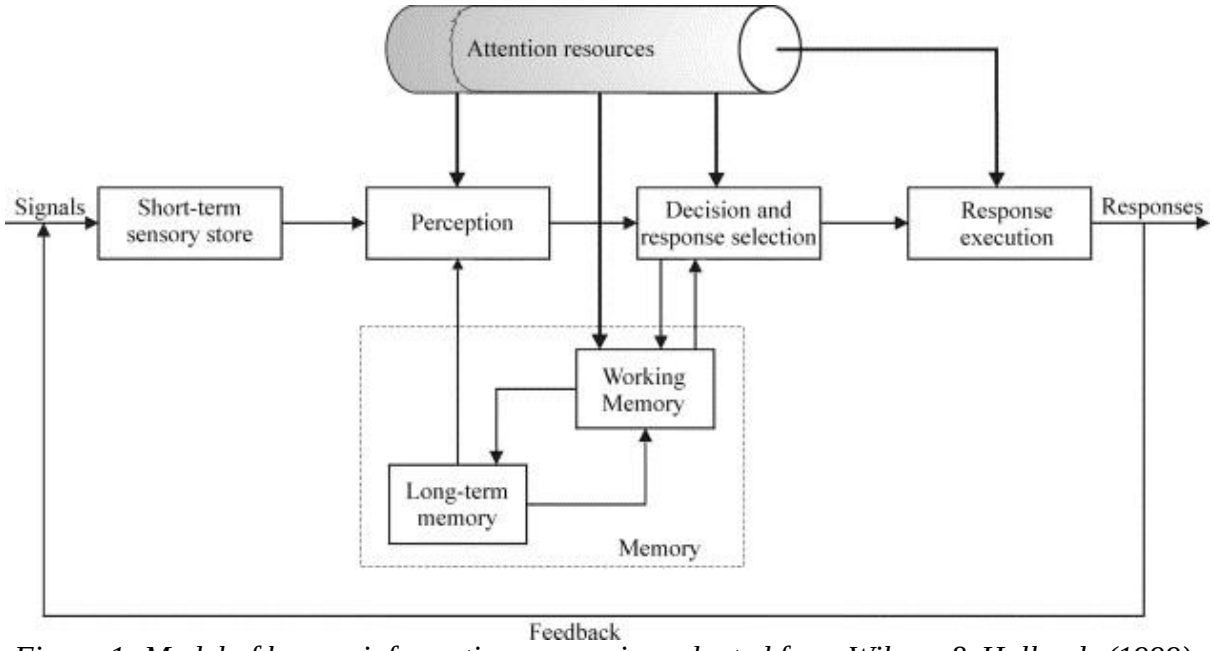


Figure 1: Model of human information processing adapted from Wikens & Hollands (1999). The figure is a courtesy of Kiencke, Majjad & Kramer (1999).

2.3 Supporting information processing

When designing an interface the users' cognitive limits and abilities have to be considered. A pillar of design of an interface is that the right information has to be presented at the right time (Osvalder et.al., 2010). Osvalder et.al. presents 13 design principles, which supports the cognitive processes; attention, perception, memory functions and metal models of the user. Their principles are described below:

Design principles which support attention:

- *Minimize the effort and time to find the information*

  The work becomes inefficient if the user needs to search information for different screens, pictures and menus, because the operator has to put in a lot of effort to find the information. The interface should make it easy to find the right information. Information which is used with high frequency should be easy to find. The information should be organized and grouped together to be found on the same display and in the same menu if possible.
- *Use proximity*

  In some situations the user has to integrate information from several sources in order to solve a task. The effect of not integrating the information is divided attention, which shows negative effects of human's ability to remember information (Schmitter-Edgecombe, 1996). Information sources can be integrated by using colours or similar markings with arrows and lines.
- *Use multiple information sources*

  When information is fed to the user by several senses like vision and hearing larger amounts of information can be observed and handled by the user.

Design principles that support perception

The perception organises the stimuli, which has been noticed and gives them a meaning. Five design principles are identified to support the perception process.

- *Good readability of the screen display*

  If the screen display has high contrast, good lighting and a correct viewing angle the base for good readability is achieved.
- *Avoid too many levels of absolute judgement of information*

  A presented variable should not have more than five alternatives. It is hard for the human to separate more than five levels of a certain parameter, for example the thickness of a pipe.
- *Highlight unexpected information*

  Messages that contain information the user do not expect needs to be presented in a way so it draws the user's attention. Examples of this are to have a popup window or flashing information.
- *Use redundancy*

  By presenting information in more than one way the chances of interpreting the information in the right way is increased. The most common way is to use both visual and audial information at the same time. Different kinds of visual information like figures and text can also be an alternative in order to make the message clearer.
- *Avoid similarities between objects*

  Similar objects can lead to confusion, mix-ups and a higher risk of misinterpretation. The differences of similar object should therefore be reinforced and similarities downplayed.

Design principles which support memory functions

The working memory has a limited capacity, it can only hold 7 ±2 units at the same time, which requires organization and minimization of the information, which is presented to the user. Information from the long-term memory is hard to recollect quickly at the right time, especially if no clues are included in the interface. The following principles have been designed to support the memory function.

- *Knowledge in the world*

  Checklists, reference values and letter- and number combinations can be visualised on the screen display to lower the amount of information the user needs to keep in the working and long-term memory. A good balance has to be reached so that not too much information is placed on the screen displays, which can lead to the information being hard to find and interpret. If this is done correctly the working memory can focus on problem solving instead of remembering data.
- *Anticipate system status*

  A system with a large amount of parameters makes it hard to the human to anticipate what will happen with the system in the future. The working memory has limitations when it comes to processing a lot of information sources at the same time as thinking of future scenarios. The mental resources have a tendency to focus on the new stimuli information and new assignments. This leads to that the human getting reactive in its behaviour and focus on what has happened or happens right now instead of being proactive and focusing on what will happen. The interface should therefore support the user with information about what will happen with the system in the future based on the present and past conditions.

- *Consistent presentation of information*

  The interface needs to be similar to previous interfaces, which the user is familiar with because a human will perform known actions automatically and instinctively. Colour coding is one example that should be kept the same and used consistently through a new interface.

Design principles which support the user's mental models

A mental model is saved in the memory of the user as an internal representation of a system with its most important characteristics and their connections. Mental models are used to anticipate and simplify behaviours of the surroundings. The following principles support mental models.

- *Illustrate reality*

  Information in an interface should be presented in a similar way as it is presented in the reality. One example is a display with several units, the units should be placed on the screen display as they are in real life to fit with the user's mental model and thereby make it easier for the user to interpret the information.
- *Displaying moving objects*

  Moving objects on a screen display should coincide with the user's mental model of how the system works. An example is that the fluid levels of a tank should move upwards when it is being filled, and downwards when is gets emptied.

3. Method

This chapter starts with a theoretical part describing the methods that were used. The second part consists of a description of the work process, why and how the methods were used.

3.1 Theory about the methods

The following section describes some theory about the methods, which has been used to gather and analyse data. The methods are interview, observation, system mapping, functional tree analysis, hierarchical task analysis, review and walkthrough analysis.

3.1.1 Interviews

Interviews are a method for investigating what people thinks and feels. The interviewee answers questions based on own dreams, experiences, opinions and values, which makes the gathered data subjective (Osvalder et.al, 2010).

A positive aspect with interviews is that the interviewer can ask supplementary questions and get deeper explanations and by that obtain deeper understanding and lower the risk of misinterpretations.

A negative aspect with interviews is that the method demands a lot of time with preparing the interview, finding a time that works for interviewee/interviewees, going through with the interview, transcribing them and analysing the result.

Three types of interviews have been used during this thesis, namely unstructured interviews, semi-structured interviews and group interviews. Osvalder et.al (2010) and Bryman (2008) describes the differences of the three interview types as:

- In an unstructured interview the questions are open and the interviewer steers the discussion in a suited direction. An unstructured interview is fitting when the interviewer has little knowledge about the topic. The method provides data for a qualitative analysis.
- In a semi-structured interview the interviewer typically have prepared a list of questions or specific topics. The asked questions may not always follow the interview guide and questions not included in the guide may be asked if the interviewer finds an answer interesting. The method provides data for a qualitative and quantitative analysis.
- In a group interview several participants are interviewed by the interviewer simultaneously. In a group interview the interviewer is typically interested in how people respond to each other's view to get deeper knowledge.

The introduction to an interview has influence over the outcome from the interview according to Dahlström (1970). The following information is a summary of what Dahlström considers should be included in the introduction to the interview.

- What the aim of the interview is
- How the interview will be conducted
- How the interview will be documented
- What the result will be used for
- How the answers from the interviewee will be processed

- How the investigation can affect the interviewee
- If the interviewee will be anonymous in the report.
- In order to lower the nervousness of the interviewee the first questions should be easy to answer.

When deciding the phrasing of the questions there are some things that Sällnäs (2014) and Bryman (2008) recommends:

- Do not use leading questions
- Do not have several questions in one
- Avoid interviewer effect, the bias of the interviewer effects the responders' answers.
- Avoid questions, which easily can be answered yes or no.
- Avoid complex words.
- Try to adjust the amount of question to the time limitation of the interview.

3.1.2 Observation

Observation is a method where the researcher gathers information about the participants by investigating how people act in different situations. It gives information about how task are performed and problem that can occur in different work tasks. Senses like vision, hearing and smell are used to collect the information. Observations can give information about behaviours, tasks and events that the participant is unaware of, cannot express or forgets during an interview. An observation can give qualitative information of how people act. It can also give quantitative information by for example measuring how many times a task was performed during a time interval. A negative aspect of observations is that it does not tell how the participant thinks; it does not give any cognitive information (Osvalder et.al, 2010)

Observations are typically divided into three types, namely controlled observations, natural observations and participant observations (McLeod, 2015). In this study natural observations have been used. In natural observations, also called unstructured observation, the researcher studies the participants in the participants' natural surroundings. The researcher records the information in whatever way possible. Natural observations are known to generate new ideas because when the total situation is studied new avenues of enquiry are often found (McLeod, 2015). Observations of this sort often lack a representative sample and are usually conducted in micro scale. With natural observations external and internal variables cannot be controlled, which lowers the reliability and makes it harder for other researches to repeat the study in the exact same way. With this type of observation the researcher does not have the ability to manipulate external variables, which affects the ability to define cause and affect relationships negatively.

Observations can also be divided by whether the researcher's identity is kept secret to the participants or not. Cases where the identity of the researcher is hidden from the participants are called covert observations or undisclosed observations. Cases were the identity of the researcher is known for the participants are called overt observations or disclosed observations.

3.1.3 System mapping

System mapping is used to make complex systems more approachable and understandable by identifying and presenting the components in the system and their links in a structured way (CCSA, 2014). Example of components in the map is users and machines while examples of links are information flow, energy flow, material flow and money flow (Morelli & Tollestrup, 2006). According to CCSA (2014) a system map can be described with only text or visualized with tables, flowcharts or graphics. The map can identify gaps, duplications, weaknesses and strengths but also opportunities. The map can help make informed decisions about for example resource allocation, goal setting and tracking changes.

3.1.4 Functional tree

A functional tree is a method for identifying the functions that the system needs. The method is often used in the beginning of the design process to refine the products functional requirement (Corpino et. al., 2012). A functional analysis is done to investigate which functions are needed in the system, to be able to guarantee that all necessary features are listed, that no unnecessary features are requested and to understand the relationship between the new products features. The first step in performing a functional tree is deciding the main function. The second step is to divide the main function into multiple levels of sub functions until a sufficient level of detail is reached.

3.1.5 Hierarchical task analysis

A hierarchical task analysis, HTA, is a method that structures the tasks that the user has to perform to achieve a certain goal. The first step in creating a HTA is to set the overall goal of the task. The goal is then divided in multiple levels of subtasks, until reaching a sufficient level of detail. Plans are connected to the HTA in form of conditions for sequences or options that are included in the task (Osvalder et.al., 2010).

3.1.6 Review

A review is a structured way of performing an evaluation of a design (Bligård, 2015). A number of persons with different knowledge bases are gathered to go through the result of the development. A moderator leads the walkthrough and makes sure that all material is studied. The comments of the participants are compiled and documented by the moderator.

3.1.7 Walkthrough analysis

Stanton et.al. (2005) describes a walkthrough analysis as a simple procedure used by designers to envision how a design concept would work but also to evaluate and modify the design concept. In a walkthrough the operator is walking through a scenario, performing or pretending to perform the actions needed to perform the tasks in the system, explaining the functions of each display and control used.

The outcome from the method is a description of how tasks are currently performed in the system, highlighted flaws, potential errors and usability problems. A positive aspect with a walkthrough compared to an observation is that the researcher does not have to wait for the required scenario to occur. The researcher can also stop or interrupt the scenario and ask complementary questions with this method. A negative aspect with the method is that the operator has to be experienced for the results to be useful and the reliability of the method is questionable.

When performing a walkthrough Stanton et.al. (2005) presents a five steps guideline:

- In step one a set of tasks or scenarios should be defined, and as a general rule they should cover every aspect of the system and its interface.
- In step two the method hierarchical task analysis should be used to describe the scenarios.
- In step three a verbalised walkthrough is conducted by the analyst team going through the tasks using the HTA map in the system. The scenarios can be frozen at any point and questions about error occurrence, controls, displays, decisions made and situation awareness can be asked. The walkthrough is often video recorded.
- In step four the gathered data is analysed.
- The last step is to modify the design based on the results from the walkthrough. If a new design is proposed a second walkthrough should be conducted to analyse the new design.

3.2 The work process

The following section describes the different steps in the work process. Figure 2 shows the main steps, which were conducted. Some steps overlapped in time but the figure shows the general order. Each step is then described more detailed in section 3.2.1-3.2.15.

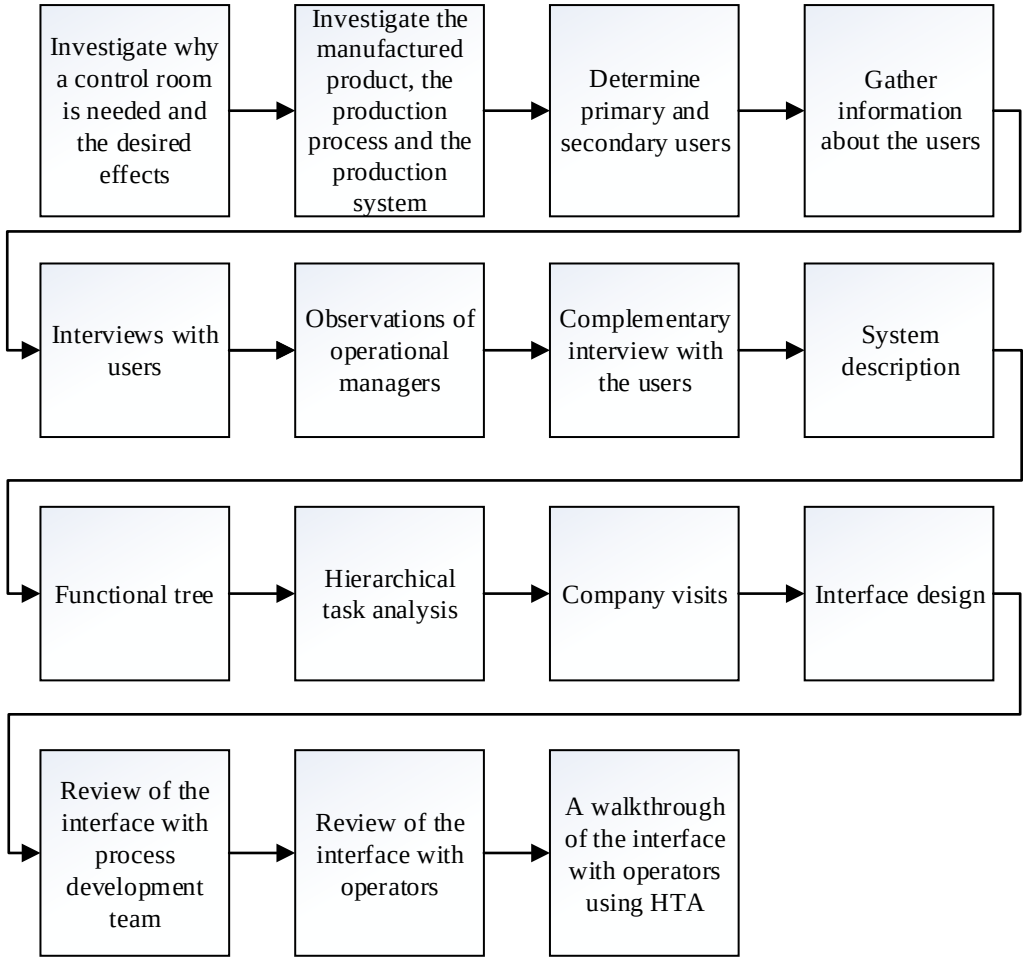


Figure 2: The work process

3.2.1 Main problem and effects

The main problem that the control room was expected to solve was identified. The expected and desired effects of the control room were also investigated. This was done by having one semi-structured and two unstructured interviews with the process development team, which are working on developing the new production system. Participating in the interviews were the technical lead of the automation cells in the new production system, the project leader of the automation cells and the control room development at SKF and the technical lead of the whole production system. They were chosen as interviewees because they were the ones that identified the need of the control room and sold in the idea to the board.
The following questions were asked during the interviews.

- What is the main problem the control room should solve?
- How have they motivated the need of a control room to the board?
- What effects are desired from the control room?
- How could each desired effect be broken down?

3.2.2 Investigate the manufactured product, the production process and the production system

To understand in which context this control room should be present in, a study of the products, which will be produced in the production system, the production process and the production system were conducted.

A comprehensive study of the new production system was conducted to get a picture of:

- the different operations that should be made
- which operations should be done in each automation cell
- where the manual inspections were planned to be performed
- the flow of direct and indirect material supply
- the layout

The gathering of data about the produced products, its production process and the production system was made by unstructured interviews with the technical lead of the automation cells, the project leader of the control room at SKF and the technical lead of the new production system. Internal documentation that SKF provided was also studied.

3.2.3 Determine primary and secondary users

A group interview with three members of the process development team at SKF was conducted. Together with the group, primary and secondary users were identified. The identified user groups were then confirmed to be correct during the interviews with the users as they were asked if they needed information from someone else apart from the users listed.

3.2.4 Information about the users

The number of operators and staffing changes of other personnel was discussed with Human Resources for the plant. The users' main work task and work hours were discussed with the process development team. Some facts about the users were also gathered during the following semi-structured interviews.

3.2.5 Interviews with the primary and secondary users

Semi-structured interviews with representatives from the identified user groups were conducted in order to get an understanding of the information and controls they needed in the control room. The reason for having semi-structured interviews was to allow the interviewer to ask supplementary questions and get deeper explanations and by that obtain a deeper

understanding and lower the risk of misinterpretations. Some of the interviews were with one interviewee while others were group interviews.

Human Resources was contacted to get a list of people for each user group that had enough knowledge and would be keen of giving elaborate information of what they thought were needed in the control room. The process development team was also inquired for input on, which users to interview. All interviews were held in office spaces of SKF.

The following list describes the interviewed users and their role:

- Two project operators
  Machine operators assisting the implementation of the new production system
- One operational manager
  Team leader of the operators
- One electrician and one mechanic
  The machine service personnel
- One former maintenance engineer
  Plan and follow-up maintenance work
- One supply chain personnel
  Plan the production sequence and material input and output
- Four tool technicians
  Preparing tools for the machines
- One channel group manager
  Manager over the operational managers and responsible for the production unit
- Two production technicians
  Works with continuous improvement of the production system
- Two process media engineers
  Supply fluids to the machines
- One quality engineer
  Follow-up of the quality of the manufactured product

Before the interview questions were prepared, found in Appendix A. The theory of how to make an introduction to an interview and how to formulate questions was used in the preparation. As a complement to the questions the researcher designed a connection document, found in Appendix B. The connection document was designed to help the interviewees to think of which information they got from the user of the future control room today and if there were more information they wanted. For the interview with the project operators a simplified flowchart over the production system was designed. The flowchart helped getting information of what the operators needed to know from each automation cell, machine, conveyor belt, AGV, buffer, product, measurement and the material order system. After the interview with the project operators the questions and the connection document were improved, the result can be found in Appendix C respective D. The first interview took three hours but without the flowchart the other interviews varied between one and two hours.

The interviews were recorded to ease the documentation apart from two interviews, which were not recorded since the interviewees did not feel comfortable with having their answers

recorded. Notes were taken for all interviews as a source for documentation. The interviews were held in Swedish. The interviews with the users was not transcribed, instead summaries were made with the information the users need presented and what information they have to put into the system as well as controls they need.

3.2.6 Observation

Two separate natural disclosed observations were made with two operational managers. The two operational managers will also be working in the new production system. The first observation was with the same manager that had been interviewed in the semi-structured interviews. The observation was made between 05:50 and 12:00 where the researcher followed the operational manager during his day. The other observation was made from 13:50 to 17:00 to make sure the shift overlap was observed and the meetings that the operational manager had during the day were followed. According to the operational managers all important meetings and work tasks were observed during the observations and if more observation were to be done it would be more of a repetition of what have been studied.

3.2.7 Complementary interviews with the users

When all the semi-structured interviews had been completed some questions were raised. The researcher performed additional unstructured interviews and structured interviews with the users in their natural surroundings. Unstructured interviews were held if the researcher just had a single question or wanted to know more about a certain topic. More than 20 operators have been interviewed, mainly about the information on their production whiteboards, the production sequence and the material supply, but also about tool change and improvement work. The production whiteboards supply the operators with information of the production system cost, environment, delivery, quality and safety. The operational managers were asked complementary questions during the observation. After the interview with the tool technicians a review of the gathered data was done with the tool technicians who lead to some data being changed and some added. There were also meetings with the plant management and the method and production system manager to get their vision for the control room.

3.2.8 System description

A system map was chosen as a method to describe the context of the control room with all devices that should be connected to it and the connections to the users. The interviews with the users were the foundation for developing the map. A system map was chosen to describe the system since the system appeared quite complex to interact with, since all the primary and secondary users wanting devices connected to the control room for receiving and sending information to the system. According to CCSA (2014) a system map is known for making complex systems more approachable and understandable by identifying and presenting the components in the system and their links in a structured way. Another argumentation for using the map was to try to identify gaps and duplications of information sources to the users.

3.2.9 Functional tree

The functional tree was chosen as a method to get an overview of aimed at functions of the control room. The foundation for designing the functional tree was the gathered information from the interviews with the users. This method was used because it is known for identifying the basic functions of a system and to refine the products functional requirements in the beginning of the design process (Corpino et. al., 2012).The outcome should according to Corpino et. al. be that all necessary features are listed and that no unnecessary features are requested. It should also give an understanding of the relationship between the products features.

3.2.10 Hierarchical task analysis

To decide which information the user needs at the same time and preferably quite close on the screen display or with few navigation steps, the method hierarchical task analysis was chosen. The reason for choosing a task analysis method for investigating which information should be grouped together is because of the method's ability to give an overview of the data that would be needed in the different steps. According to the theory the HTA analysis should cover every aspect of the system and its interface. Due to time limitation and the size of the information system all possible tasks in the system were not possible to describe in the HTA analysis. The scenarios for the walkthrough were chosen so that all screen display would be included at least once in a task and that the most common and important tasks were included.

3.2.11 Company visits

A company visit at Volvo Cars in Skövde was conducted. Volvo Cars in Skövde was chosen because Skövde have several manufacturing plants while their factories in Gothenburg mostly are assembly plants. The visit to Volvo Cars in Skövde was divided in two parts. The first part was to get a presentation of their screen displays for machine park overview, cell overview and machine HMI. The production whiteboards showing information of cost, environment, delivery, quality and safety for the operators was also investigated. The other part was to get their Andon system presented, a system for getting help quick when problems in the assembly stations occur.

The researcher visited a control room at SKF for the process media such as cutting fluid, honing oil and hydraulic oil. This was done to discuss which data from the control room could be taken direct from the process media control room but also to get inspiration from how they visualized their data.

SKF has developed an app for the heat treatment, which is used by the operators for controlling its process. The responsible personnel for the development of the program contacted the researcher for a presentation of the control room and what parts of the control room information the researcher found interesting to have on the operators' mobile device. The app for the heat treatment, MOST, was presented for the researcher for this thesis during a meeting.

3.2.12 Interface design

During the thesis all the gathered data was documented and grouped continuously. The amount of data was large, and a suggestion of how the data should be presented was developed in order to easier describe the identified needs for the users so they could give feedback. The interface that was developed is not the finished screen displays but a description of which data the users need access to at the same time. The level of details of the screen display varies a lot, all between a more or less finished suggestions of how to display information to a list of information that should show on the screen displays. The interface was designed using Microsoft Power Point and Microsoft Excel. The design guidelines for information processing described in the theory chapter were considered when designing the interface.

3.2.13 Review of interface with the process development team

A review of the suggested interface was made with the process development team. No semi-structured interviews had been conducted with this user group. During the review they were asked which information they wanted to show in the control room and what information they needed from the control room. The feedback from the process development team was considered important because they have knowledge from designing the new production

system that the other users lack. The researcher asked the team before the presentation started to come with feedback about the conceptual screen displays and ask questions directly when they thought of something.

3.2.14 Review of interface with operators

A review of the suggested interface was conducted with two operators involved within the project. One of the operators was earlier interviewed in a semi-structured interview. The goal of the review was to get feedback of the operators' opinions on the suggested interface, if they wanted or missed data and functions, if they were willing to put in their data. The time for going through the whole walkthrough was not enough so a second walkthrough was planned. The same operators were however not able to attend the second meeting. Instead, the whole interface was presented to another operator from the earlier semi-structured interviews.

3.2.15 Walkthrough of interface with operators

A walkthrough was made with two operators who both participated in the previous review of the suggested interface, and therefore knew which information the screen displays contained and how to navigate between them. They were asked to perform tasks in the interface based on the HTA analysis. The last step of Stanton et. al. (2005) walkthrough guide, described in section 3.1, was not performed. The goal of this walkthrough was to evaluate the system and to identify problems, missing information and problems with the navigation. The walkthrough was not video recorded, the documentation was instead made by taking notes.

4. Results

This chapter presents the results from the different steps in the work process.

4.1 Main problem

The main problem that the control room should solve is to give an overview of the status of the new production system. With the new production system there will be fewer operators controlling more machines on a larger area, which makes it more difficult to get a complete overview.

4.2 Effects

The main effect that SKF needed from the control room was to reduce the time of machines not producing. The main effect was further broken down to shorten the response time for alarms and warnings, shorten the time from problem detected to solution found and shorten the time from solution found to solution implemented.

4.3 The product

The products being produced in the new production system are spherical roller bearings with an outer diameter between 160 mm and 360 mm. The product consists of:

- One outer ring
- One inner ring
- Rollers, the number of rollers needed depends on the size of the bearing
- Two cages for the rollers
- One guide ring

A picture of the parts in a spherical roller bearing is visible in Figure 3.

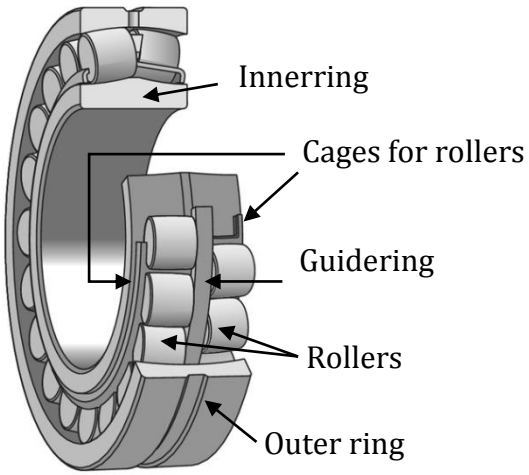


Figure 3: A visualisation of the parts in a spherical roller bearing. Source (SKF, 2016)

4.4 The process

The main process steps in the new production system are grinding, honing, assembly, preservation and packaging.

4.5 The production system

SKF chose to redesign their production system to lower the manufacturing cost get higher availability and more flexibility, which was a requirement from the top management. The biggest change from today according to the process development team is that they will have a mix of cell and line production instead of only line production.

The layout of the production system with its cells, machines, conveyor belts, kitting stations, and buffer can be seen in Figure 4. The abbreviations of the objects in the production system are explained in Table 2.

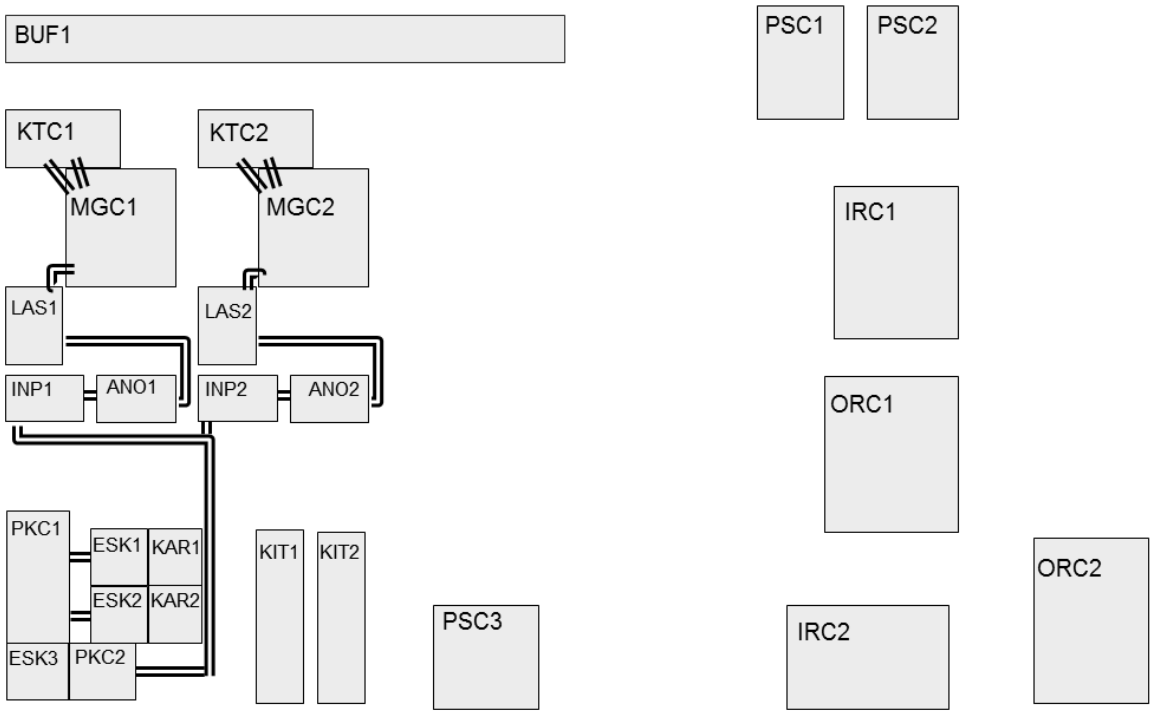


Figure 4: The layout with the abbreviations of the cells, machines, buffer and kitting stations.

Table 2: Explanation for the abbreviations on the layout in both Swedish and English

Abbreviation	Swedish explanation	English explanation
PSC	**P**lan**S**lips**C**ell	Face grinding cell
IRC	**I**nner**R**ings**C**ell	Inner ring processing cell
ORC	**O**uter **R**ing **C**ell*	Outer ring processing cell
KTC	**K**omponen**T** **C**ell	Pairing cell
MGC	**M**onterin**G**s**C**ell	Assembly cell
LAS	**LAS**er maskin	Laser machine
ANO	**ANO**ljingsmaskin	Preservation machine
INP	**INP**lastningsmaskin	Wrapping machine
KAR	**KAR**toneringsmaskin	Cardboard machine
ESK	**E**ttikett **SK**rivare	Label machine
PKC	**P**ac**K**eterings**C**ell	Packaging cell
KIT	**KIT**ting station	Kitting station
BUF	**BUF**fert	Buffer

*The names “Innerringscell” which gave us the abbreviation IRC is very similar to the abbreviation to “Ytterringscell”, YRC. IRC and YRC sounds similar and they also look quite similar so instead of choosing the Swedish name of the outer rings cell the English word was chosen.

4.6 Identify primary and secondary users

The primary users were identified as

- Operational managers
- Operators

The secondary users were found to be

- Supply chain personnel
- Service technicians, both electricians and mechanics
- Maintenance engineers
- Production technicians
- Process media personnel
- Quality personnel
- Channel group manager
- Tool technicians
- Process development personnel

A short description of the users follows in the list below. A description of how the users relate to the control room can be seen in section 4.9.

- Operational managers are the team leaders for operators. An operational manager has usually worked as an operator before. The operational manager helps and guides the operators if they have any problems, for example material shortages and quality problems. The operational manager works as the link between the operators and the factory management. Therefore the operational manager attends many meetings during a day. An operational manager also has the responsibility to appraise the personnel performance. There will be four operational managers working in the new production system, one for each shift.
- Operators are the ones who are operating the production system and make sure the machines produces as planned. Examples of work tasks in the production system are: taking care of alarms and warnings, preforming measurements, changing tools, doing setups, filling up material and cleaning. There will be 28 operators operating the production system. The 28 operators will work four-shift with seven operators on each shift.
- The supply chain personnel coordinate the production orders and the material to the production system. Supply chain personnel only work daytime.
- The service technicians fix machines with failures and make preventive maintenance on the machines. There will be one electrician and one mechanic on each shift who works with unplanned maintenance for the whole D-plant. Ten additional service technicians are working only daytime with planned maintenance, inspections, and improvements.

- The production technicians works with continuous improvements of the production system. Both fixing problem in the production day to day and larger improvement projects of machines, instructions, work procedures, tools and so on. There are three production technicians working daytime for the whole d-factory.
- The process media personnel make sure pressure, flow and temperature of fluids to the machine are within the given tolerances. They work four shifts with one person responsible for the d-factory. There are also additional personnel working daytime with the process media system.
- The quality personnel work daytime and follow up the product measurement variation and values.
- The channel group manager is the manager of the LCHO channel and the chief of the operational managers.
- The tool technicians prepare the tools for the machines. There are five people working as tool technicians during daytime.

4.7 Result from interviews with the users

The interviews showed that the users need to know what has happened in the production system, what will happen in the production system and the present state of the production system. Alarms and warning from the production system should be presented. They need support for deciding what task to do first. Information about what to produce at which time and the material supply is needed. The users need different communication methods and contact information through the control room. Information on whiteboards placed in the production area should be presented on screen displays in to control room instead, to make sure it is updated and easy to access. A need for analysing scrap, staffing, alarms, first piece measurements, process measurements, OEE, setup times, cycle times, pace, net output was identified. A need to develop own instructions of how to reset alarms and warnings and deal with quality problems was also identified. The users wanted the be able to control the material flow by the AGV from the control room, block and order out products from the buffer and order consumables from the control room.

See Appendix E for the gathered information from the interviews with all information each user group needs presented, all the data they have to enter manually and all the identified controls that should be included in the control room.

4.8 Observation

At the time of the observations with the operational managers the idea was that meetings should be held in a room connected to the control room with the same screen displays. The process development team later decided to not have these meeting rooms connected to the control room because the size of the control room area would become too large. For the operational managers' meetings the following information was needed; information about staffing problems, problem history for the system during the last 24 h, if there are setups coming up and if some material are missing. If a material shortage was identified the operation manager helped decide if the operators should wait until material was supplied or if the operators should do a setup to produce another type of product, which they had material for. A problem with password was raised when the operational manager should hold a meeting but did not have the password to the computer. The operational manager handled the workforce and decided if personnel could take vacations. If an operator became sick or injured the operational manager made sure the operator was taken care of.

4.9 System description

From the interviews a system map was developed in order to get a better view of which devices and personnel the control room will have connections with. The map is visualized in Figure 5.

The system boundaries shows that the operational manager and the operator will interact within the control room by both information sharing and energy impact of pressing both keyboard and computer mouse while the other users will interact with the control room through their own devices. In order to be as efficient as possible a need of a mobile device for the operators were found, it would not the efficient for the operator to back and forth to the control room between tasks. The mobile should show parts of the information that is available in the control room. The mobile device should be able to show a lot of visual information. But also to call people, take pictures, send text messages, read QR-codes, make sound alarms and retrieve vibration signals. A smartphone was chosen to be the most suited device. A tablet would be better for the visual information function but the frequency of use and the carrying aspect tells against this. The operator will use the control room for important tasks like ordering material, ordering AGVs, handling the buffer, for analysis of data and for finding information, which is seldom needed. The operational manager will be the main user of the control room. The operational manager or an operator always has to monitor the process from the control room because the information about the status of the AGV system is not included in the mobile.

The maintenance personnel, which works with unplanned maintenance wants a tablet because they will need more detailed information than the operators and the screen size of a smartphone would not be enough. The frequency of use will be less than the operators mobile. The maintenance department and the tool preparation want to have a big screen display in their offices with information from the control room. All the secondary users want to be able see, add and change information that they find interesting to the information system by their regular computers.

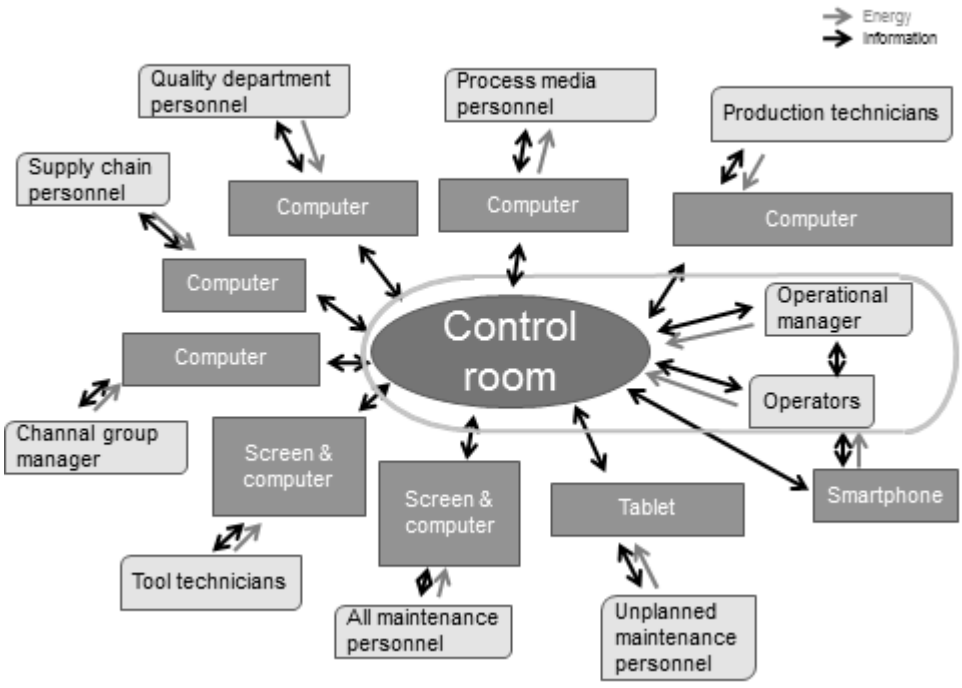


Figure 5: The system map of the information system connected to the control room

The interviews and observations identified the need to have the following units available in the control room to operate the system: screens, a keyboard, a computer mouse, a phone, a whiteboard and a printer. However, the process development team has a goal of having a paper free plant. If the goal can be fulfilled has not been investigated in this master thesis.

4.10 Functional tree

The functions that were identified for the control room can be seen in the functional tree in Figure 6.

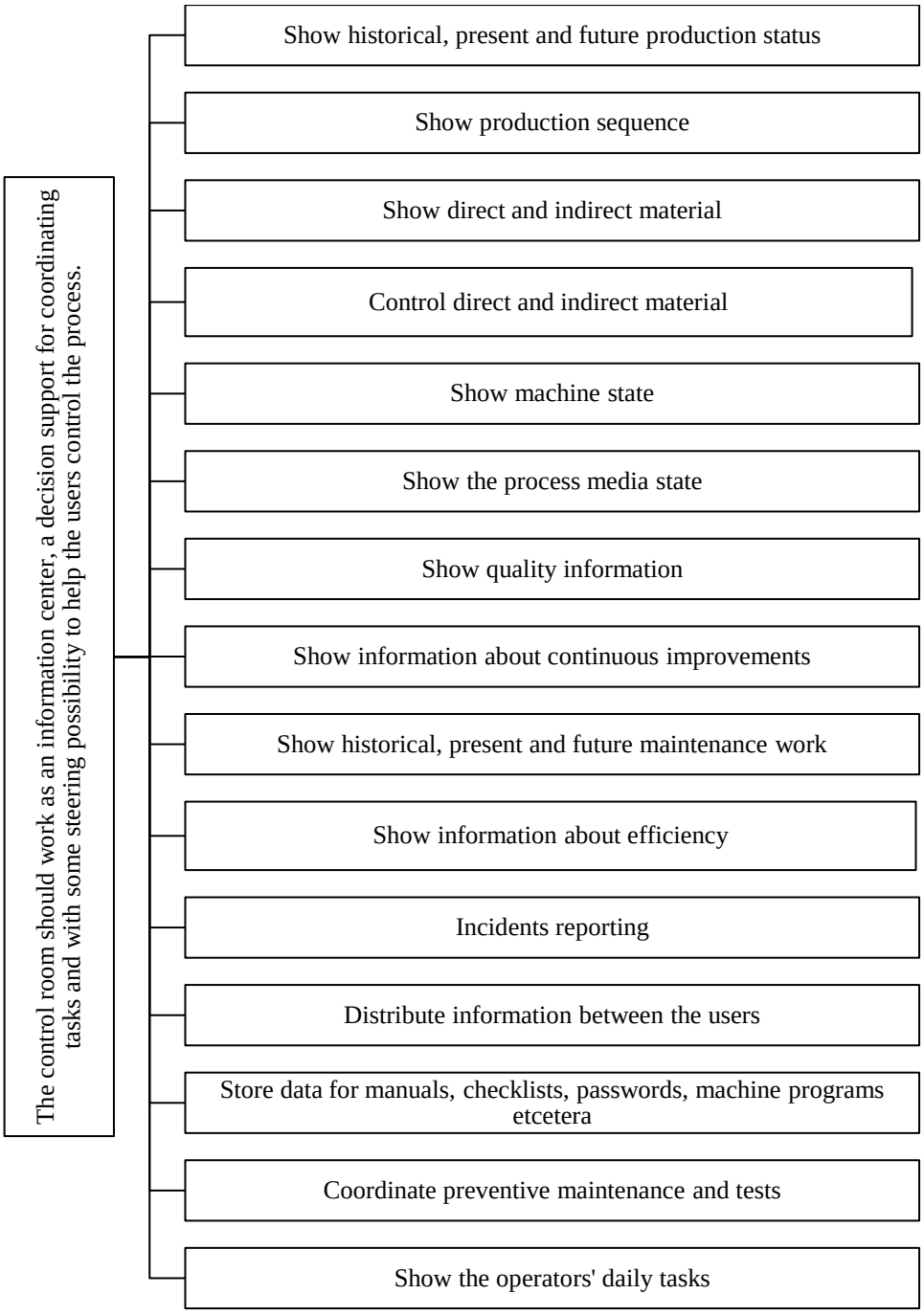


Figure 6: Functional tree of the main functions, which will be included in the control room

There are some functions that have been requested by the users but that the researcher has chosen to not include in the information system. Those are:

- The ability to reset alarms and warnings from the control room
- The ability to make measurement changes on a detail from the control room based on the measurement machines' result.

The problem with these two steering abilities is that in the control room the user does not get as much information to base the decision on as when standing next to the machine. When the user is standing next the machine additional information is given by the surroundings in form of visual information, sounds, smells, haptic information and extra manual measurements.

4.11 Hierarchical task analysis

Five hierarchical tasks analysis were developed to describe typical work tasks within the control room. The following list describes the main tasks and the first level in their HTA. The complete HTA for the tasks with all levels included can be seen in Appendix F.

Perform shift turnover

1. Go through the calendar stops of the previous shift with the previous shift.
2. Go through the diary with the previous shift.
3. Investigate what to do next and what will happen during the shift.
4. Perform a preventive maintenance task.

Plan: Do step 1 to 3, if no jobs are found when step 3 is done do step 4. If a task was found in step 3 skip step 4 and do the identified task.

Reset alarms or warnings

1. Information gathering of all active alarms and warnings.
2. Prioritize what to do.
3. Sign in "I will fix the problem" for the chosen alarm or warning.
4. Solve the problem (partly out on the production floor).

Plan: Do step 1 and 2, if the user identify an alarm or warning that the user decides to solve do step 3 and 4.

Quality assurance

1. Checks if any measurements from the measurement machines in the cells are alarming or warning.
2. Checks if there is a trend of measurements within control limits.
3. Discuss possible causes.
4. Discuss possible solutions.
5. Resolve problem.
6. Work to minimize scrap level.

Plan: The operator or operational manager does step 1 and 2 regularly. If a trend is identified in step 2 do step 3 and 4. When the measurement goes outside control limit do step 5 based on the result from step 3 and 4. Step 6 is done whenever time is offered.

Manage material shortage

1. Monitor material supply
2. Collect information
3. Decide strategy
4. Handle material shortage according to decided strategy

Plan: Do step 1, if material shortage is detected during the first step do step 2 to 4.

Prepare and do an assignment during a preventive maintenance stop

1. Investigate if the operator has been appointed to which job.
2. Investigate if the operator can sign up to a preventive maintenance job.
3. Performing the preventive maintenance job.
4. Sign that the preventive maintenance job is finished.

Plan: Do step 1, if a job was appointed to the operator do step 3 and then 4. If no job was appointed the operator in step 1 do step 2. If the operator find a job that fits the operator's free time and the expected knowledge requirement do step 3 and 4.

4.12 Company visit at Volvo Cars

The visit at Volvo Cars inspired what information should be visible on the screen displays in SKF control room, namely their machine park overview screen display, sensor information, alarm texts, availability based on alarms, a graph for analysing alarm, a diary, an information control document. Exactly where and how the information was used is described in Appendix H, I, K and L.

4.13 Visits at SKF

The following information is showed in the app MOST, Mobile Operator Support Tool, used by operators in the heat treatment at SKF for sharing information about its production system. The app has no control functions. MOST has an overview of the machine park with possibilities to get deeper information by pressing each machine. Alarm and warning messages are available. The user can get suggestions of solutions to a problem in the production system. The users can communicate with each outer through a messenger function. The app has instructions available for common tasks like setups and tool changes. Daily tasks that the user can sign are also available. With the app the users can also report values and report actions. The result from the data gathering during this thesis is very similar to the identified need from the study of MOST. This shows that the identified needs for the control room seem reasonable.

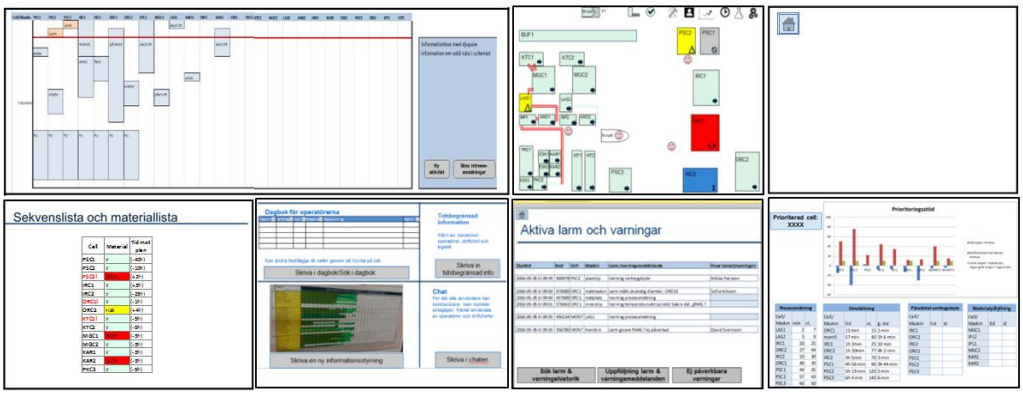
During the visit at the control room for process media at SKF it was discussed which data should be taken from the sensors in the tanks in the basement and which values should be measured nearby the machine. The screen display layout is the same as the new control room with an overview screen display with boxes indication the status of subsystems with colours. Each box was possible to click on with the computer mouse and more information would show about that subsystem, in the same way as it will be proposed for the control room.

4.14 The interface

Seven main groups of screen displays were designed, which contains primary information for the user. The displays and their placement are shown in Figure 7. Short descriptions over the screen displays are showed in the list below:

- The first screen display is the calendar screen display, which shows when machines will be stopped.
- The second screen display is the machine park overview, which shows the present state of the machine park.
- The third screen display shows deeper information from the links in the machine park overview.
- The fourth screen display shows changes in production sequence and material shortages.
- The fifth screen display is a communication screen display, which is used as the communication link between the users.
- The sixth screen display shows the active alarms and warnings.
- The seventh screen display is the prioritizing screen displaying information, which helps the operator prioritize the work tasks.

1 2 3



4 5 6 7

Figure 7: The main screen displays in the control room.

4.14.1 Calendar screen display

The first main screen display is a calendar screen display showing when the different automation cells and machines will be stopped. The operators have expressed a need for knowing when and how long time the machines will stop so they can plan their work. They especially expressed a need of knowing when unscheduled maintenances will be finished. The supply chain personnel want to know when machines and automation cells will be standing still to plan the production rate accordingly. The electricians, mechanics and production technicians wants to know when setup are to be made because they have problems following up the result of a change or test when it coincide with a setup because fine tuning of the machine is often needed after the setup. The same group wants to know when a machine is planned to stand still because then they can have time doing planned maintenance and tests. The tool preparers want to know when the setups and tool changes will happen so they can prepare the tools.

The result of all these needs can be shown in the fifth main screen display, Figure 8, the calendar screen display. The screen display is the size of two regular screens in width to be able to show all cells, single machines, kitting stations, conveyor belts and the buffer in the columns. The buffer and the conveyor belts are though missing from Figure 8 but they should also have columns.

On the vertical axis there is a time scale with the standard time; present time and 8 hours forward. More information about the time interval is presented in Appendix G.

The red line in the calendar shows the present time. If the user goes back in time orange boxes in each column will show when each machine, cell, kitting station, buffer and conveyor belt have hade active alarms. If the users press the alarm box the alarm text should show in the blue information box on the side of the calendar.

Activities that will stop the cell, machine, buffer, kitting station and conveyor belts are shown as light blue boxes in the columns. The boxes placement and length shows the date and time the stop will start and end. The abbreviation shows what kind of activity it is.

If a user clicks on an activity box in the calendar with the computer mouse more information about that activity will pop up in the big blue box at the side of the calendar. The user will have the ability to change the information about the activity in the blue information box. The information that will be showed is the same information as the user or production system will write in to describe the activity. A description of the activities and how there are put into the schedule can be read in Appendix G.

When a user writes in an assignment for the maintenance department or for the production technicians they will have the ability to check a box if they are interested to know what happened to with that assignment. There is a button in the blue big box at the side of the schedule which the user can press to get information of these activates if the user logs in with his/her ID.

There should be a setting button where the user can choose which activities will be visible in the schedule. There should also be a choice of which cell, machine, buffer, kitting stations and conveyor belts should be visible in the schedule.

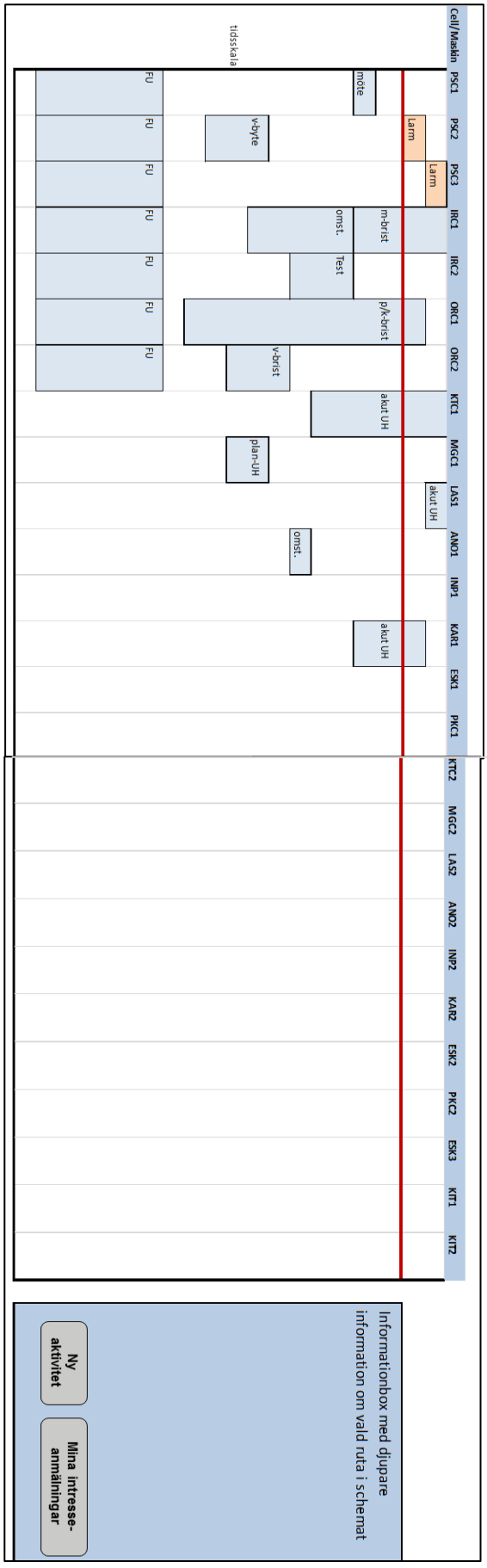


Figure 8: The calendar screen display

A summary of the information that can be shown in the calendar screen display is presented in Figure 9. The white boxes have suggestions for interface design in Appendix G while the grey boxes' information is only described.

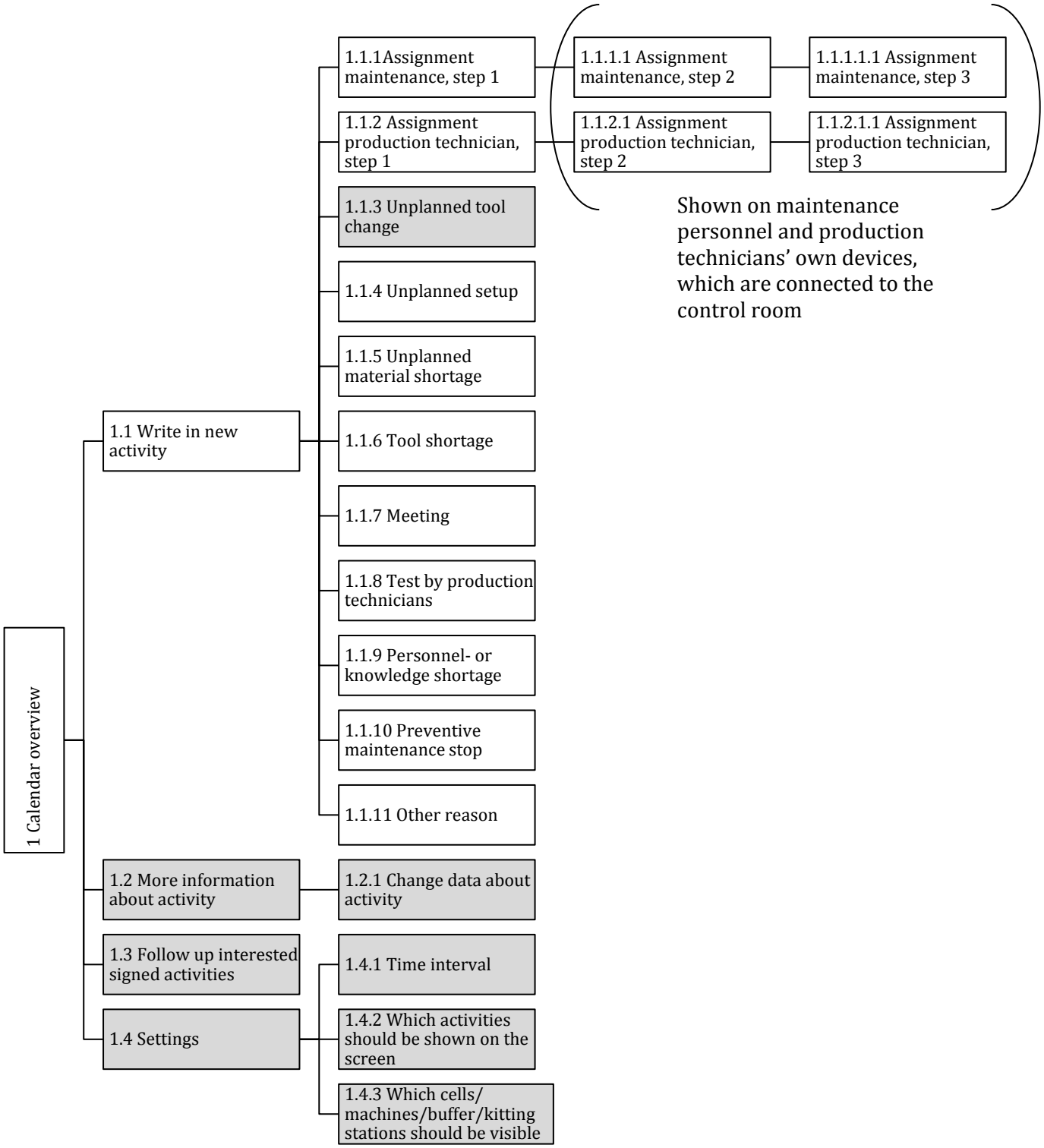


Figure 9: A summary of the information showed in the calendar screen display

4.14.2 The machine park overview screen display

The machine park overview, Figure 10, was developed from a need the operators and operational managers had of a screen display that would describe the present status of the machine park. This is, according to the operators, the screen display that would help them the most if only one screen display could be implemented. The background of how this screen display was created can be seen in Appendix H.

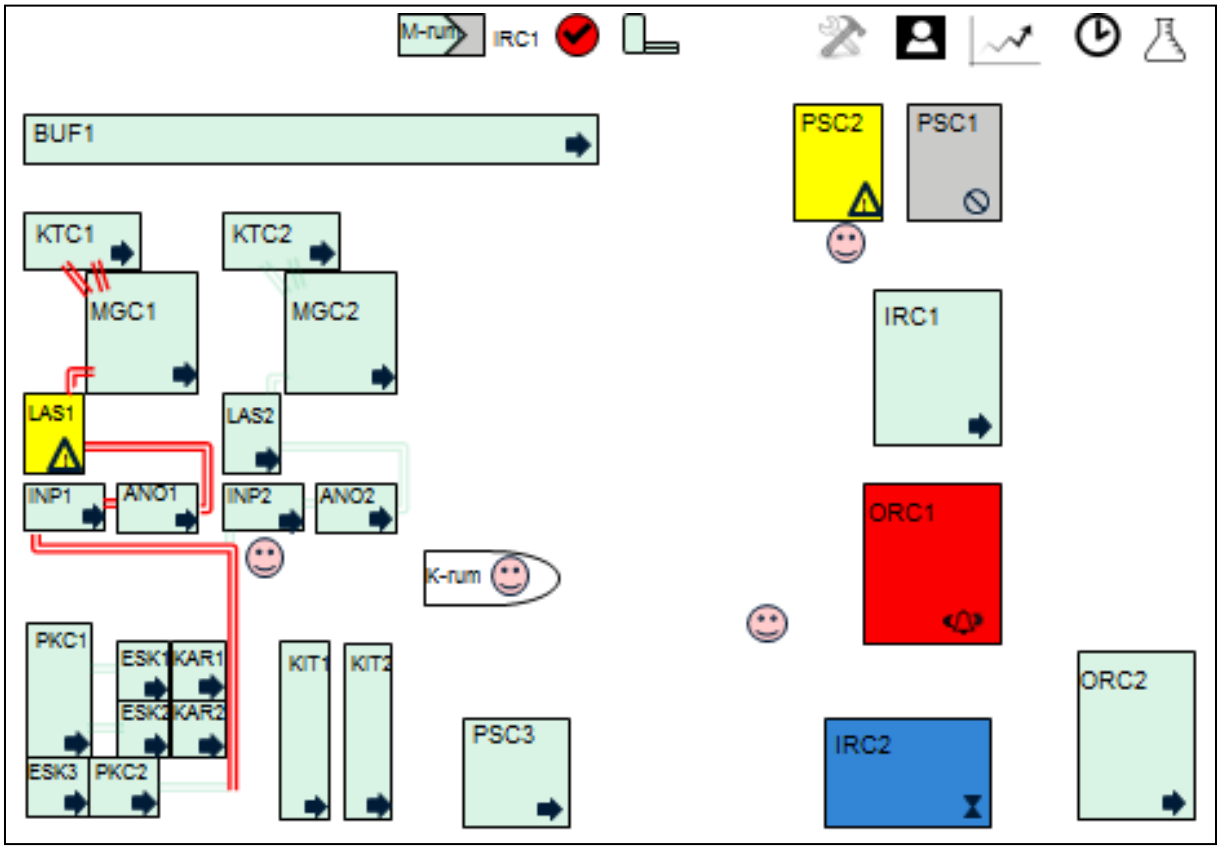


Figure 10: The second main screen display, an overview of the machine park at SKF LCHO line in the D-factory. Sources: Hammer and spanner icon (Wikimedia commons 1, 2016), Person icon (Pixabay 1, 2016), Graf icon (Pixibay 2, 2016), Time icon (Wikimedia commons 2, 2016), Lab icon (Pixabay 3, 2016), Bell icon (Wikimedia commons 3, 2016)

Cells, machines, buffer and kitting stations are symbolised in the layout as boxes.

- The letters in the boxes describes which operations are being done in the different objects. An explanation of the letters in the boxes can be seen in Table 3. Boxes with the same letter combination but different numbers and the end are identical cells, machines or kitting stations There is only one buffer, BUF1. The number was added to ease the implementation of more buffers in the system.
- The boxes are colour and symbol coded to describe the status of the object. The symbol in the lower right corner of each box is designed to help the colour blind. A description of the meaning of the colour and the symbols are shown in Table 4. The colours and symbols were chosen with the intent to have the similar meaning as the status. In Scandinavia red colour symbols stop, danger, hot and fire. Yellow symbolise warning, testing and slowly. Green colour symbolise OK, go, continue and on. Blue colour means calmly, cold and water (Osvalder et. al., 2010).

- Ivergard & Hunt (2009) describes how information with high colour contrast increases visibility for the user. This is the reason for having light green and a light grey colour on machines that are okay respective turned off because then the user does not have to do anything with those machines. Alarming, warning and waiting machines demands that the operator should act which is the reason for those colours are more pigmented and have a higher contrast to the white background.
- The user can press the boxes for the cells and the single machines and the deeper information screen display will present more detailed information about the cell's or the machine's status.

Table 3: A description of the figures at top of the machine park overview.

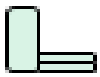
	The figure shows that a detail from cell IRC1 is being measured in the measurement room. The bar moves forward as the measurement continues, when it is finished box will blink to inform the operator. When details are measured in the measurement room there has typically been a set up or a machine crash, which means that cell is not allowed to produce more details until the measurement is approved. The operator does not want to wait in the measurement room, but do other things until the measurement is finished. This would allow the operator to know when he/she should go back.
	The figure is an indication of the measurement result from the measurement machines in the cells. If all measurements in all machines are ok the colour of the figure is green. If there is one or more measurement machine that has an active warning but no alarms the colour of the figure is yellow. If there is at least one measurement machine has an active alarm, which has not been reset by the operator the colour of the figure is red. The symbol also works as a button to show the quality screen display on the deeper information screen display.
	The colour of the figure shows if there are AGVs alarming or if all of them are OK. If at least one AGV is alarming the colour of the figure is read otherwise it is green. An AGV cannot give warnings. The symbol also works as a button to show the AGV screen display on the deeper information screen display.
	The symbol works as a button to show the maintenance screen display on the deeper information screen display.
	The symbol works as a button to show the administration screen display on the deeper information screen display.
	The symbol works as a button to show the improvement screen display on the deeper information screen display.
	The symbol works as a button to show the efficiency measure screen display on the deeper information screen display.
	The symbol works as a button to show the lab screen display on the deeper information screen display.

Table 4: A description of colours and symbols used to show the status of the objects in the production system.

Colour	Symbol	Meaning
Light green		The object is OK.
Yellow		The object is warning because a warning level is reached and the object will probably be stopped soon. Example of warnings are material levels, tool changes, measurements and process media levels
Red		The object is alarming, which means the object is stopped. Example of this is a machine crash, process media levels, measurements, communication problems between systems.
Blue		The object is stopped because it is waiting for the AGV to deliver material or fetch material or the object has passed it cycle time with more than X seconds. How many second has to be decided by the process development team.
Grey		The machine is turned of

The face symbols on the screen display are the different operators. In the operators mobile there will be a GSP function. The movement of the operators will be tracked on the screen display. The reason for having the this tracking device on the operators is because the user can then see if a face is near a machine that is alarming, and can be assume that person is taking care of that alarm.

The name of the user connected to a face symbol should be possible to see if the computer mouse is placed upon the face symbol. The reason for not having the name showing all the time is because the screen display can become cluttered and hard to read. The reason for having the function of seeing which colleague is standing where is because the operators know how experienced their colleagues are and can thereby decide if they need to help a colleague standing by an alarming machine.

The K-rum symbol is the planned placement of the control room. The object is included in the layout so the operators on their mobiles will know if an operator is sitting there.

The kitting stations, the conveyor belts and the buffer can only have the status OK green or alarming read. While the cells and machine can have all the status levels. More information about the conveyor belt can be seen in Appendix H.

4.14.3 The deep information screen display

Because it is important for the primary users to always see the present state of the machine park this screen display was developed as a screen display to show deeper information about the production system linked to the machine park overview. This screen display has a lot of sub screen displays that are reached from the machine park overview. The main sub screen displays are the: machine overview, cell overview, buffer overview, AGV, quality, maintenance, administration, improvement, efficiency measure and lab report from process media. Figure 11 and 12 shows all screen displays that can be seen on this deeper information screen display. The white screen displays are visualized in the Appendix I, while the grey only has a description of the information that should be shown on the screen display in Appendix I.

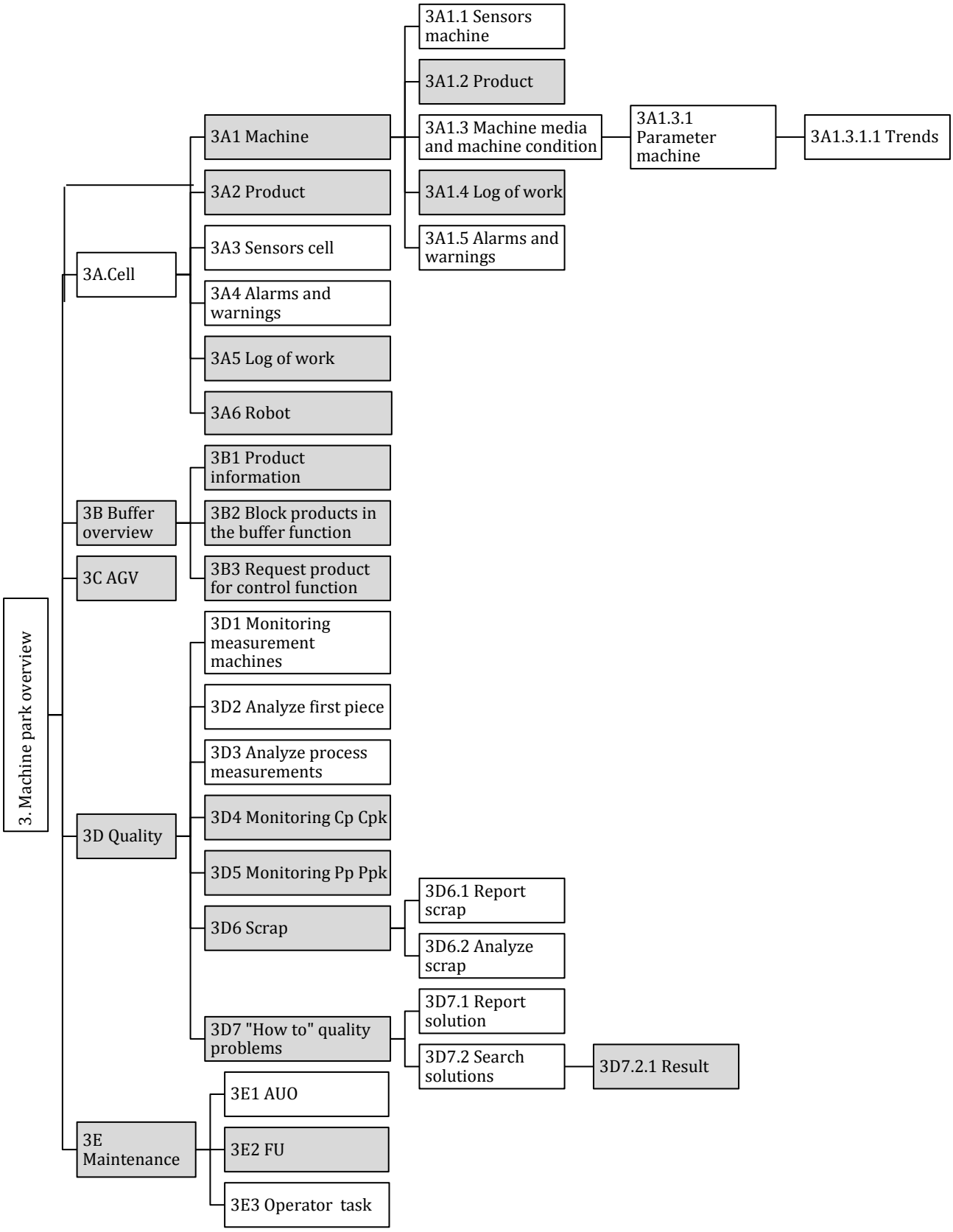


Figure 11: Summary of the sub screen displays on the deep information screen display part 1

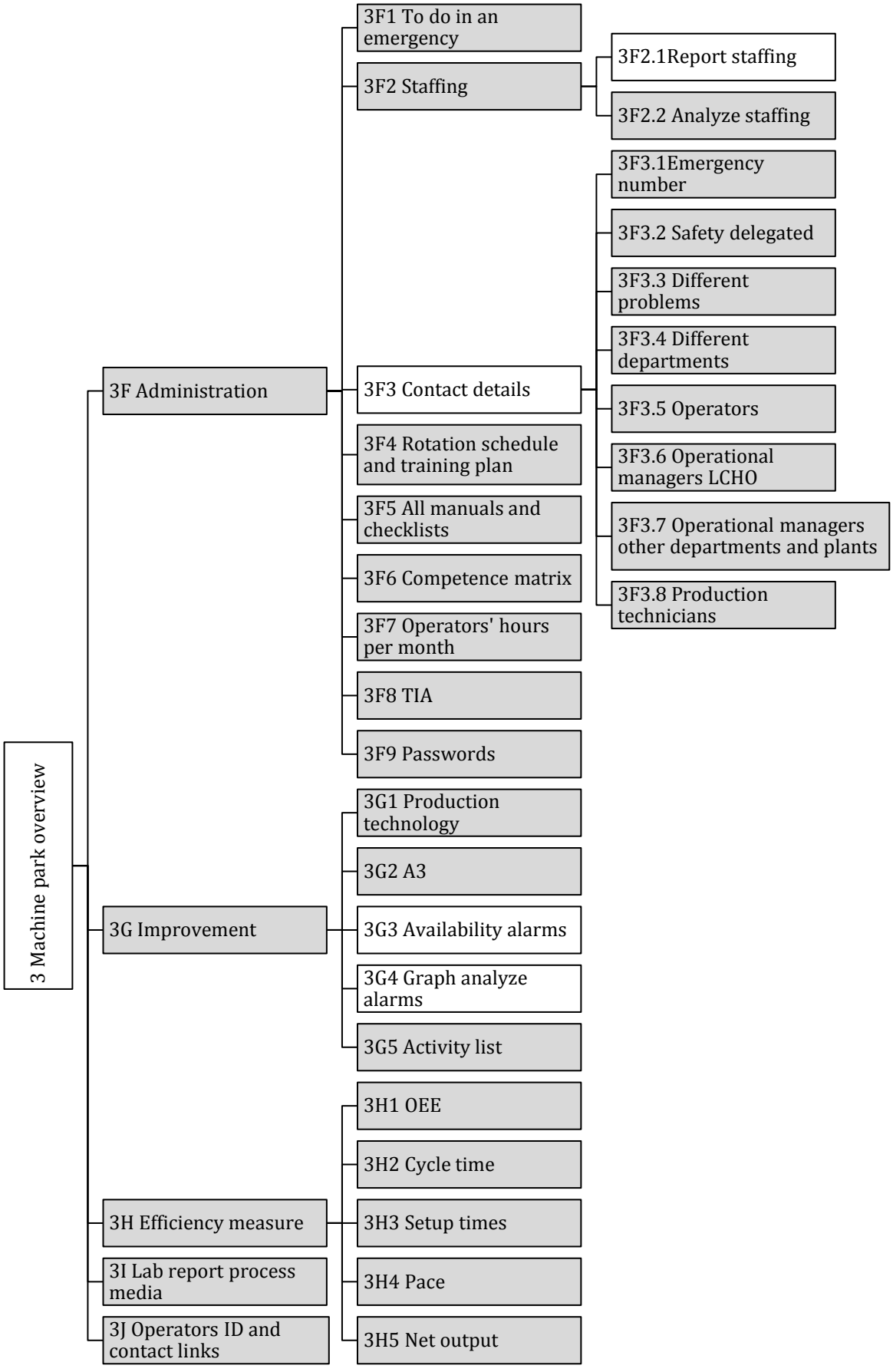


Figure 12: Summary of the sub screen displays on the deep information screen display part 2

4.14.4 The production sequence and material list screen display

The operators and the operational managers need to know what to produce and when and if they will have enough material. The overview screen display, seen in Figure 13, shows changes in the production sequence for all the cells and a colour coding of if the cell, that the supply chain department supply with material, will have material a decided number of hours forward. The screen display also shows the number of hours the cell is before or after plan.

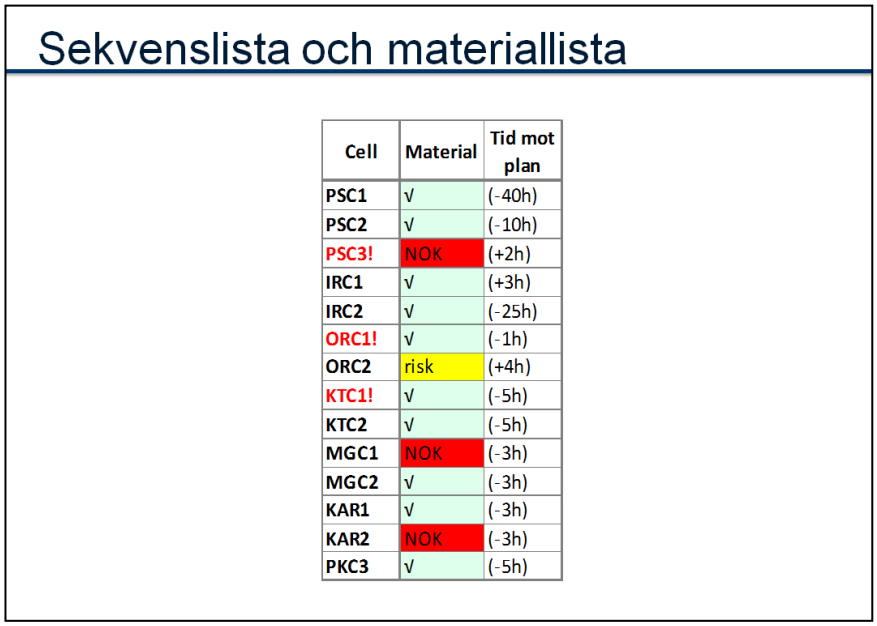


Figure 13: The overview screen display of sequence changes and material shortages

From this screen display the operator can press a cell and get to a more detailed production sequence description of the chosen cell and the material needed. On the sub screen display there are also links to changes in the sequence list, a function for following a product throw the production system and a data base for machine programs. There is also a link to an inventory and material order program for those items that the operator is responsible for. Appendix J describes the information on the sub screen displays more deeply. Figure 14 shows a summary of the information on the sub screen displays.

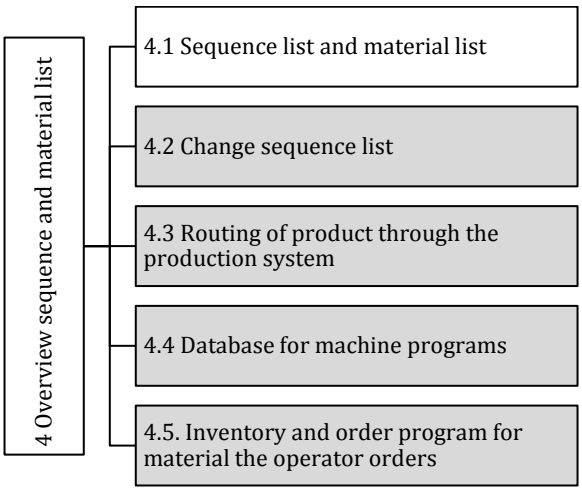


Figure 14: The sub screen displays for the production sequence and material list

4.14.5 The communication screen display

On the communication screen display, the users share information with each other. The screen display is showed in Figure 15.

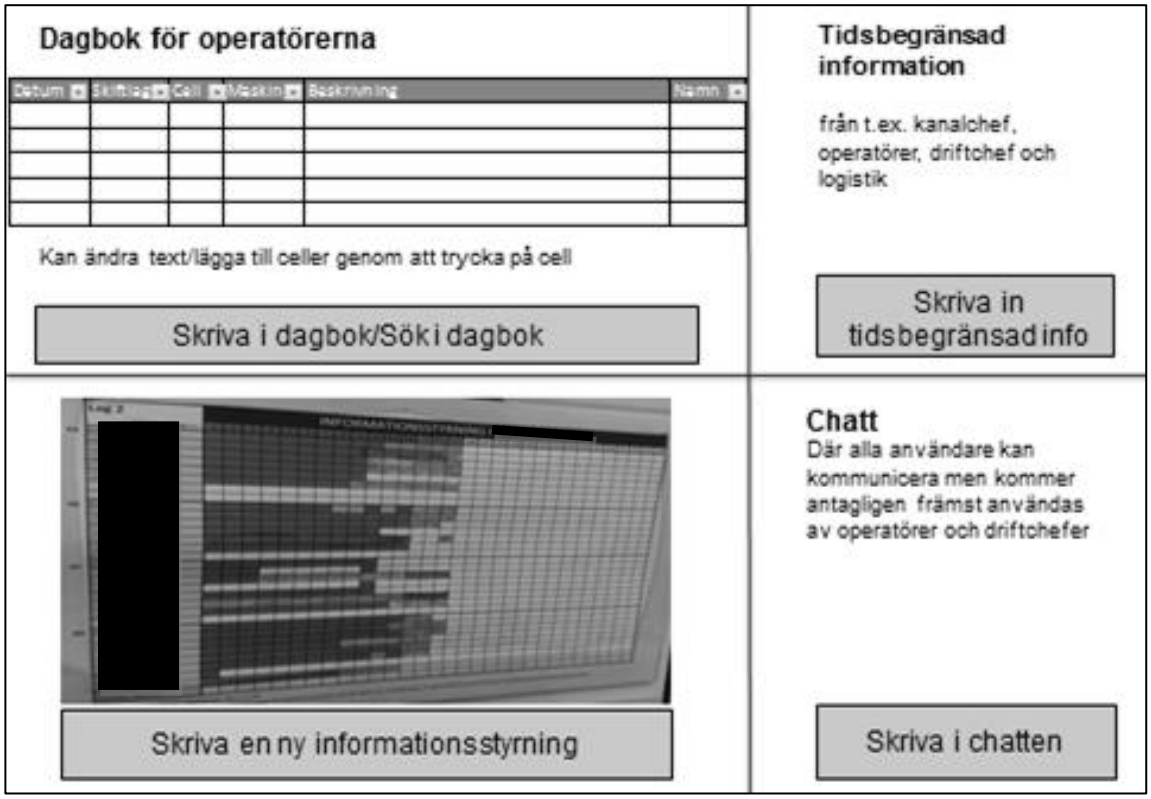


Figure 15: The communication screen display, from this screen display the different users communicate with each other. The factory's and the operators' names are censured.

In the upper left corner of the main screen display there is a diary for the operators. The operators said that they have problems with the renditions they make at each shift turnover. It is easy to forget something, especially information from the shift before. If the diary is filled in continuously they can just go through it quickly with the next shift to make sure nothing is forgotten. Appendix K contains more information about the diary.

In the upper right corner of the communication screen display both the primary and secondary user of the information system will be able to write in information that all users will see. This information will be visible during a certain time. The start and end time for visualising the information will be decided by the user when the information is written. Time limited information sharing was a wish from the channel group manager because today there are problems with outdated information that is not removed from the production whiteboards.

In the lower left corner there is an information control document, a possibility to make a handshake with the operators that they have read important information about for example a change in a manual. The production technicians were the ones that were asking for a method to make sure the operator get important information. It was a wish from the operators that only information documents that concerned the areas that the operators were working at should be visible. The researcher is however not sure that is a good idea because this puts a lot of pressure that the competence matrix at all time will be updated, which the researcher is questioning, will be the case. More information about the information control document can be read in Appendix K.

In the lower right corner a chat is visible where all users will be able to communicate with each other, like asking for help. The writer should be able to put in pictures in the messages in order to ease the communication.

The functions of the communication screen display are summed up in Figure 16.

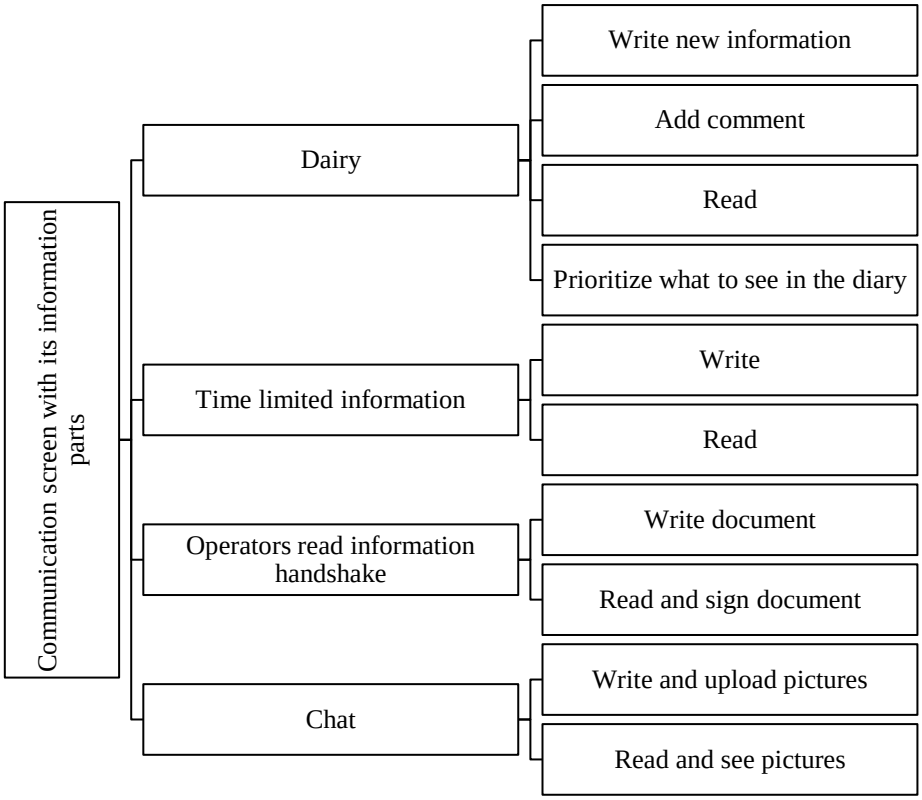


Figure 16: A summary of information showed on the communication screen display.

Navigation on the screen display is described in Appendix K.

4.14.6 The active alarm and warnings screen display

The sixth main screen is the active alarm and warning screen display, shown in Figure 17. On this screen display the user sees the active alarms and warnings. The machines, which are not included in a cell in the assembly flow, have been assigned the cell "MONT". The buffer, conveyor belts and the kitting stations also have the cell "MONT". The alarm and warnings are grouped in rows after its cell, secondly its machine and lastly the newest alarm/warning from the machine should be put highest in the cell group. The reason for doing this grouping can be read in Appendix L.

The following information is shown in each row:

- The time the alarm or warning started. This is interesting for the operator, when prioritizing what to do first.
- The code of the warning or the alarm. This would help the maintenance worker to search for instruction of how the problem was fixed last time.
- Which cell and machine that is alarming or warning. This is interesting for the operator and operational manager so they will know where they should go, if they are responsible for that cell/machine.

- The alarm or warning text so the operator can assess the possibility of being able to solve the problem.
- A box where the user signs that that he/she will be solving the problem. This will help the colleagues to decide if they should take the alarm or help someone.

The user can press a row in the active alarm and warnings table and get to that machines alarm log.

The operators has described that the present machines at SKF have poor alarm texts. The worst texts only contain a code. An example of how alarm texts are designed at Volvo can be seen in Appendix L.

There are three buttons at the bottom of the screen display.

- One for searching and analysing alarms and warnings.
- The other button was a need from the operators that they wanted to be able to create instruction for how they have reset machines from alarms and warnings in the past. One function will be to search "how to" instructions and the other to write a "how to" instruction.
- A need of a function to hiding warnings that the user cannot act on was raised. A button is leading to the possibility for the user to hide warnings and getting a list of which warnings are already hidden.

Figure 17: The fifth main screen display describing active alarm and warnings

A summary of the active alarm and warnings screen display's sub screen displays and their functions can be seen in Figure 18. The grey boxes are not described in Appendix L but for the rest of the sub screen displays suggestions of screen displays are showed.

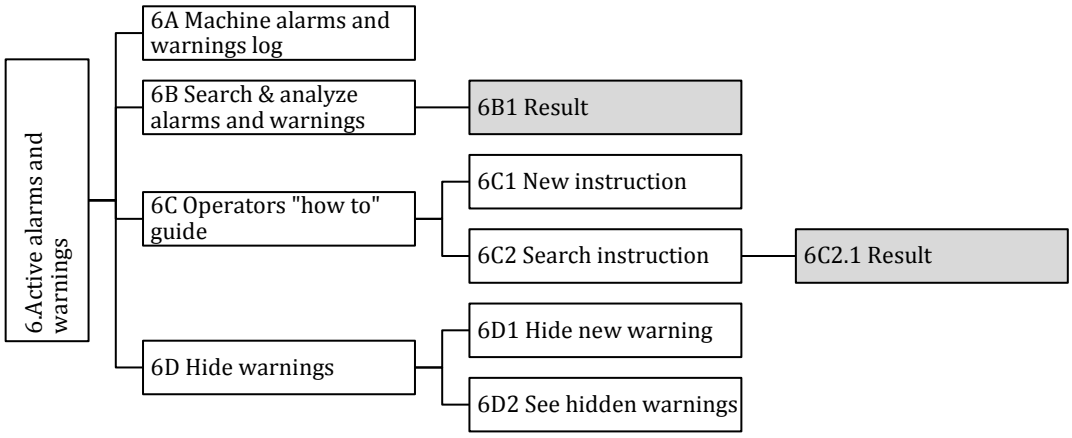
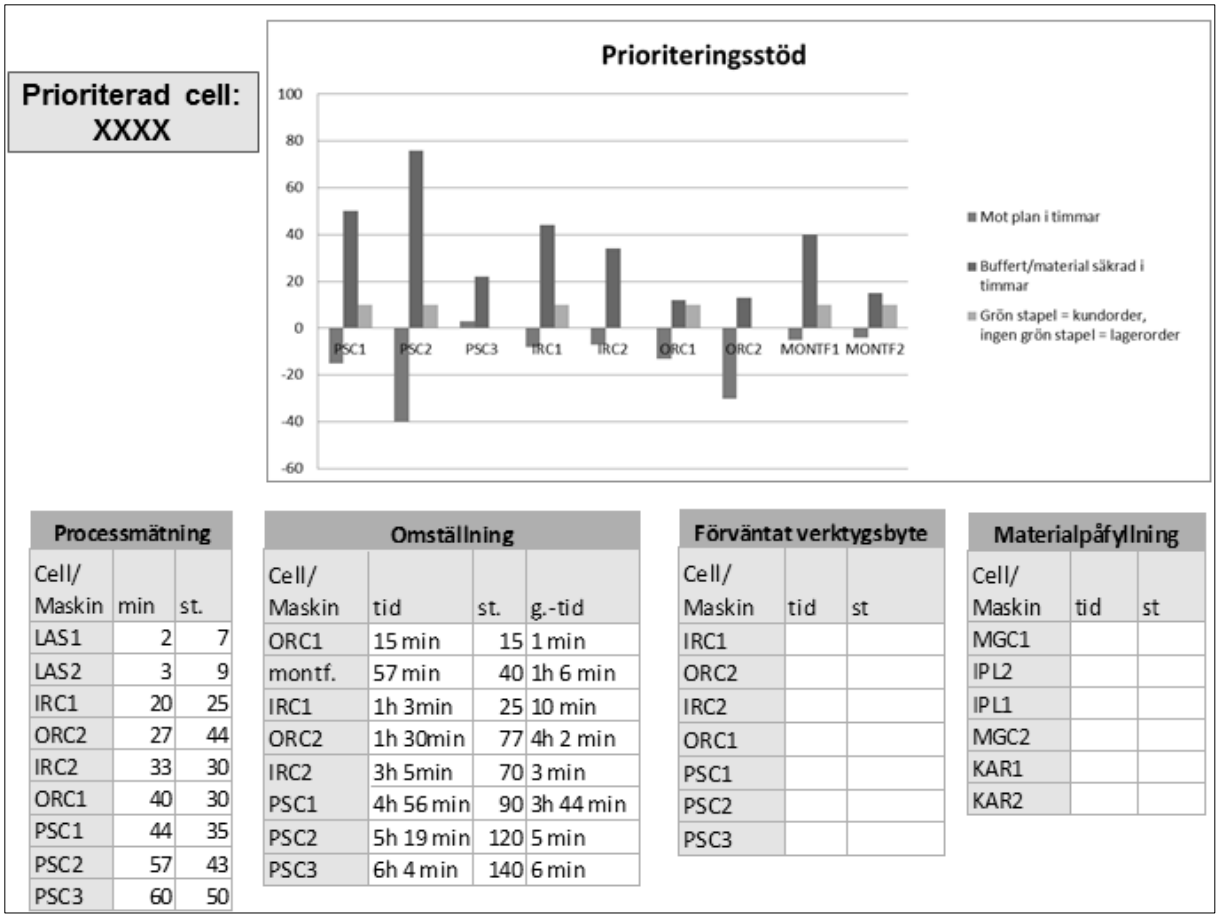


Figure 18: A summary of the sub screen displays to the active alarms and warnings screen display

4.14.7 The prioritizing screen display

The operators expressed a need for support in knowing, which task to do first. This screen display, Figure 19, was designed as a support to them. The screen display does not have any sub screen displays.



Processmätning

Cell/ Maskin	min	st.
LAS1	2	7
LAS2	3	9
IRC1	20	25
ORC2	27	44
IRC2	33	30
ORC1	40	30
PSC1	44	35
PSC2	57	43
PSC3	60	50

Omställning

Cell/ Maskin	tid	st.	g.-tid
ORC1	15 min	15	1 min
montf.	57 min	40	1h 6 min
IRC1	1h 3min	25	10 min
ORC2	1h 30min	77	4h 2 min
IRC2	3h 5min	70	3 min
PSC1	4h 56 min	90	3h 44 min
PSC2	5h 19 min	120	5 min
PSC3	6h 4 min	140	6 min

Förväntat verktygsbyte

Cell/ Maskin	tid	st
IRC1		
ORC2		
IRC2		
ORC1		
PSC1		
PSC2		
PSC3		

Materialpåfyllning

Cell/ Maskin	tid	st
MGC1		
IPL2		
IPL1		
MGC2		
KAR1		
KAR2		

Figure 19: The prioritizing screen display

In the box “Prioriterad cell: XXXX” the operational manager can write in which cell or cells that should be prioritized by the operators. More information about the prioritized cell box can be seen in Appendix M.

The bar chart is a help to the operator to know which cell they should prioritize when the “Prioriterad cell: XXXX” is empty or the operators are choosing between cells, which are not specified in the “Prioriterad cell: XXXX” box. The bars shows how many hours each cell is ahead or after plan, the calculated hours of the material the buffer is holding for each cell and if the order which is produced in the cell is to a customer or to stock. More information about the bar chart can be seen in Appendix M.

The tables in the lower part on the screen display are a help to the operator to know when frequent tasks will happen so the operator can prioritize tasks. The first tables shows when frequent measurement will happen. The second table shows how many minutes and products it is left until a setup will happen and the implementation time of the setup. The last two tables shows then a tool change is calculated to happen and when material have to be refilled in the cells. More information about the tables can be seen in Appendix M.

4.15 Information on mobile

It is believed that the operators will not have time to go back and forth to the control room to find out what their next task is, and that they thereby need a mobile phone. The information on the mobile should look similar as is does in the control room to follow the rule of consistent presentation of information describe in the theory chapter. Appendix N describes the information from the control room that also should be visible on the mobile. The information that operator have to write in on the mobile is also included. As well as the information that only will be possible to add to the system from the mobile.

4.16 Result from review of interface with the process development team

On this review the AGV placement and status were showed on the machine park overview screen display. The process development team raised the problems that the AGV will travel outside the map to other production systems. They also saw problem with combining all data sources on the machine park overview with the AGV system. The outcome was to have a symbol of the AGV with colour coding describing the AGVs’ status on the machine park overview. The symbol also works as a link to the AGV sub screen display at the deep information screen display. The change was implemented on the interface presented in this thesis.

The process development team wanted to use the machines’, cells’, robots’, buffer’s, and conveyor belts’ own screen displays out in the production system for displaying deeper information about the objects on the deeper information screen in the control room. By having the same screen display in the production and in the control room the design principle of consistent presentation of information is followed. This lead to that the researcher only focused on finding the needed deeper information about the objects and not focus on the information presentation and screen display navigation as she had done for the other screens in the presented interface. The screen displays of the machines’ out in the production are not developed jet so the investigation was made to show which information should be shown om them.

The service electrician and mechanic wanted information from the process development team of what they were doing and future changes in the production to be able to plan their work accordingly, and having the possibility to support each other. The process development team was not willing to put in the data with the argumentation that they are working with sensitive information that could be harmful to share. The possibility to access information about what the process development team is working with from the control room was thereby removed.

The process development team saw no meaning in showing broken promises (how many promises of delivery times to customers have been broken) and available to promise (the percentage of order the company can supply direct from stock), in the control room. The only users that have ask this data is the supply chain and the channel group manager. A decision was made to only show the information on their computers and not in the control room. The change was implemented in the interface suggested in this master thesis.

The employee number was in the first draft of the interface shown in the contact list. The process development team explained how that was sensitive information used by the operators for identification and going in and out in the ports of SKF. The employment number was therefore removed from the contact information.

The process development team was not interviewed during the semi-structured interviews, during this review they were asked if there was any more information they needed. They answered that they needed the raw data from the machines, but that they will go directly to the machine to pull out the data. The reason for asking the process development team was because the knowledge they have about the new production system.

The process development team wanted the researcher to focus on the machine park overview screen display and the alarm and communication screen display. The sequence and material screen display was according to the process development hard for them to affect because the new material planning program, SAP, holds the information possible to show in this screen display.

The process development team did not think it was possible to show hours of material in stock to each cell on the prioritization screen display. The need that the user expressed was to know some time before if the material that will be supplied will be enough, or if there is a risk for shortage or if a shortage is bound to happen and in that case when it will happen. The implementation of the material planning system makes it impossible to tell which information will be available. The researcher has no other idea of how this could be shown.

If the order was a customer order or a stock order was harder to determine than what the researcher had understood but this is still what the operators want to know. Today they have a system for identifying the product as a stock order or a customer order before it is produced. But a product for stock can be changed to a customer order during the product process time if a customer order is received. If no other way of identifying order to stock or customers is found todays method is better than nothing according to the researcher.

The process development team did not see any problems with showing when process measurements, tool change, setups and material refills has to happen with the parameter time and number of products left.

The process development team saw the need of the calendar screen display, but was hesitant if it will work to have automatic information from the material system, the maintenance system and the production technician system plus all manual inputs from all the other users connected on one screen display. The researcher has not investigated this further. The interface should be seen as in an ideal world the described information would be shown. The process development team should choose supplier partly based on the requirement from the ideal interface.

The interviews showed a need for following up tool problems. The operator will write a description of the tool problem on the mobile that should be shown on both the tool technicians' computer and in the control room. The function of showing the tool problems and the analysis from the tool technician was identified to the missing in on the screen displays in the control room. This information should be included in the next version of the control room interface.

4.17 Result from review of interface with the operators

A result from the review of the interface with the operators was to merge 14 bars in the prioritization graph of cells and machine in the assembly flow to two bars, assembly flow 1 and assembly flow 2. Because the machines and cells in the assembly flows is connected by conveyor belt the data of the hours to plan will be similar for the machines and cell in each assembly flow. The customer/stock order indication should be chosen to customer order is there any customer orders in the flow. The hours of material in the buffer to the cells should be chosen as the lowest amount of material hours in the flow. The effect by merging data is an easier overview of what to prioritize.

The operators wanted to be able to search for "inbyggnadsmått" in the buffer to help them chose which pallets to order out to get the right clearance between the inner ring, outer ring and rollers in the bearings. The "inbyggnadsmått" was included in the search function.

The operators described how the product denomination has a role in how quality problem and alarms and warnings can be fixed. The product denomination was therefore added in the template for the operators own instruction for solving quality problems and alarms and warnings and the search function to find "how to" guides. A wish of having the possibility to add a picture in the instructions was also expressed and implemented.

Another function the operators wanted to include in their own "how to" guides was to be able to put a stars on instructions that they have tested and that work. The operator should then be able to see which instruction has worked before based on which instructions have the most stars.

Another need identified in the review was to show the position of the operational manager on the machine park overview screen display so that operators would not have to spend time finding the person.

4.18 Result from the walkthrough of the interface with the operators

From the walkthrough of the task reset alarm or warning the operators described the interface as clear and easy to use.

One operator raised the question if all search parameters have to be filled in to be able to use the search functions available in the control room. The question was regarding all search function in the interface. The thought of the researcher has always been that the user should fill in the appropriate parameters for the situation and leave the other parameters blank.

When pretending to send a message to other operators a need of choosing who the text message should reach was identified. The operator wanted the possibility, when writing a new chat message, to decide who should get an indication that something has been written. They wanted all users to be able to read all chat messages regardless who the text message were meant for but that only the chosen receivers should get a signal that a message has been sent that regards them. Connected to this message signal the operators also wanted a colour coding of the messages in the chat describing what the message was about. The different identified messages types is described in the list below. The user has to choose which kind of message is written. The list is also connected to who will get the message signal type.

- Messages between operators
- Messages between operators and operational managers
- Messages about personnel
- Messages about logistics
- Messages about quality
- Messages about technology

A wish was to be able to press on the face symbol on the machine park overview and in addition to get the name of the operator get the possibility to send a message to only the chosen operator and to press a call button to call the operator on his/her mobile.

The discussion that was raised from the shift turnover assignment was be able to follow up how the staffing of operators changes during a shift instead of only having a set number for the whole shift time. The operators wanted the login of the mobile connected to a data base of how many operators they are during all times. The reason for having a more detailed staffing follow-up is because the operator often has to explain that a task took longer time because a colleague was late or had to go early. Otherwise the operators did not have any comments on the shift turnover task.

From the quality assurance task the operator expressed a wish to be able to press the quality symbol on the machine park overview screen display, which should then change the machine park overview screen display to only show the cells connected to the quality symbol and their quality status described by colour coding and symbols in the cells. This would help the operator to get quick information of which machines have quality problems. Figure 20 shows how the display could look.

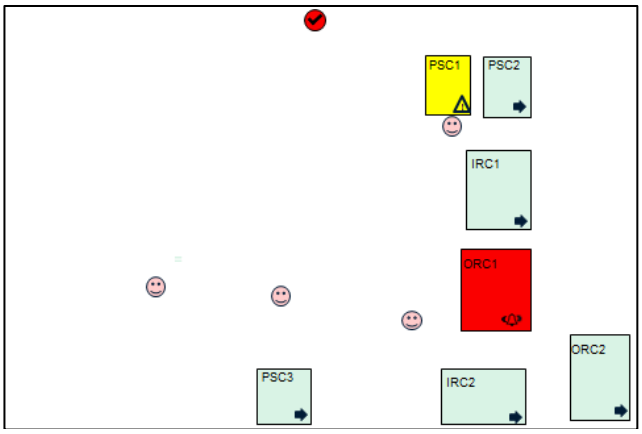


Figure 20: The machine park overview showing the quality status of the cells and where operators are standing.

No feedback was given from the "manage material shortage" task and the "prepare and do an assignment during a preventive maintenance work" task other than that the interface was easy to use and intuitive.

5. Discussion

The purpose of this master thesis was to aid SKF in reducing their production system losses through information sharing and control possibilities of the new production system. The goal was to identify which information and controls the operators and operational managers need in the control room to operate the new production system and to present a visual suggestion of the screen displays in the control room.

The result showed that the users need information about the present state of the product system, what has happened in the production system and what will happen in the production system. They need to know what should be produced and when and if they will get enough material. The users also need communication functions, manuals and a place for analysing results. The identified controls for the control room are blocking products in the buffer, ordering out products from buffer for controls, ordering consumables and giving order to AGVs.

The following discussion expresses factors that may have affected the result and may affect the quality of the information system in the future. In the discussion the effects of the used methods are analysed. The effects of manually entering information to the information system are discussed. A discussion of if the result is reliable and verified is done. The discussion ends with recommendation to SKF and what could be interesting further research.

5.1 Method discussion

In this subchapter the effects from the interviews, not observing operators, the researcher's background and the number of company visit is discussed.

The interviews effect on the result

The base of this thesis is the semi-structured interviews with the developed questions, connection papers and the flow map. The prepared documentation was improved after the first interview. The theory of how to express questions and introduce an interview was reviewed again for the second issue of the prepared documentation in order to make sure the interviewee felt conformable and not forced to give certain answers. The order of the questions was redesigned to follow the rule of starting the interview with questions that were easy to answer. The researcher added questions about the users to easier find the user if the researcher had any questions later on, but also to make sure the interviewee had the experience needed to answer the questions. The interviewer got more direct answers from the addition of having the interviewee describe which parameters should be showed in the control room. The questions also lead to deeper discussions of which information was actually needed.

During the interviews the users wanted to talk about what information they wanted in the control room. The interviewer listened, took notes, asked question of why the information is important and in which situation they wanted the information. However, it is a difference describing which information you think you want and identifying the information you really need. The interviewer tried to identify the need by asking questions about what their work task were and which parameters they based their decisions on for those tasks. A frustration of the interviewees was identified, especially from the secondary users who had a lot of tasks where the control room could not help them. They believed they already knew what information they needed and where therefore reluctant to talk about their work tasks. This may have affected the interviewer to in some cases not go in depth on all the questions, which may have resulted in information being missed.

Another aspect worth to mention is that there is only one or a few persons from each user groups that have been interviewed. The answers may have been different if other persons in the user groups were interviewed or if more interviews had been possible to conduct.

Observations with operators
The operational managers were observed but not the operators. A reason for this was because the new production system is not in place which meant that some work task would disappear while other will be added. The background of the researcher, as having worked as an operator and tool technician for sex years at different plants at Volvo Cars in Skövde, going an expanded industry highs school program with internships as operator, assembler, production technicians and electrician made the researcher think she knew a lot of which information the operators need. However it is different companies producing different products so there will be some differences in work tasks. Instead of observations, the operators were asked question about their work both in the semi-structured interview and out on the production floor. If this study was made again the researcher would have taken the time to observe the operators because she is convinced new information would be found.

More company visits
Volvo Cars in Skövde did not use a control room for controlling their production; instead they used machine screen displays, strategically placed machine park overview screen displays, production whiteboards and a digital dairy of the operators. Discussion was made to visit a company that had a control room. The only companies that the researcher could find that had control rooms were in the processing industry and no manufacturing industries like SKF. Because of the difference in interesting information for a process industry versus manufacturing industry, the believed outcome from visiting a processing industry control room was to investigate how they show their data and not which data they show. The main goal of this thesis is to gather which information the user of a control room at SKF will find useful, and with that in mind no more company visit outside SKF were conducted.

Influenced by Volvo Cars
As described in the section before the researcher has a background of working at Volvo Cars. The positive effect of this was that identified problems at SKF could be solved by methods of how they share information at Volvo. The response from the users of these methods has only been positive. The background also made it easier for the researcher to understand how the users worked and the information they would need. The negative aspect of working at Volvo Cars before is that the researcher may have become too involved, lose objectivity and become biased. The knowledge the researcher possess may have made her value the information differently compared to someone with no industry knowledge. It can have made the researcher jump to conclusions based on how it works at Volvo. As McLeod (2015) writes "*there is always the danger of that we will "see" what we expect (or want to) see*".

5.2 Manual data entering
In the interface there is a lot of information that the users have to enter manually. The consequence of this is not done or done badly because of for example inadequate interface, poor routines, time pressure or to low motivation are discussed in this section.

The calendar display is the weakest point of the interface; it has a lot of manual entering of data, which are not entered today. The often stressful situation were unplanned activities should be entered can made the user unwilling to do the work. A solution in those cases can

be to ask a colleague to write in the activity or to add the information in after the stop. The effect of adding the information after the stop is that it is still possible to do follow up of what had happened during the day but you lose the help all the users got of planning their work according to the stops. Today the users have no function similar to the calendar so if the activities are not entered they will communicate the activities out on the production floor as they are doing today, but then they lose all the befits of having the documentation. The data input of the activities for the maintenance personnel, production technicians and the FU stops are already done today, with similar data so those activities should not be a problem to show in the calendar.

For the machine park overview the user do not have to write in any information, besides that operators have to login to the mobile in order to see the faces of the operator on the screen displays.

On the deep information display the maintenance personnel, operators and production technicians have to write what should be done on the preventive maintenance stops. They already do this today on a computer so this should probably not be a problem. The operator should sign FU jobs, which are finished. The operator and the operational manager should write in injury and incidents reports as they are today, so no problem is expected there. If a password is changed the person who made the change should write in the new password in the database, if this is not done they risk not being able to login to the program.

On the communication screen display all the users will write documents that the operators have to sign that they have read. If the operators forget to read the documents the operational manager can see this and remind the user to read the documents. They will also have the possibility to chat with each other and write information that will be showed during a limited time. The diary is written by the operators for the operators, but also for the other user to see what has happen. If information is missing from the diary it is an increased risk of missing conveying useful information between the shifts. All of this functions are to ease information flow between the users and if the tools are not used it up to the user to share his/her information in other ways.

On the prioritizing screen display the operational manager can write which cell or machine the operator should prioritize, if this is not done the operators uses the prioritizing graph instead. If the operational manager makes a poor decision of which cell to prioritize some operators would follow his/her advice while other would probably use their own prioritizing knowledge.

On the alarm screen display the operator signs which alarm the operator will solve, this is also possible to do from the mobile. If this is not done the position of the operators on the machine park overview will tell if an operator is trying to reset an alarm or warning. The technical and quality responsible operators have the possibility to write in instructions of how to fix alarms and warnings. If this is done poorly the instruction bank will probably not be used in the future. If there are instructions, which are not reported the operator will spend unnecessary long time trying to solve the problem. The operators will have the possibility to set stars on instruction to indicate if the instructions work. If this is not done the operator will not get an indication or as good indication of which instruction works. Warnings which the operator cannot act on, also called false warnings, should be hidden from the all alarm and warning logs. This is done once manually by the user and the warning is then automatically programed to be removed from the active alarms and warnings log. If this is not done there will be

warnings always showing in the active alarm and warning log which lower the perception of the user.

The goal, according to the process development team, is that the sequence and material list should be created with as little involvement of the supply chain personnel as possible according to the process development team. The interface, presented in this master thesis, shows which information the operators and operational managers need in the control room. Most of the information of the sequence and material list is provided today. The process development team understood the need of adding information about setup instruction, drawing of products, the number of scraped parts and information from the tool technician to the sequence and material list but once again saw problems with mixing different data programs on one screen. If it is possible to pull out information from SAP to show together with other information sources is unclear. The uncertainty of what SAP could deliver was the reason for the process development team wanting the thesis to focus on other needs. Alternative solutions have therefore not been produced.

As a conclusion most of the manually entered information is done to help the user and give them more information than what they have today. None of the manually entered information is vital except the information about the production sequence and material supply. It is not a lot more information that should be written in the future control room compared to what is manually entered today. The screen displays have been designed to make it as easy as possible to manually enter information by using list and buttons and as little manual typing as possible. The degree of motivation for entering the needed information should be high because the users have themselves expressed the need for the information. The effects if information is not manually entered is communication problems, which will lead to time loss, wrong decisions being made and time being spend on user have to contact the person, which should have written the information. The efficiency of the plant, its OEE value, will be lower as a consequence if the information is not entered.

5.3 In relation to other studies

The presentation of MOST, the app used by the operators for monitoring the heat treatment at SKF, confirmed that the data for the control room was relevant because there were similar data and functions implemented in the app or planned to be implemented in the app. There are far more needs identified for the control room compared to the app but on the other hand more information can be presented in a control room. The app shows education instructions, which has not been identified as a need for in this thesis but should maybe be something to consider.

During the study visit at Volvo Cars it was investigated how they share information about their production system. Different methods they used have been implemented in the interface because the effect of the methods solved desired needs at SKF. This can also be seen as a way of relating to other studies and strengthens the reliability of the result.

The similar needs identified at Volvo and at the heat treatment at SKF indicate that the result probably is generalizable over factories and companies in the manufacturing industry around the world.

5.4 Recommendations to SKF

A recommendation to SKF is to observe the operators before the control room is implemented. The researcher strongly believes that observations of the operators would lead to identifying more information and controls needed in the control room.

The thesis identified a need for the user to show information from different programs and data sources the same screen display. The process development team at SKF has to make further investigations about which programs and data sources whey will use and what limitations they entails but also what effects the limitation has for the users.

Problems from all the manual entered information to the information system have to be further analysed by SKF.

5.5 Further research

During the thesis work there has been indication that it could be possible to generalize the information companies in the manufacturing industry need to operate their production systems efficiently. Further research at other manufacturing companies could be used to investigate if general information could be found by comparing their result to this thesis.

6. Conclusion

The conclusion of this master thesis is that the users of the control room need seven main screen displays to display the information and control necessary to make decisions in their daily work.

- All users expressed a need to know information about activities that will stop the production in the future and past to plan their work and to be able to lower the downtime of the production system. The calendar screen was developed to satisfy these needs.
- Few operators operating a many machines over a large area lead to the need of an overview of the present machine park status. The overview should be possible to change so that only the quality status of each cell is shown.
- Deeper information about the status of the objects in the production system can be reached by the deep information screen display. Quality information, maintenance information, administration information, improvement work, efficiency measures and lab reports of process media is other information that is reached on the screen display.
- The users have expressed a need to know what should be produced at which time and if they will get enough material. The production sequence and material overview screen leads the user to this information.
- The operator needs a diary to share information between the shifts. Time limited visualization of information is an identified need to make sure information is shown when it is needed and secure that it is updated. A messenger function between the all user groups was identified as a need. A possibility to share information with the operator where the operators have to sign that they have read the information was identified as a need. This information will be shown in the communication screen.
- A need to show the active alarms and warning from the production system was identified. The operators should have the possible to sign that they will fix an alarm or warning. Functions of searching alarm and warnings logs, writing and searching guides of how to fix alarms and warnings and a function to hide false warnings were identified as needs.
- A prioritizing screen display will help the user prioritize which tasks to do first by showing a bar chart of prioritizing parameters, a box were the operational manager can write which cell or assembly flow to prioritize, tables giving information to the operators when they have to do frequent measurements, setups, tool changes and material refill.

The interface that was developed is in no way the finished screen displays but a description of which data the users need access to at the same time. Further investigation is necessary, this master thesis have done a first but not exhaustive investigation. However the similarities of identified needs of this thesis to the needs identified from the company visit at the manufacturing plants at Volvo Cars in Skövde and the developed app the operators at SKF use for controlling the heat treatment strengthens the reliability of the identified needs. It also indicates that the needs are probably generalizable for manufacturing industries over the world.

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Appendix A. Interview guide for the operators

The interview started with the researcher presenting herself, welcoming the interviewees and showing them where they could sit down. The researcher told some background facts about herself and how she ended up at SKF. The interview proceeded as follows:

"In your new production line in your d-factory the plan is to build a control room. My task is to investigate which information should be handled in the control room and give a suggestion on how this information should be presented. This is where I need your help. I will ask you some questions about your work tasks as they are today, how you make decision about what to do, who you interact with and how you would describe the typical operator.
Your answers will be anonymous. I will take notes during the conversation, is it okay if I also record the conversation as a backup in order to not miss anything?
Okay so now I will start the interview.

- We are going from a connected production line to islands of processing machines, which information do you need for the new system?
- Can you describe your work task today?
- Do you know if any of these tasks will become redundant with the new production system?
- Do you know if there will be any tasks added with the new production system? In that case which?
- For which work tasks would you like to make decision or get information for making a decision from a control room?
- For every identified work task that would be performed in the control room
    - Which decisions do you make when you perform task XX.
    - What do you base those decisions on?
    - How do you find that information today?
    - Where do you find that information today?
    - When do you need the information in form of frequency and time of day?
- Can you with the help of this flow map describe which information you would like to get from every machine, cell, buffer, AGV and conveyor belt to the control room?
- This connection paper has been designed in order for you to easier remember which information you need from other users of the production system. We will fill it in together.
- How do you think a control room would help you?
- What do you want from the control room?
- Do you foresee any negative impacts from implementing a control room?
- What would you like to be able to control from the control room?
- Can you describe a typical operator?

That were all the questions I had. Do you have anything more you would like to add?
Thank you so much for taking your time and helping me."

Appendix B. The connection document used in the interview with the operators

Information shared between the following user groups and the operators.

Operator	Information flow: When: Where:

Operational manager	Information flow: When: Where:

Maintenance engineer	Information flow : When: Where:

Mechanic	Information flow: When: Where:

Electrician	Information flow: When: Where:

Chanel group manager	Information flow: When: Where:

Supply chain	Information flow: When: Where:

Process development	Information flow: When: Where:

Quality	Information flow: When: Where:

Process media	Information flow: When: Where:

Tool technicians	Information flow: When: Where:

Production technicians	Information flow: When: Where:

Appendix C. The improved interview guide

The interview started with the researcher presenting herself, welcoming the interviewees and showing them where they could sit down. The researcher told some background facts about herself and how she ended up at SKF. The interview proceeded as follows:

"In your new production line in your d-factory the plan is to build a control room. My task is to investigate which information should be handled in the control room and give suggestions on how this information should be presented. This is where I need your help. I will ask you some questions about your work tasks as they are today, how you make decision on what to do, who you interact with and how you would describe the typical operational manager/supply chain personnel/process media personnel…?

I will take notes during the conversation, is it okay if I also record the conversation as a backup in order to not miss anything?

- What is your name? I am only asking this in case I have further questions. Your name will not be written in the report, you will remain anonymous.
- What workplace are you operational manager/channel group manager… at?
- How long have you worked there?
- Can you describe the typical operational manager/tool technician… ? Age, gender, education, work experiences and skills.
- Can you describe a typical workday?
- Are there certain meetings, which you have periodically?
- Will your work tasks change with the new production system?
- We are going from a connected production line to islands of processing machines, which information do you need for the new system?
- For which work tasks would you like to make decisions or get information for making decisions from a control room?
- For every identified work task that would be performed in the control room
    - Which decisions do you make when you perform task XX.
    - What do you base those decisions on?
    - How do you find that information today?
    - Where do you find that information today
    - When do you need the information in form of frequency and time of day?
- This connection paper has been designed in order for you to easier remember which information you need from other users of the production system. We will fill it in together.
- How do you think a control room could help you?
- What do you want to gain from the control room?
- Do you foresee anything negative impact from implementing a control room?
- What would you like be able to control from the control room?

That were all the questions I had. Do you have anything more you would like to add?
Thank you so much for taking your time and helping me."

Appendix D. The improved connection document

Information shared between the following user groups and the operators.

Operator	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Operational manager	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Maintenance engineer	Information flow : Parameters to show: When, frequency, time of the day: Where today:

Mechanic	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Electrician	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Chanel group manager	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Production technicians	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Quality	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Process media	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Tool technicians	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Supply chain	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Process development	Information flow: Parameters to show: When, frequency, time of the day: Where today:

Appendix E. Summary from interviews

This appendix show what information the different users want from the control room and what information each user group has to manually enter. The needed controls are also described. Parts of this appendix thereby describes the information that should be seen and entered on the secondary users' devices, which were not in the scope of this thesis but still interesting information for SKF. This appendix is written in Swedish because you can find the same information about the control room but more in depth in the English written section 4.14 and Appendix G, H,I ,J ,K ,L and M.

Operatörer vill få följande information i kontrollrummet:

Planering och prioriterings stöd

- Vad som kommer att ske under dagen, vilka aktiviteter som kommer att stoppa maskiner och information om dessa aktiviteter så att de kan planera sitt arbete runt aktiviteterna.
- Vilken cell eller maskin de ska prioritera och när process mätningar, verktygsbyten, omställningar och materialpåfyllning måste göras.

Statusen på maskinparken och stöd vid felsökningar

- Statusen på maskinparken, vad larmar, vad varnar, vad står still, vilka maskiner är avstängda och vilka producerar.
- Var befinner sig personer i produktionssystemet så att man ser om de håller på med en larmande/varnande/väntande maskin.
- Mer djupgående information om maskinparkens AGV:er, robotar, bufferten, celler, maskiner och produkter är efterfrågad.

Kvalitet

- Övervaka resultatet på cellernas mätmaskiner.
- Uppföljning av förstabitsprodukt
- Uppföljning av process mätningar
- Rapportering och uppföljning av kassationer
- En databas där operatören själva skriver om hur de har löst kvalitets problem tidigare som de ska kunna söka i när de får kvalitets problem med produkter.

Underhåll

- Få mer information om vilka akuta underhåll som har gjorts, görs och står i kö.
- Få ett schema på vad som ska göras på FU-stoppen där aktiviteter ska kunna läggas till av operatörer, driftschefer, underhåll och produktionstekniker.
- Signera och följa upp dagliga arbetsuppgifter för operatörerna.

Förbättringar

- Vad har produktionsteknikerna jobbat med, vad jobbar de med nu och vilka uppdrag står i kö.
- Uppföljning av operatörernas A3 dokument för förbättringar
- Veta tillgängligheten på maskinerna/cellerna med procentsatsen för larmtider subtraherad.
- Se fördelningen mellan hur många gånger en maskin har fått olika larmmeddelande och summan av tiderna från alarm startat till alarm borttaget under en viss tidsperiod. Detta för att veta vilket larm meddelande som ska jobbas med.

Administration

- Rapportera och följa upp bemanning
- Vad som ska göras vid nödläge
- Kontaktuppgifter
- Kompetensmatris
- Rotationsscheman och utbildningsplaner
- En samlings plats för alla instruktioner och checklistor där de är kopplade till olika maskiner. Så det räcker at man ändrar en instruktion och inga versionsproblem uppstår.
- Vilka timmar operatörerna ska jobba varje månad
- Tillbudsrapportering och olycksfallsrapportering med programmet TIA
- En databas för alla lösenord

Labbrapport från process media om kvaliteten på deras vätskor.

- Visa labbrapporterna

Larm och varningar

- Se vilka celler och maskiner som larmar och varnar
- Larm- och varningsmeddelanden
- Se vilka operatörer som redan har signerat att de håller på att fixa ett larm eller en varning samt signera själva om de kan fixa ett larm eller varning.
- En funktion för att söka och analysera larm- och varningshistorik
- En funktion där operatörer kan göra egna instruktioner för hur de återställer maskiner efter olika larm och varningar. Funktionen ska även innehålla en sökfunktion för att hitta en instruktion när de inte vet hut de ska återställa ett larm eller en varning.
- En funktion där operatörerna ska kunna dölja varningar som denne inte kan reagera på, som egentligen är falska varningar. En lista med de dolda varningarna ska vara tillgänglig.

Vad ska produceras när och materialförsörjning

- Visa vad som ska produceras i cellerna med hjälp av parti beteckning, typ beteckning, typens ordernummer och produkt ritning.
- Visa hur många som ska produceras och hur många det är kvar att producera på aktuell produkt typ och hur lång tid det beräknas ta att tillverka ordern.
- En manual till omställning för produkttypen
- En indikation på om det finns material i bufferten som täcker behovet och skrotpålägget, om bara täcker behovet men inte skrotpålägget eller om de inte täcker behovet alls.
- Visa om produkten är för en kundorder eller en stockorder för hjälp vid prioritering
- Tid mot plan för varje cell
- Starttid och sluttid för varje parti
- Veta om verktygsteknikerna riggat verktyg till partiet och huruvida de kört ut verktygen till maskinen.
- Veta vilka verktyg operatören ansvarar för att beställa för varje parti
- Vilket material ska användas till varje produkt typ i sekvenslistan, hur många de behöver och skrotpålägget.
- I och med att samma material ska användas till flera produkttyper i cellen finns en sammanfattande materiallista som beskriver produkten, behovet och hur många som levereras till dem, var produkterna kommer ifrån samt hur många som skrotats av produkten.

- Operatören har efterfrågat lista över inventeringen på slipskivorna de beställer, med information om många fler inner- eller ytterringar som kan köras med varje skiva.
- En länk till operatörernas beställningsprogram för indirekt material där de kan beställa slipskivor, handskar och öronproppar.
- Om operatörerna måste ändra produktionsordningen så finns det en funktion för detta, det är viktigt för logistik att veta.

Kommunikationscentral
- skicka meddelanden och bilder genom chatten med alla användare
- en dagbok för operatörerna så att de kan kommunicera över skiften
- informationsstyrningar för att säkerställa att alla operatörer kommer att ta del av informationen.
- tidsbegränsad information som idag sitter på tavlor i produktionen

Information som operatörer ska skriva in i kontrollrummet:
- skriva in aktiviteter att göra under FU-stoppen
- signera aktiviteter under FU-stopp
- signera dagliga arbetsuppgifter för operatörerna
- skriva in skrot
- skriva i A3 för förbättringar
- uppdrag underhåll
- uppdrag produktionsteknik
- möte som stoppar produktion
- oplanerad omställning som stoppar produktionen
- oplanerat verktygsbyte som stoppar produktionen
- oplanerad materialbrist som stoppar produktionen
- övrig anledning som stoppar produktionen
- signera att jag tar larmet eller varningen
- instruktion på hur man återställer larm och varningar
- instruktion på hur man fixar produkter med kvalitetsproblem.
- dölja falska varningar
- signera om de har läst informationsstyrningar
- skriva i dagboken
- skriva i chatten om de har något som de vill meddela användarna
- skriva in informationsstyrningar om de vill säkerställa att alla operatörer kommer att ta del av informationen.
- Skriva in tidsbegränsad information om de har någon information som de vill ska visas ett bestämt tidsintervall.

Styrfunktioner operatörerna vill ha:
- följa ring genom flödet för att se var och när den har blivit bearbetad.
- beställa material
- blockera produkter i lagret
- begära ut produkter från laget för kontroll

Driftchef vill få samma information och styrfunktioner som operatörerna i kontrollrummet

Driftchef ska skriva in följande information i kontrollrummet:

- Vilka tider de olika driftcheferna jobbar
- Uppdatera kontaktuppgifter för operatörerna
- Uppdatera operatörernas arbetstid/månad
- Uppdatera rotationsschema & utbildningsplan
- Uppdatera kompetensmatris GBO
- Följande aktiviteter som stoppar produktionen ska skrivas in av driftchefen
    - Personalbrist/Kunskapsbrist leder till stopp
    - Möten som stoppar produktion
- Prioriterad cell/maskin, kan även var flera celler/maskiner som ska prioriteras
- Bemanning
- Skriva i chatten ifall de har något de vill meddela användarna.
- Skriva in informationsstyrningar ifall de vill säkerställa att alla operatörer kommer ta del av informationen.
- Skriva in tidsbegränsad information ifall de har information som de vill ska visas ett bestämt tidsintervall.

Information som produktionsteknikerna vill få via kontrollrummet till deras dator:

- Kapabilitetsuppföljning
    - Övervaka Cp och Cpk som handlar om spridning och förskjutningar av mätvärden mot målvärdet
    - Övervaka Pp och Pk som handlar om spridning och förskjutningen av mätvärden i omställningen mellan olika produkttyper
- Cykeltidsuppföljning på maskiner och celler
- Tillgänglighet i form av OEE
- Operatörernas A3 dokument
- En databas för maskinprogram

Produktionsteknik ska skriva in följande information på deras dator som skickas till kontrollrummet:

- Vem har kundvecka
- Vad jobbar de med, vilka jobb står i kö och visa vad som hände med gamla uppdrag. Detta ska de visa genom att:
    - Fortsätta fylla i och jobba med uppdrag som de fått av andra användare
    - Skriva in nya uppdrag
- Skriva uppdrag till underhåll
- Information om tester som kommer stoppa maskinen/cellen
- Skriva i chatten om de har något som de vill meddela användarna.
- Skriva in informationsstyrningar
- Skriva in tidsbegränsad information om de har någon information som de vill ska visas ett bestämt tidsintervall.
- (Underhållsingenjören vill även att produktionsteknikern ska berätta för honom om produktionen har kvalitetsproblem.)

Information som processmedias personal vill få via kontrollrummet till deras dator:

- Vilka celler som körs, när celler och maskiner ska startas och när de har stängts av, så att de ska veta vilka pumpar och så vidare som behöver var igång.
- Operatörer, driftchefer och underhåll ska meddela om fel uppstått som påverkar media genom att ringa och skriva i chatten

Process medias personal ska skriva in följande information på deras dator som skickas till kontrollrummet:

- Vid problem som påverkar produktion skriva i chatten samt ringa kontrollrummet och berätta:
    - problembeskrivning
    - plats/tank
    - effekt på maskiner/celler/operatör (om de vet)

- Skriva i chatten om de har något som de vill meddela användarna.
- Skriva in informationsstyrningar om de vill säkerställa att alla operatörer kommer att ta del av informationen.
- Skriva in tidsbegränsad information om de har någon information som de vill ska visas ett bestämt tidsintervall.

Information som verktygsteknikerna vill få via kontrollrummet till deras dator och sin skärm:

- Verktygskomponenter att använda för produkt typ och vilka som ska återanvändas från förra produkttypen (från recept)
- Jämföra recept mellan standard produkter och specialprodukter på en skärm
- Hur många timmar och antal det är kvar till aktuellt och framtida partier tar slut
- Ritningar ska kopplas till produkttyperna och standard produkter med skillnader utmärkta och beskrivna.
- Visa sekvensändringar på sekvenslistan
- Problem med verktyg.
- Indikation på att en planslipsskiva är bytt.

Övriga önskemål från verktygsteknikerna

- Telefonsamtal från logistik vid sekvensändring för snabb kommunikation
- Längre framförhållning med verktyg till produktionstekniker och processutveckling och ändringar/tester som kommer att påverka verktygsteknikerna.
- Vill kunna printa ut receptet för att plocka komponenter utifrån den.
- Vill ha ”In- och ut-rutor” för verktygsvagnarna så att det kan vara tydligt om verktygen är nya eller använda och ska bytas.
- Vill involvera kanalerna utanför LCHO i kontrollrummet, vill ej ha flera olika arbetssätt.

Verktygsteknikerna ska skriva in följande information på deras dator som skickas till kontrollrummet:

- VP har riggat färdigt för omställning (står fortfarande hos VP)
- Kört ut vagn/fräs för omställning
- Uppföljning av verktygsproblem
- Skriva i chatten om de har något som de vill meddela användarna.
- Skriva in informationsstyrningar om de vill säkerställa att alla operatörer kommer att ta del av informationen.
- Skriva in tidsbegränsad information om de har information som de vill ska visas ett bestämt tidsintervall.

Mätrummet ska ge följande information till kontrollrummet:

- Förstabitsmätning
    - tid kvar
    - cell
    - resultat av mätningar ska sparas automatiskt i förstabitsdatabasen i kontrollrummet.

Supply chain och kanalgruppschefen vill få följande information till deras datorer:

- Broken promises
- Available to promise
- Timmar i buffert
- Sekvens och materiallista
- Ett schema över vilka aktiviteter som kommer att stoppa produktionen och har stoppat produktionen
- Tillgänglighet i form av OEE
- Cykeltids uppföljning på maskiner och celler
- Uppföljning på hur lång tid verkliga omställningar tog i jämförelse med standardtiden
- Uppföljning över hur taken förändrats under en tidsperiod till exempel efter en omställning.
- Uppföljning på hur många produkter blev paketerade under en viss tidsperiod mot mål värdet.

Supply chainpersonal ska skriva in följande information på deras dator som skickas till kontrollrummet:

- Skriv in data till sekvenslistan och material listan, exakt vad som kommer att skrivas in automatiskt och vad de behöver skriva in manuellt är ännu oklart på grund av införandet av SAP.
- Kommentar till materialbrister - varför det blir en materialbrist och när material är beräknad att levereras igen.

- Skriva i chatten om de har något som de vill meddela användarna.
- Skriva in informationsstyrningar om de vill säkerställa att alla operatörer kommer att ta del av informationen.
- Skriva in tidsbegränsad information om de har information som de vill ska visas ett bestämt tidsintervall.

Kanalgruppschef ska skriva in följande information på sin dator som skickas till kontrollrummet:

- Skriva i chatten om han/hon har något som han/hon vill meddela användarna.
- Skriva in informationsstyrningar om han/hon vill säkerställa att alla operatörer kommer att ta del av informationen.
- Skriva in tidsbegränsad information om han/hon har information som han/hon vill ska visas ett bestämt tidsintervall.

Underhåll vill få följande information till deras datorer och till sin skärm från kontrollrummet:

- Automatikorder till underhåll vid möjliga larm
- Vilka akuta jobb har skett det senaste dygnet för att kunna följa upp hur det gick
- En tydlig planering vad som ska ske under veckan.
- En tydlig planering över vad som ska ske på FU stoppen vem som ska göra vad, i vilken maskin, och när. Idag kan det bli problem när operatörer, produktionstekniker och underhållare vill jobba med samma maskin samtidigt.
- Vill ha reda på om en maskin har kraschat. Ofta funkar maskinen hjälpligt de två först veckorna men efter det ligger den utanför toleransen. Underhåll vill därför veta när det började krångla och varför för att slippa de följd fel som uppstår och få en enklare felsökning
- De vill veta statusen på maskinmedia och maskintillstånd
- De vill ha snabb och enkel manövrering till manualer, givarbilder, vakter-, samt reservdelssystem

Övriga önskemål från underhåll

- Planera underhåll efter tiden maskinen kört och inte hur länge den stått på golvet som de ofta gör idag.
- Vill att el och mek. konstruktör samt processutveckling placeras i närheten till serviceteknikerna för att få bättre kommunikation
- Mer transparens mellan processutveckling och elektriker/mekaniker. Underhåll kan lägga pengar på maskiner som ska skrotas. Det förekommer även dubbel arbete då de inte kommunicerar. Underhåll anser att processutveckling och underhåll ska dela sin kunskap i högre utsträckning och vara mer till stöd för varandra.

Underhåll ska ge följande information till kontrollrummet från deras dator och deras surfplatta:

- Akuta och ej akuta jobb
    - Ansvarig, datum starttid, uppskattad sluttid
    - Verklig sluttid, problem beskrivning, lösning, grundorsak, restpunkter, återkommande fel
- FU jobb
    - Tid (Datum, starttid, sluttid), cell, maskin, uppdrag, ansvarig, måste maskinen stängas av, måste en viss typ köras, behöver de hjälp av en operatör, kunskapsbas operatör
- Skriva i chatten om de har något som de vill meddela användarna.
- Skriva in informationsstyrningar om de vill säkerställa att alla operatörer kommer att ta del av informationen.
- Skriva in tidsbegränsad information om de har information som de vill ska visas ett bestämt tidsintervall.

Appendix F. Hierarchical task analysis

The first HTA, seen in Figure 21, describes how operators perform a shift turnover with the help of the control room. Figure 22 describes how operators reset alarms or warnings with the help of information from the control room. Then there is a HTA about how quality assurance is supported in Figure 23. Figure 24 describes how a material shortage is handled and Figure 25 shows how a preventive maintenance is prepared and done by an operator.

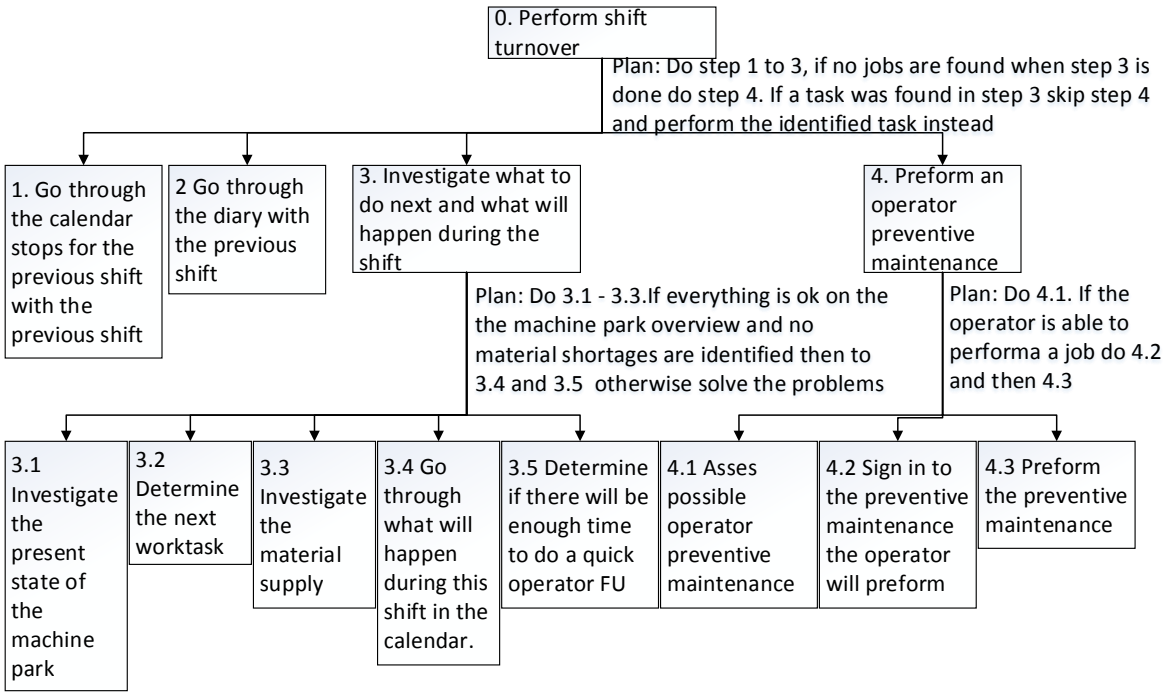


Figure 21: A HTA over a shift turnover

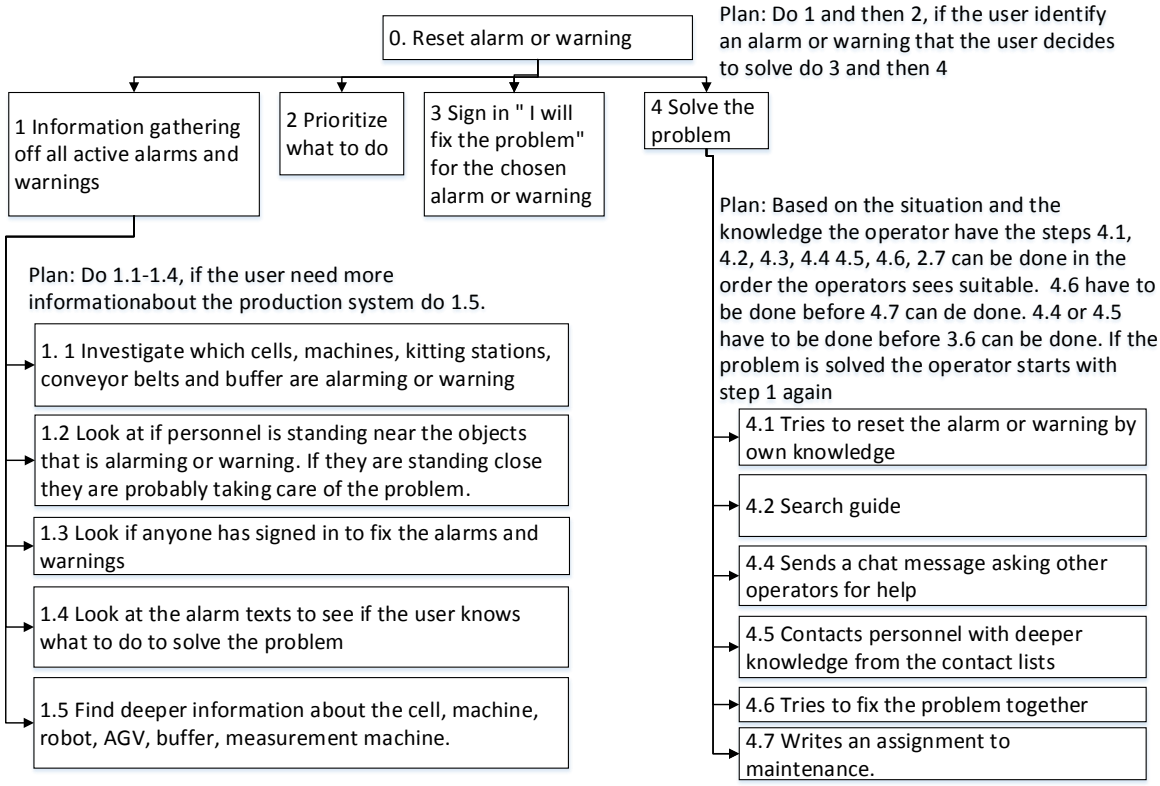


Figure 22: A HTA over how operators reset alarms and warnings from the production system

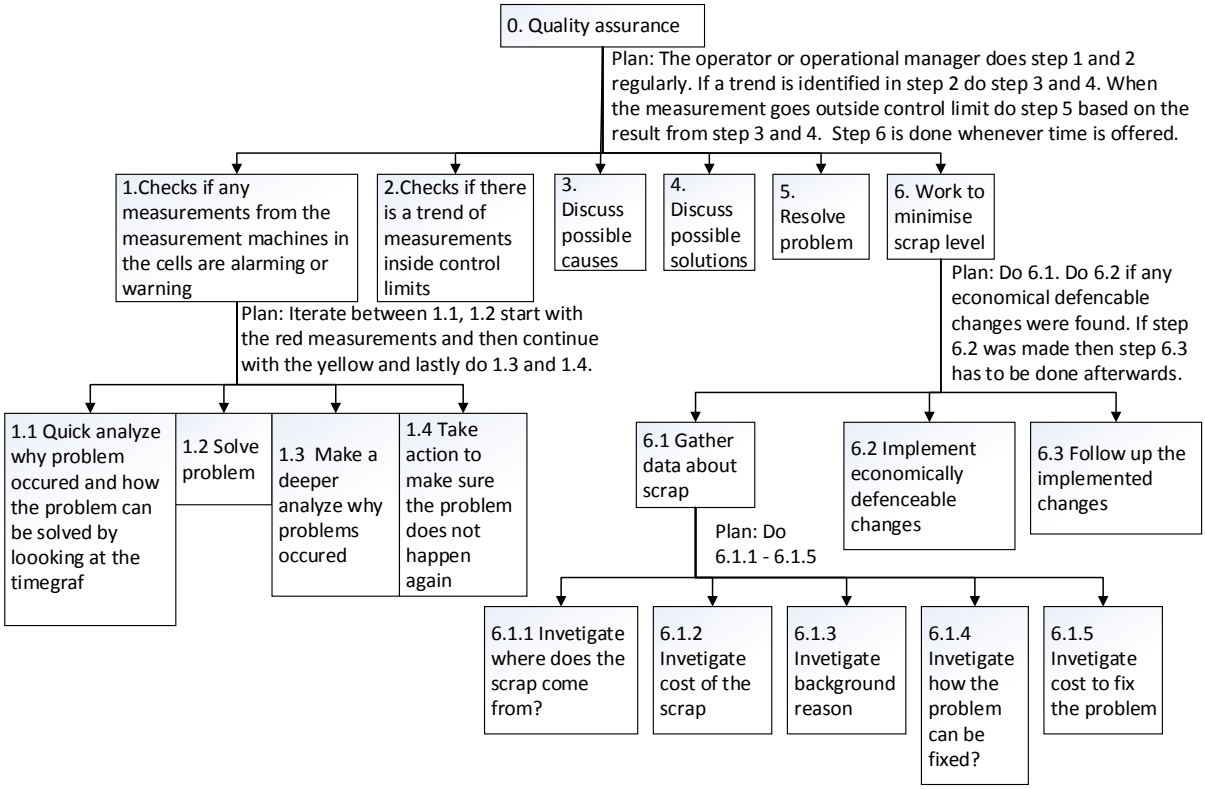


Figure 23: A HTA over how quality is assured

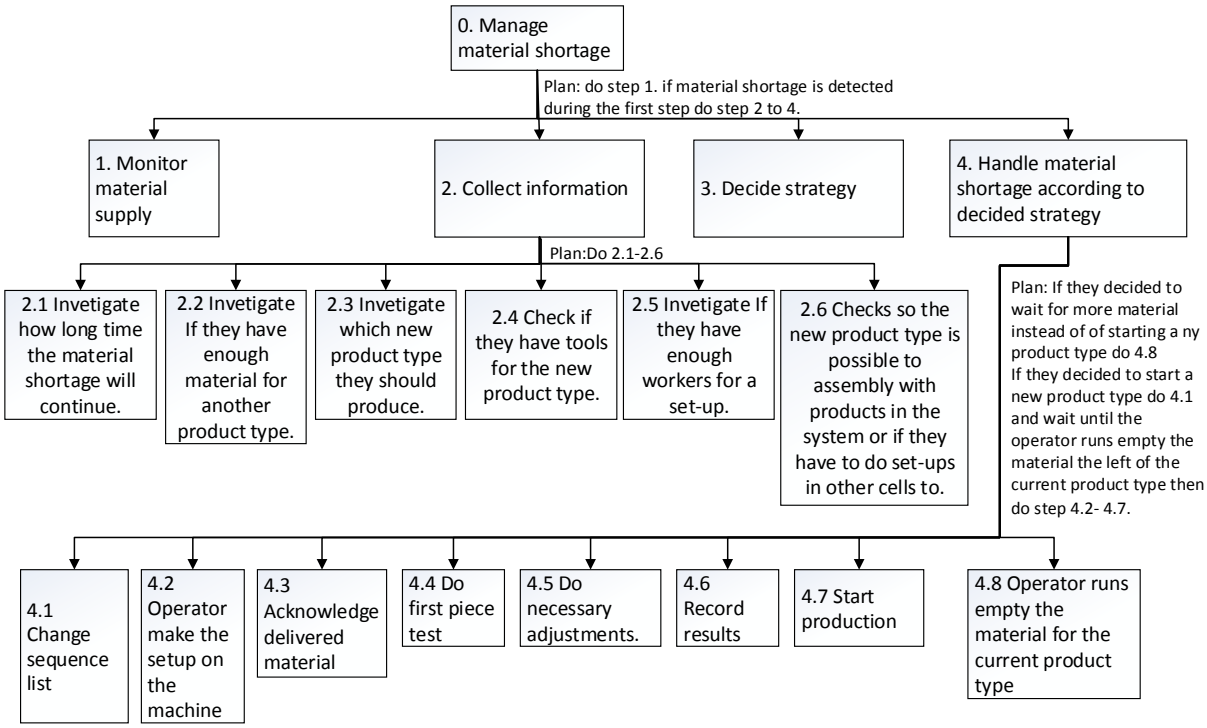


Figure 24: A HTA over how a material shortage is handled

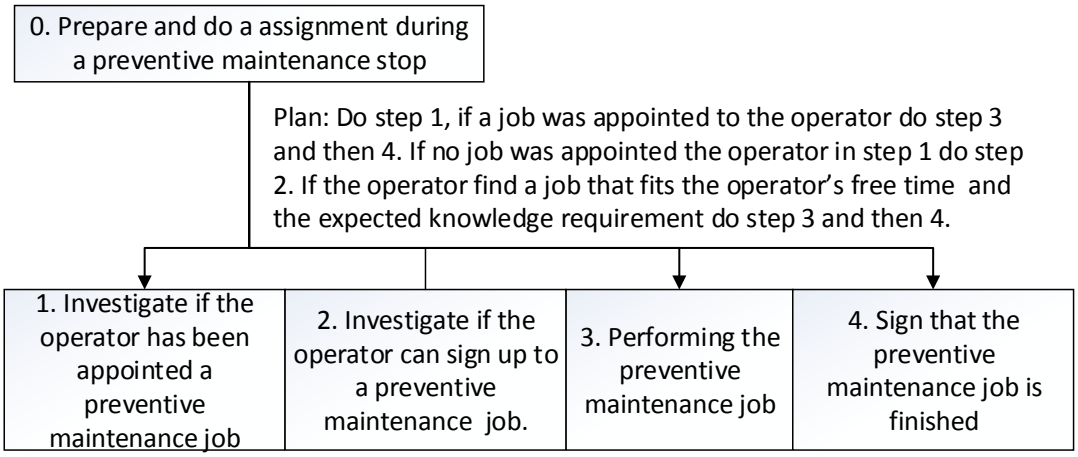


Figure 25: A HTA over how operators prepare and carry through a preventive maintenance job

Appendix G. The calendar screen display

This appendix starts with a description of how the time interval is set in the calendar. It continues with a description of activates that will be shown in the calendar and how these are entered in the calendar.

The time interval of the calendar

The standard time interval was chosen in order to allow the operators to see what will happen during a shift. A shift is 8 h except on Saturdays and Sundays when it is usually longer. If the user presses on the timescale the time interval can change to any time and date, even back in time.

The showed activities:

The activities in the boxes in the columns are abbreviated to limit the width of each column. Table 5 describes both the activity that can be shown with and without abbreviation in Swedish, and an explanation in English.

Table 5: The activities that can be seen in the calendar schedule with abbreviations and explanations on Swedish and English

Abbreviation Swedish	Swedish without abbreviation	English
P-V-byte	Planerat verktygsbyte	Planned tool change (automatic input)
P-omst.	Planerad omställning	Planned setup (automatic input)
P-M-brist	Planerad materialbrist	Planned material shortage (automatic input)
FU	Förebyggande underhåll	Preventive maintenance (input from FU screen display)
O-V-byte	Oplanerat verktygsbyte	Unplanned tool change
O-omst.	Oplanerad omställning	Unplanned setup
O-M-brist	Oplanerad materialbrist	Unplanned material shortage
AUP	Avhjälpande underhåll planerat	Planned maintenance
AUO	Avhjälpande underhåll oplanerat	Unplanned maintenance
V-brist	Verktygsbrist	Tool shortage
Möte	Möte	Meeting
Test	Test av produktionstekniker	Test by production technicians
P/K-brist	Personal eller kunskapsbrist	Personnel- or knowledge shortage
FU	Förebyggandeunderhållsstop	Preventive maintenance stop
Övrigt	Övriganledning	Other reason

Write in new activity:

If the user wants to put in an activity in the system he/she presses the “Ny aktivitet” button in the big blue information box at the side of the calendar. A scroll list is shown in the information box where the user can chose between the following activities:

- Assignment maintenance
- Assignment production technician
- Unplanned tool change
- Unplanned setup
- Unplanned material shortage

- Tool shortage
- Meeting
- Test by production technicians
- Personnel- or knowledge shortage
- Other reasons

The corresponding screen display is shown in Figure 26.

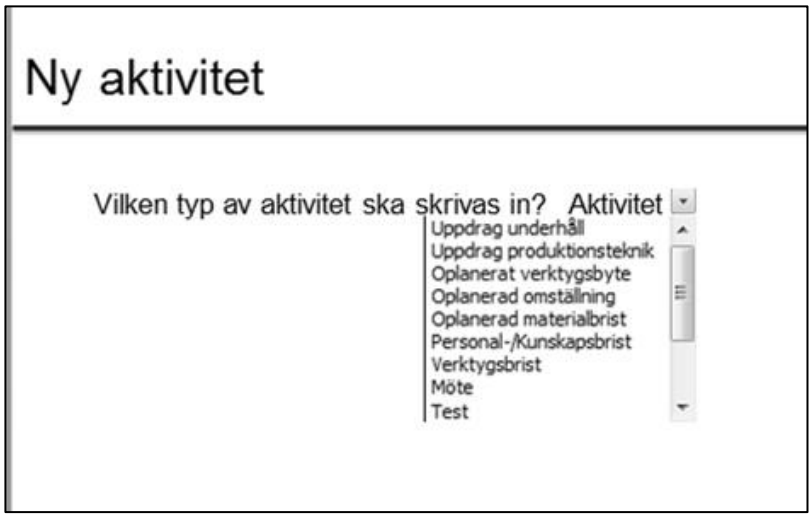


Figure 26: Choosing activity

The activity "assignment maintenance" is chosen if the operator has a problem with a machine and wants help from an electrician or mechanic. A form of report is written to the maintenance personnel shown in Figure 27.

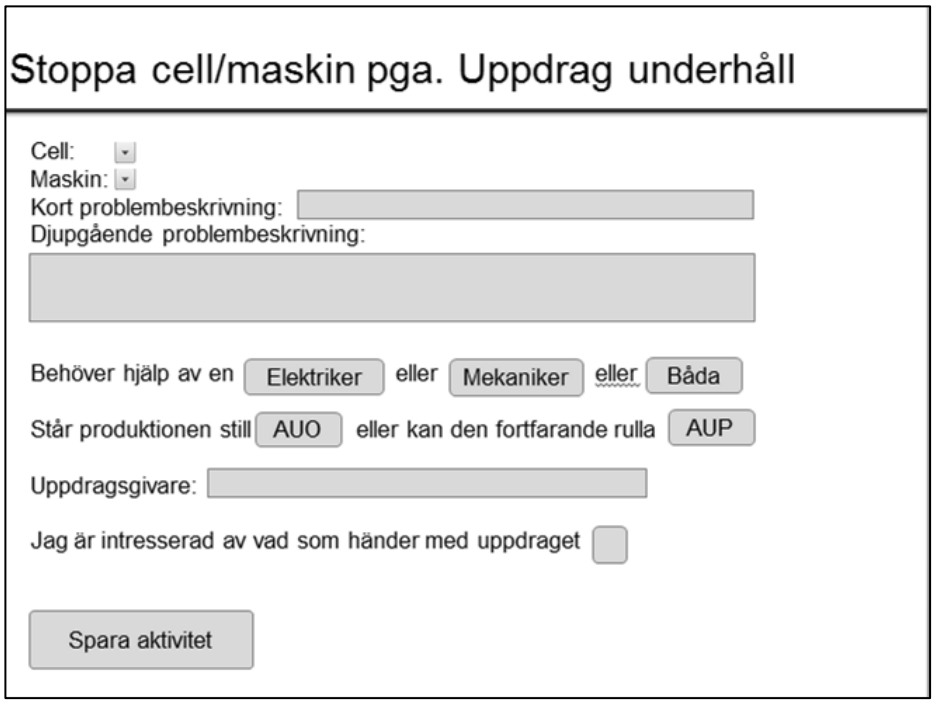


Figure 27: Assignment for maintenance, step 1

The next step is for the maintenance worker to read the report and put in information shown in Figure 28.

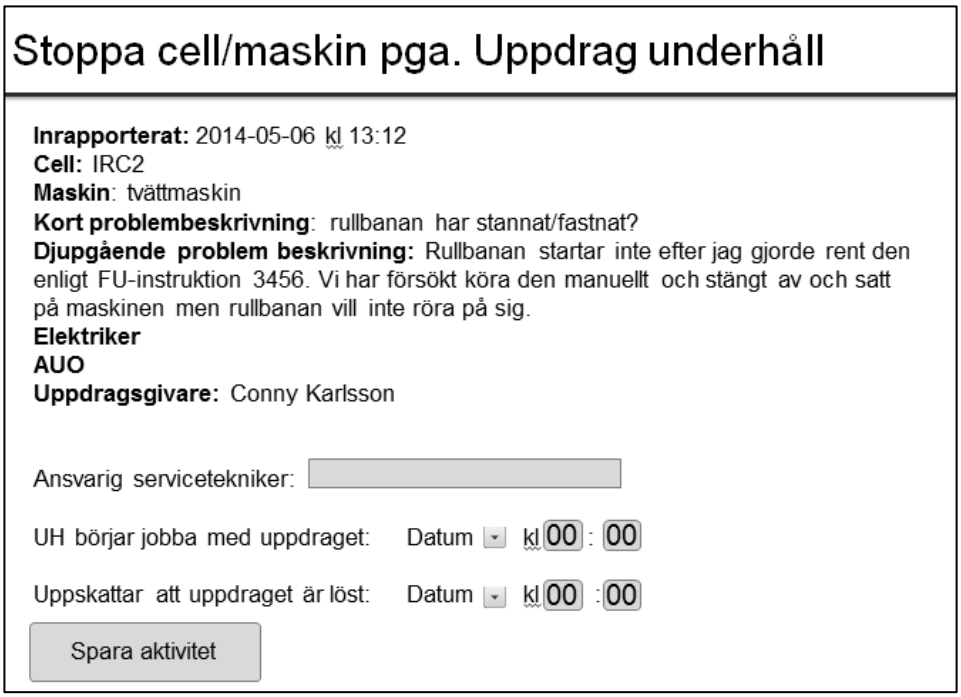


Figure 28: Assignment for maintenance, step 2

After the maintenance worker has press the save button an activity is added in the calendar for cell IRC2 with the text AUO with the placement and length corresponding to the dates and times the maintenance worker wrote in. The other information will be reached when the user presses the cell. The maintenance worker will have the possibility to change the date and time during the work.

When the maintenance worker is finished with the machine the following information should be written:

- Changes to the short problem definition
- Changes to the long problem definition
- The real finished time of the job
- What was done to solve the problem
- What the root causes were.
- Subsequent assignments and connecting them to this job. An example of a subsequent assignment could be to order and assemble a spare part if the right spare part was not in stock during the job.
- Last step is to save the data

The corresponding screen display is shown in Figure 29.

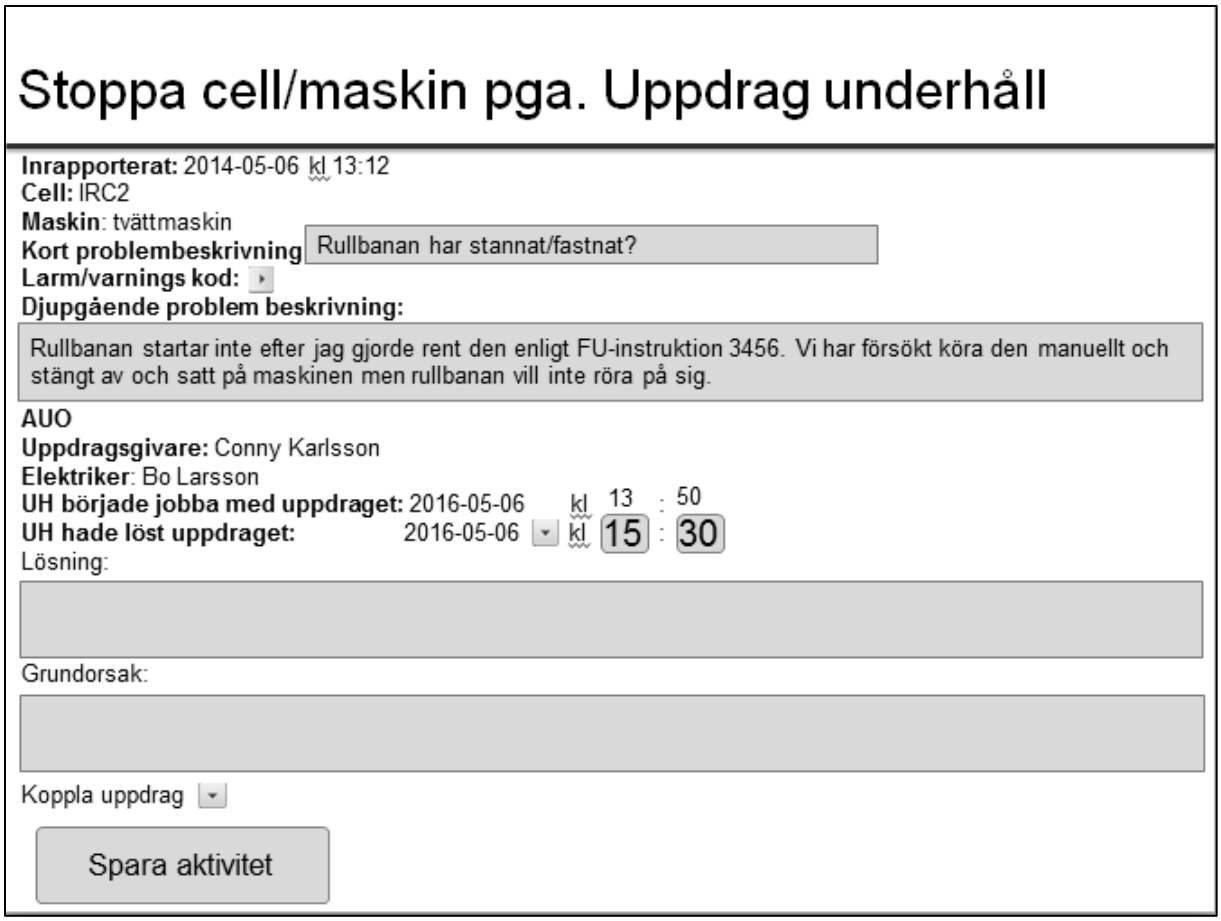


Figure 29: Assignment for maintenance, step 3

If the user wants to report an assignment to the production technician team he/she writes in information according to Figure 30:

Figure 30: Assignment for production technicians, step 1

The production technicians then inputs:

- The start date and expected end date
- The responsible production technician
- Additions or changes to the short and long problem/improvement definition.
- A description on what they should do for example tests, measurements or order goods.
- If they decide not to do anything they should write an explanation for this choice.

No figure is available for this screen display.

When the production technicians have finished a job they input:

- The real end date
- The outcome
- The root cause
- Connect new assignments to the job if it is necessary

No figure is available for this screen display

If the production technicians want to conduct a test, which will stop a machine or cell, the production technician inputs information according to Figure 31.

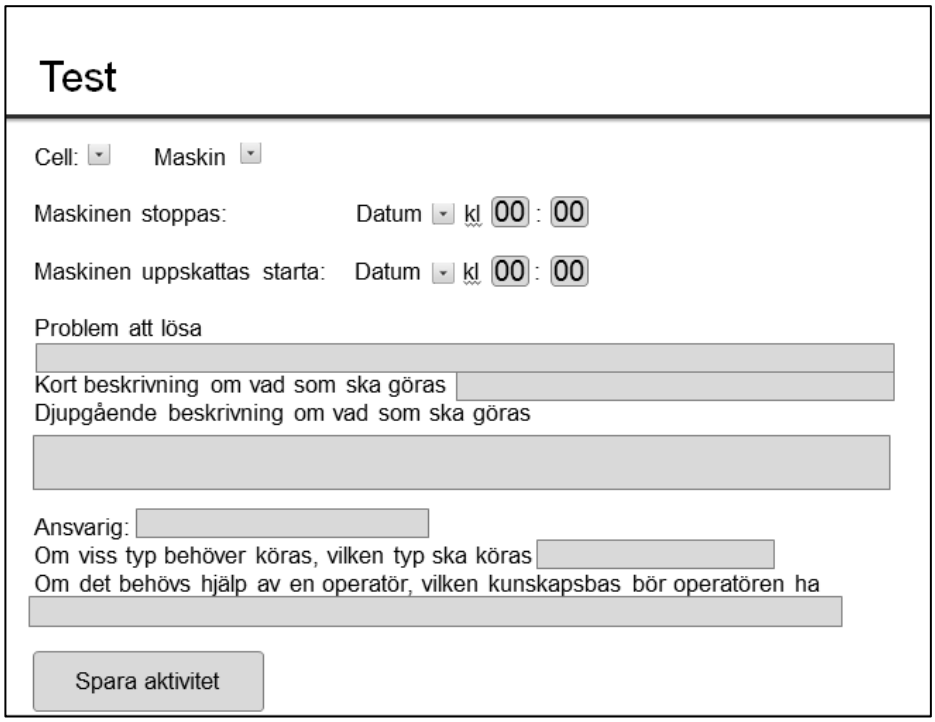


Figure 31: Production technician screen display for writing in a test which will stop the production

The operational manager has the responsibility to input if a cell or machine is stopped because of personal or knowledge shortage. Figure 32 shows which information should be entered for the activity. The alternatives in the scroll menu can be seen in Figure 33.

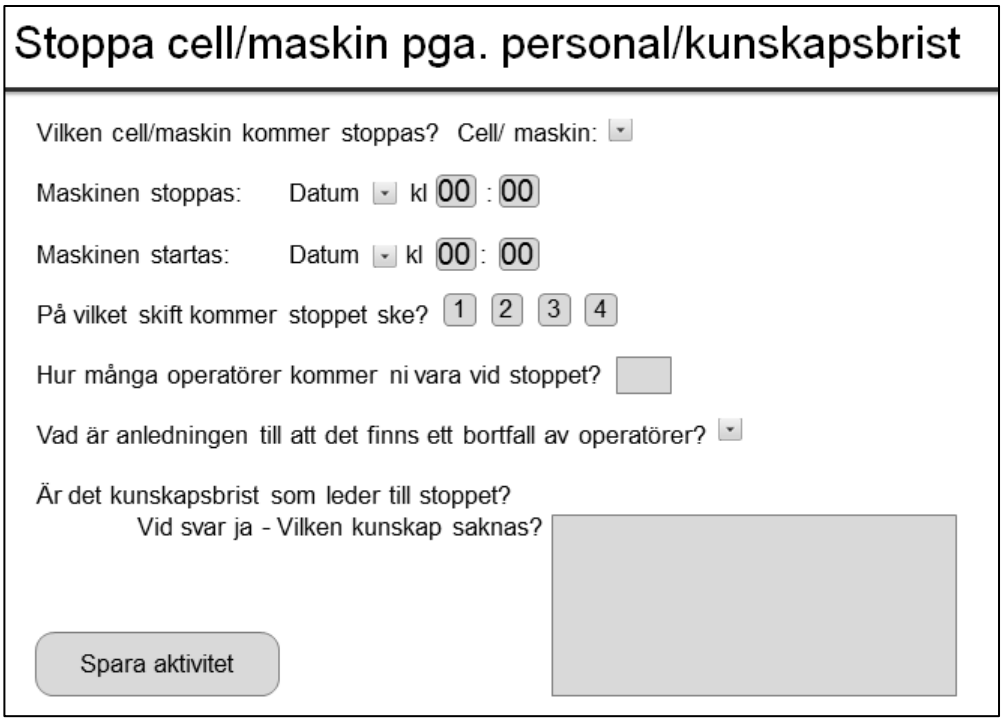


Figure 32: The operational manager's screen display for writing in a personal or knowledge shortage in the calendar

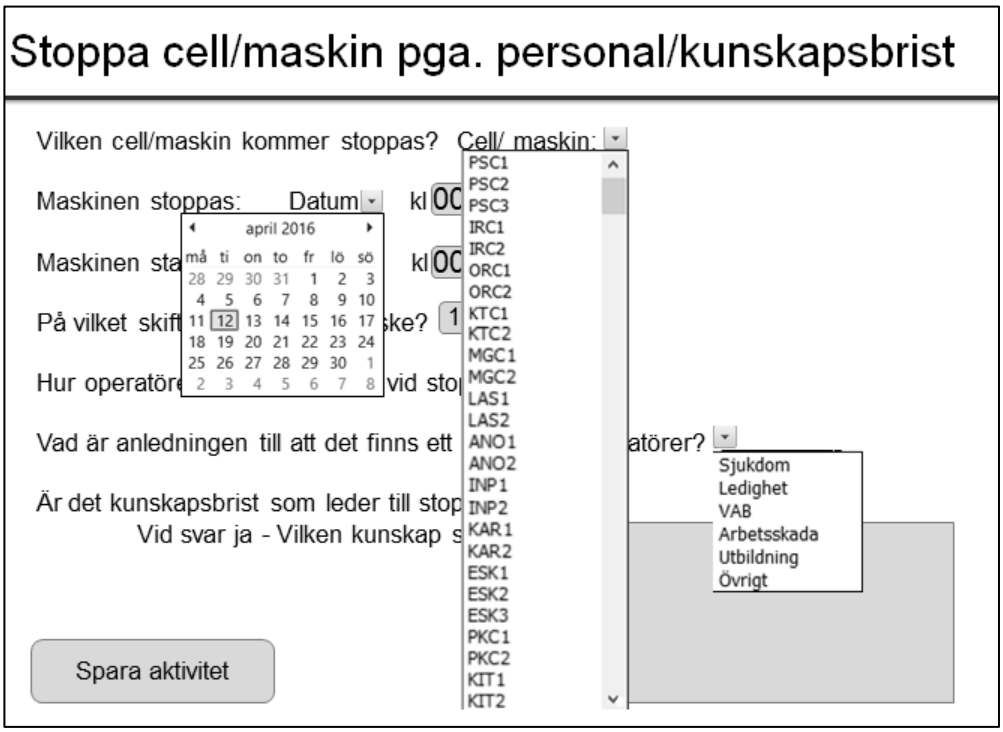


Figure 33: The different choices in the scroll menus for writing in a personal or knowledge shortage in the calendar

An activity that can stop a cell or machine is meetings. Operators and operational managers write in information according to Figure 34.

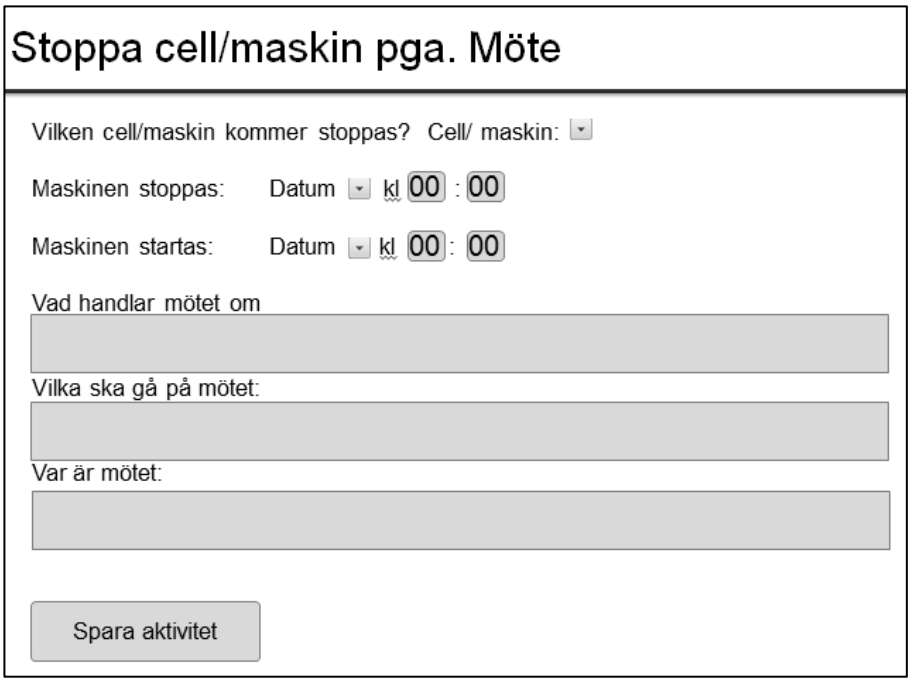


Figure 34: The screen display for writing in a meeting as an activity that will stop production

If there is no activity category that matches the reason for stopping a machine or cell the "other" activity is chosen. In that activity the user writes in information according to Figure 35:

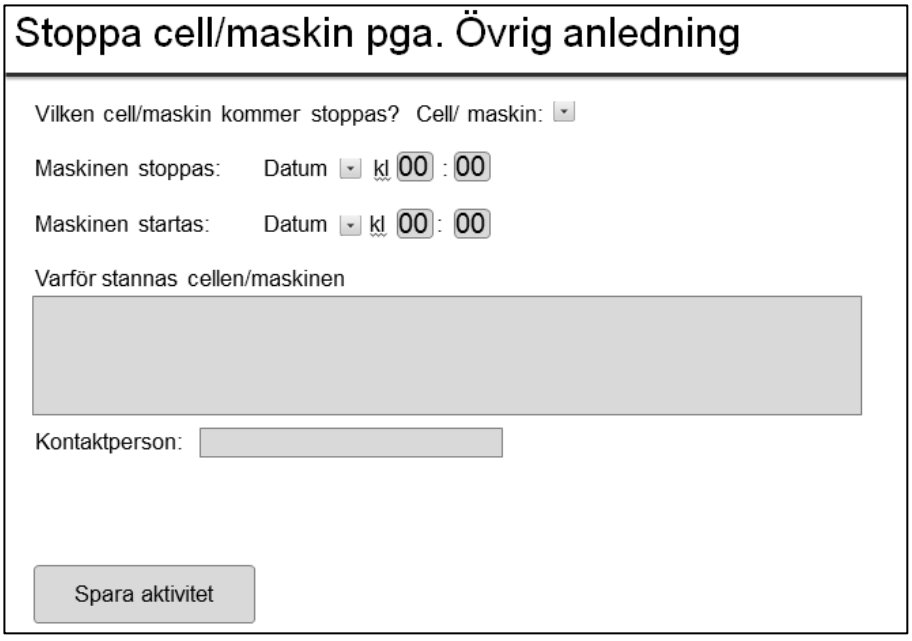


Figure 35: The screen display for writing in an "other" activity that will stop production

The times for a stop because of material shortage should be possible to calculate automatically but all material shortages will probably not be possible to predict. That is the reason for both having an automatically planned material shortage activity and a manually entered unplanned material shortage activity. In the manual input for the material shortage,

Figure 36 shows which information should be put in. Material shortages that is reported are automatically should show the same information but the reason why the component is not included and the comment is added by the supply chain when the activity is shown in the calendar.

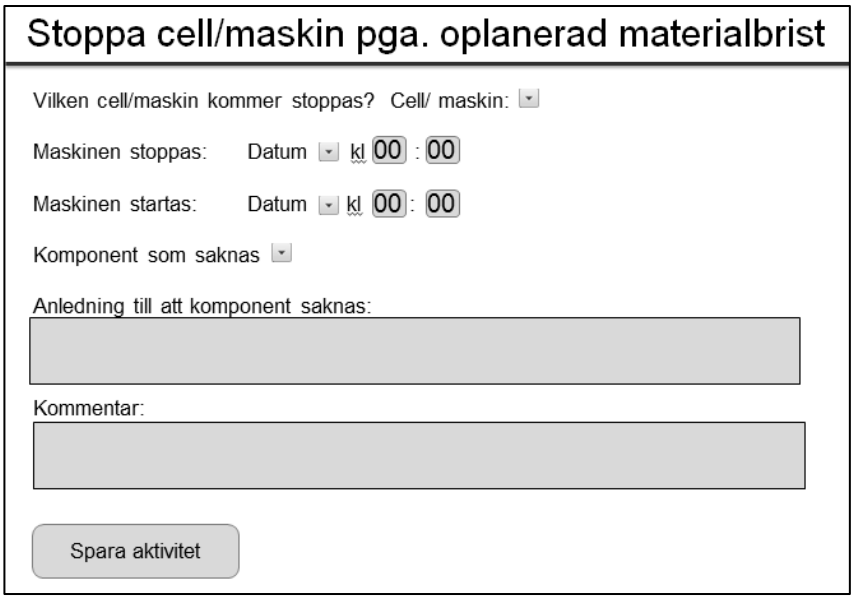


Figure 36: The screen display for writing in an unplanned material shortage activity that will stop production

The times for a stop because of setups should be possible to calculate automatically but all setups will probably not be possible to predict. That is the reason for both having an automatically planned setup activity and a manually entered unplanned setup activity. In the manual input for setups, Figure 37 shows which information should be written. Setups that are reported automatically should show the same information the difference is that since the setup is planed the reason why there is a setup is not included.

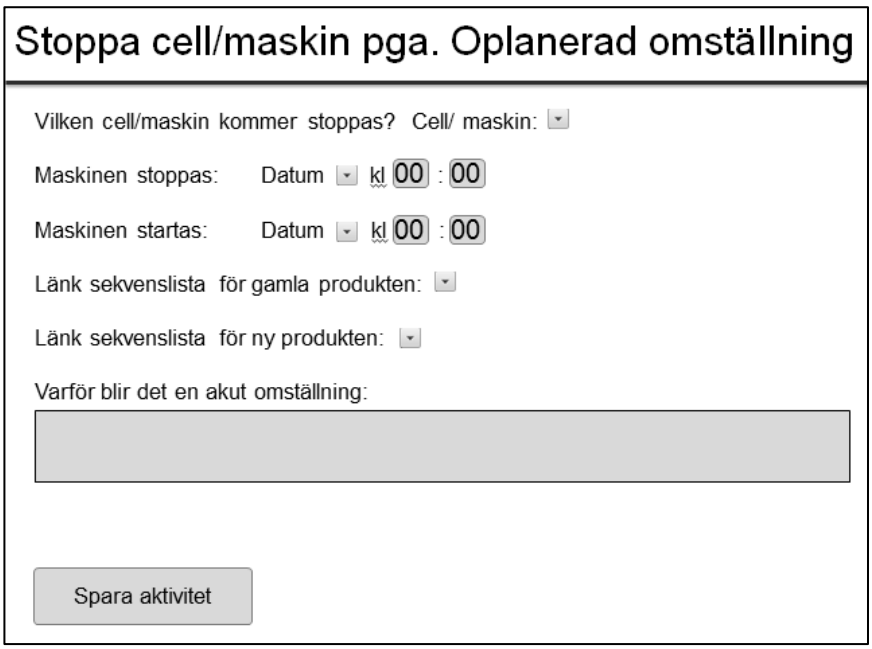


Figure 37: The screen display for writing in an unplanned setup activity

The times for a stop because of a tool change should be possible to calculate automatically but all tool changes will not be possible to predict because of tool breaks. This is the reason for both having an automatically planned tool change activity in the calendar and a manually input unplanned tool change activity. In the manual input for tool change the following information should be input:

- Which cell is the tool change connected to? Choose from a scroll list
- Which machine is the tool change connected to? Choose from a scroll list
- What tool will be changed? Choose from a scroll list
- A start date and time for the tool change
- An estimated end date and time for the tool change
- The reason for changing the tool ahead of time.

For the automatic tool change the same information will be shown with the exception for the reason for changing the tool, which is not included.

Appendix H. The machine park overview screen display

In this appendix the inspiration for the machine park overview is described as well as more detailed information about status visualisation of the conveyor belt.

Background

The inspiration for the machine park overview screen display came from the company visit at Volvo Cars in Skövde. Figure 38 shows a screen display of their machine park overview, which they have placed on strategic position around the plant. Each box symbolise a machine or a buffer. The connection between the cells is conveyor belts and portals. Every box could be either read with means the machine is turned off or green, which means that the machine is OK. If the machine is flashing in red and grey the machine is alarming. This screen display is connected to walkie talkies, which the operators use. The walkie talkies soundly alarms "Alarm machine XXX, alarm machine XXX", or "Alarm portal XXX, alarm portal XXX" when a machine or portal alarms.

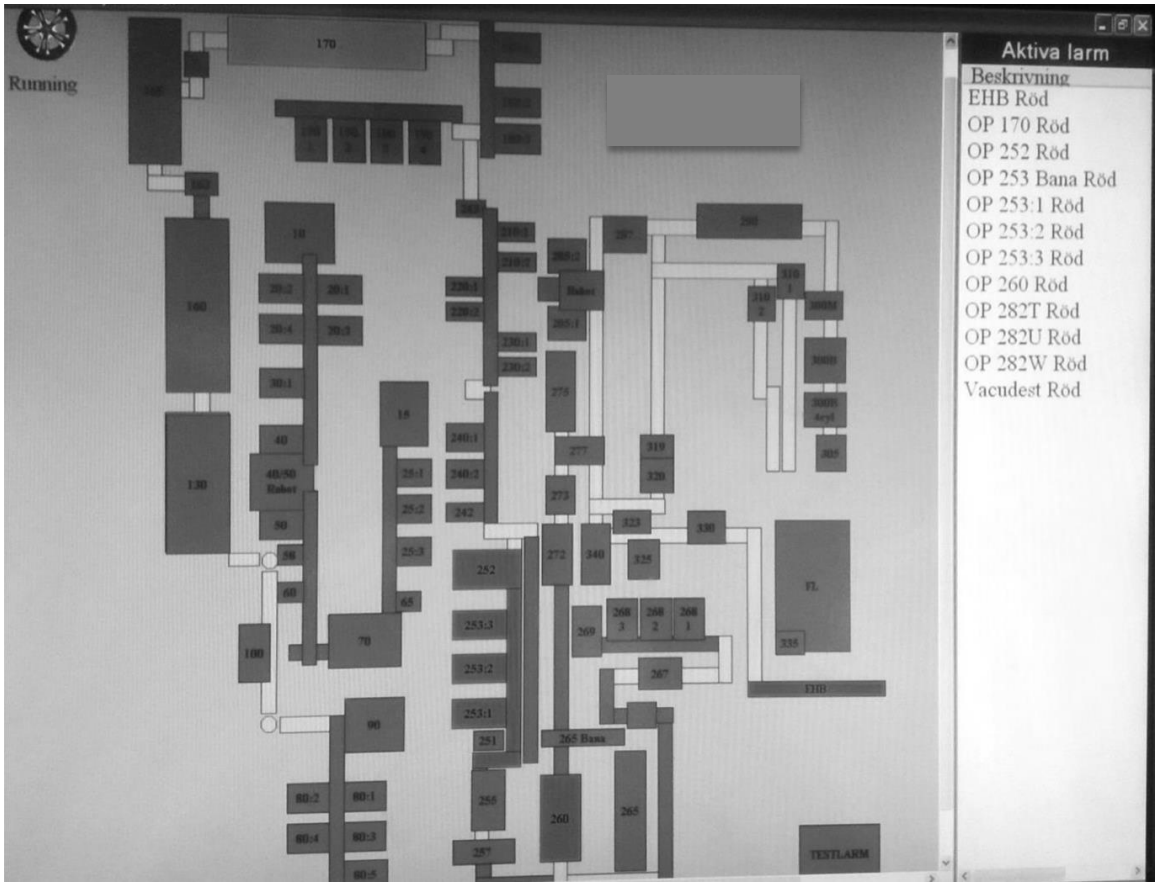


Figure 38: An overview of one of the machine parks at Volvo Cars in Skövde. The factory's name is censured.

Conveyor belt

The conveyor belt of the assembly line will be controlled by five PLC's controlling flow A, B, C, D and E showed in Figure 39. Figure 10 shows how it will look when flow A is alarming and flow B, C, D, E is OK. The reason for having the conveyer belt flow divided in the five flows on the screen display for the machine park overview is because the five different PLC will probably have their screen display on different places in the layout. The machine park overview screen display will therefore help the operator in knowing which screen display the alarm can be reset from.

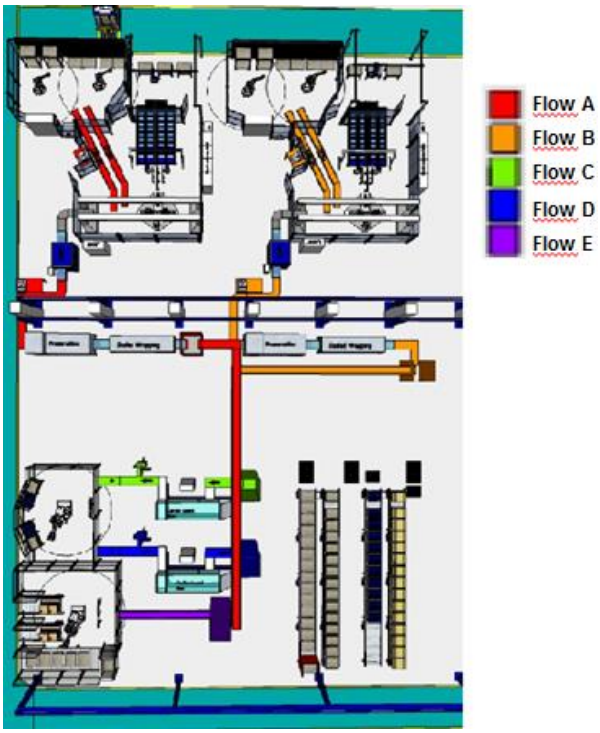


Figure 39: A layout description of the five flows of the conveyor belts.

Appendix I. The deeper information screen display

This appendix describes the sub screens shown on the deeper information screen display according to Figure 11 and 12.

3A Cell overview

The cell overview screen display is showed in Figure 40.

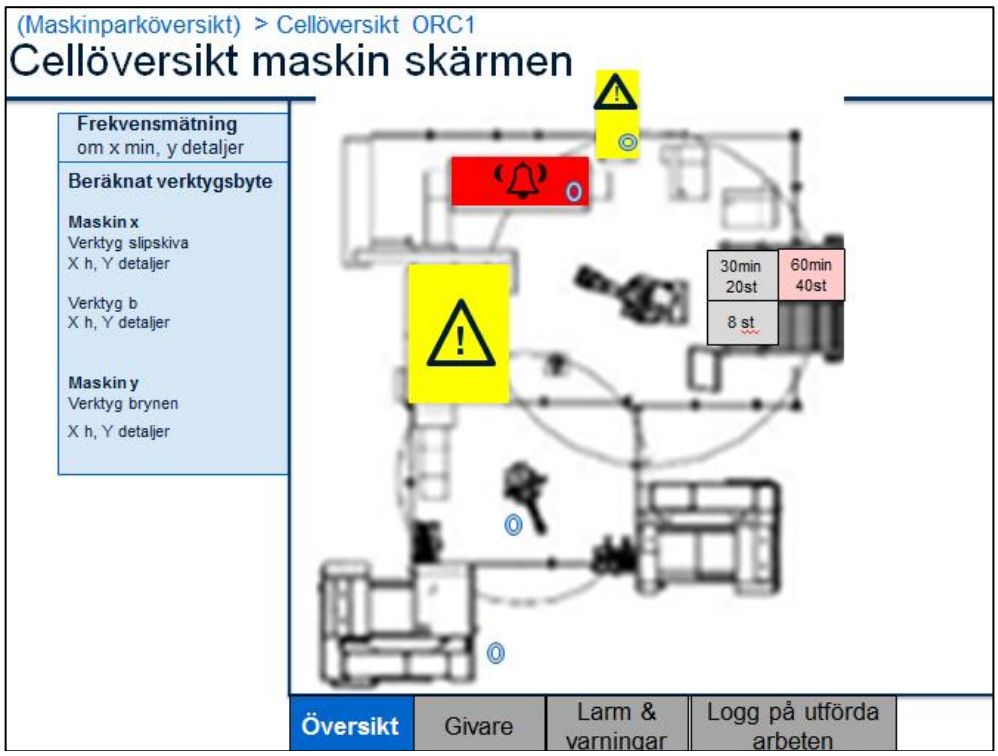


Figure 40: A cell overview

If the user presses a cell in the machine park overview screen display an overview of the cell will show in the deeper information screen display.

- In the cell overview the user should see the status of the machines and robots with colour and symbol coding. The green colour and its symbol not included on this screen display since they were seen as unnecessary.
- If there is a product placed on the process measurement place waiting for the operator to measure the colour of the measurement place should become yellow. If the machine has stopped because the user has not measured the product in time the colour of the measurement place should be red.
- The grey rings show where products are placed.
- The inlet and outlet should show how many pallets are standing on the conveyor belts. The inlet should, besides the number of product left on the pallet, also show how long time it is supposed to take in order to process the products that are left on the pallet. The colour of the pallet shows if the pallet is "dirty", that an operator has manually placed or moved products on the pallet, or "clean", that the products have not been moved. The time for the robot to find and grip products from a dirty pallet will be longer than what is calculated, which is interesting for the operators to know.

- The number of details until a process measurement will stop the machine should be showed and its corresponding time.
- Tool changes for the different machines should be showed by how many details is left until a tool change and the corresponding time to the tool change. Which tool that should be changed should also be visible.
- In the cell overview you will be able to press machine, robots and products to get deeper information on these sub screen displays. It should also be possible to get to the cell's alarms and warning, sensors and log of work.

If a cell in the machine park overview is blue the following information should be shown:

- If the cell is waiting because the inlet is empty, the pallets on the outlet are not fetched by the AGV or the cycle time is passed by a decided number of seconds.
- If there are any orders to the cell in the schedule
- When the AGV is planned to service the cell to see if the users need to move the order up in the prioritizing scale
- Which AGV has been appointed the order so the user can see if it is the particular AGV that is alarming

3A1 Machine

From the single machines in the machine park overview but also from pressing a machine at the cell overview you should be able to go to these sub screen displays: the sensors for the machine, get product information, machine media and machine condition, log of work, alarms and warnings log.

3A1.1 Sensors

The operators have asked for a visualization of the sensors placement so they can find sensors quicker. They wanted a description of what the sensor is measuring and if the sensor is affected or not. The code of the sensor should be visible, because the code should be visible in the alarm texts and is also used by the maintenance service personnel. At Volvo Cars they show their information about sensors as shown in Figure 41.

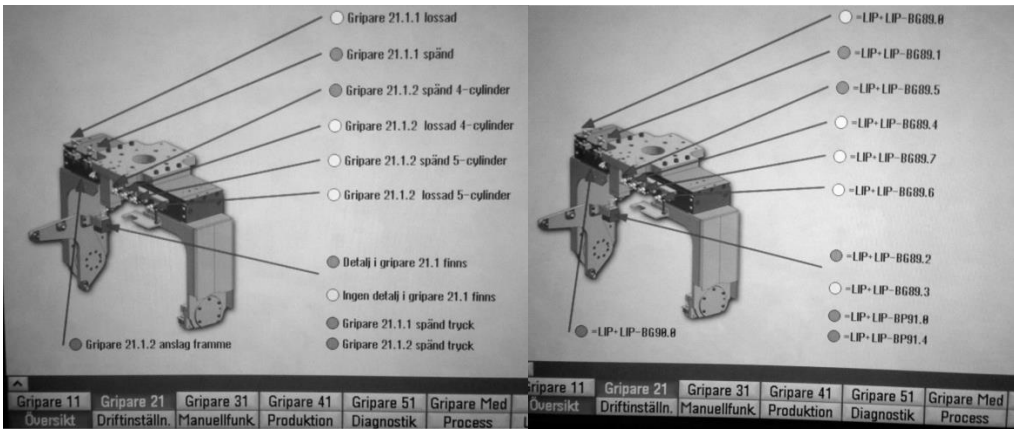


Figure 41: The sensor screen displays at Volvo cars.

3A1.2 Product

If the user presses a product on the machine overview the following information should show

- Denotation
- ID number
- Order number for the production portion
- Order number for the denotation
- Routing describing
    - By which cells and machines the product have been processed in this production system but also earlier machines in other SKF plants and the date and time for each operation
    - Future machines and cells it should be processed by.

3A1.3 Machine media and machine condition

An overview of the machine media status and the machine condition. The status and condition are indicated by colours and symbols.

3A1.3.1 Parameter machine

The status of the process media to and from the machine has to be supervised. As well as what condition the machine is in. The following parameters have been identified as interesting for the operator and the maintenance personnel.

Machine condition

- Vibration of spiders
- Vibration of engines
- Clearance ballscrew, the measuring should preferably start by itself with a certain frequency
- Engine effect in percentage with a goal of 70% of the capacity

Process media

- Temperature washing fluid
- Pressure pneumatics
- Pressure, flow and temperature for cooling fluid, grinding water, polishing oil and hydraulic oil

An example of the visualization of the data can be seen in Figure 42.

Today the operator often calls the process media personnel if they encounter problems, but the problem is often that the operators have forgotten to open a valve. The process media personnel therefore want to indicate their valves' status to the operators. The measurement devices have to be placed tactically to show problems like this.

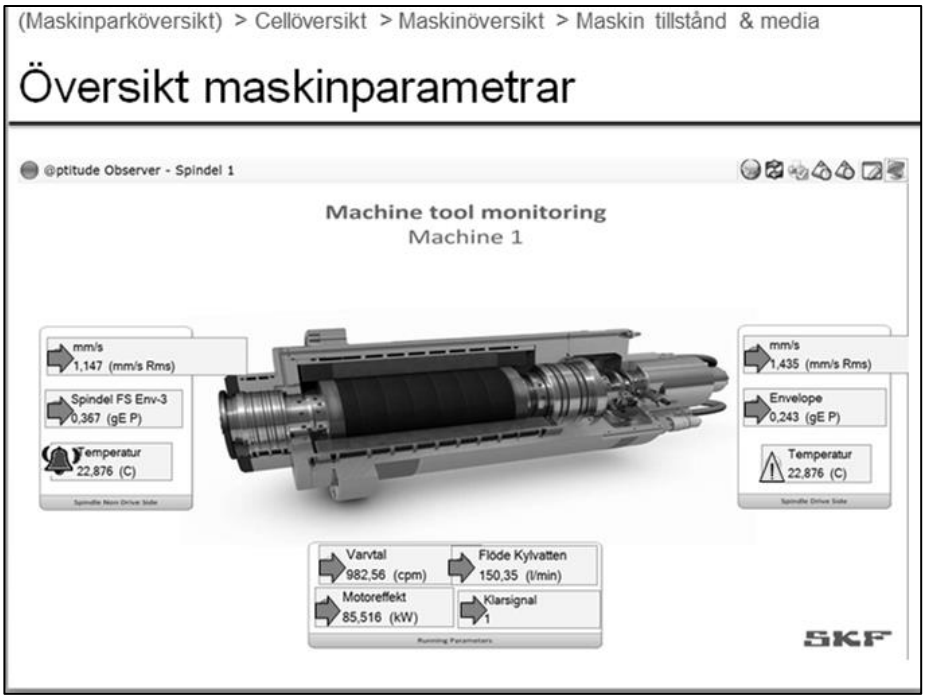


Figure 42: An example of the process media and machine condition parameter visualization

3A1.3.1.1 Trends process media and machine condition

If the user presses a parameter in the process media and machine parameter visualization, a trend over time for that parameter should be shown, Figure 43. It should be possible to choose which other parameters you want to have visible simultaneously.

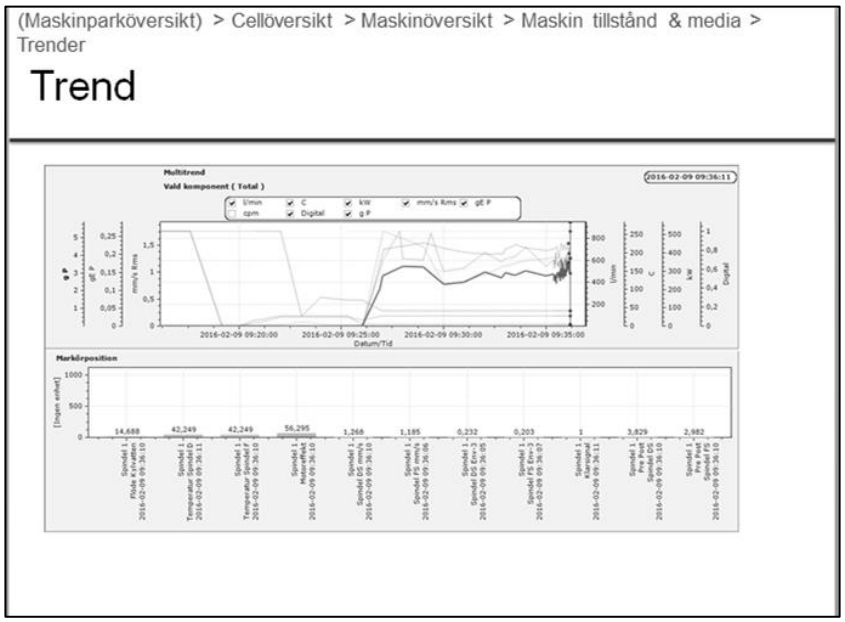


Figure 43: The trends of process media and machine conditions

3A1.4 Log of work
The production technicians have asked for a log of the different changes that have been made with the machine to be able to trace back problems to changes with the machine. The maintenance personnel and the production technicians but also the operators should write in if they have made changes with the machine for example program changes, changed parts, bent parts or crash of the machine. The production technicians and maintenance personnel report program should be connected to this screen display so they do not have to write in the same information twice.

3A1.5 Alarms and warnings
The alarms and warnings log for the chosen machine.

3A2 Product
Shows information about the product in the cell. The information should be the same as the screen display 3A1.2.

3A3 Sensors cell
Visualization and description of the sensor for the cell as screen display 3A1. 1.

3A4 Alarms and warnings
The alarms and warning for the cell, which include alarms and warnings from the robot, inlet, outlet, process measurement box and door of the cell instead and not machines within the cell.

3A5 Log of work
Shows the same information as screen display 3A1.4. The information should though show information about changes in the cell and not the machines in the cell.

3A6 Robot
When a robot is alarming, the operators want to know the current robot command and the next command in order to know what will happen when they start the robot again. They also want to know what the robot is waiting for, for example a certain sensor to be activated.

3B Buffer overview
A need for a visual or table description of the products in the buffer has been identified. The following parameters should be possible to search for:

- product denomination
- number of details
- routing with earlier cell and machines and times
- clean pallet or dirty pallet

A measure of how full the buffer is, is also a wish. If the buffer is nearly empty the output will probably be reduced for some time. Then the operator could, instead of having the manufacturing line going, focus on the other cells for some time to build up the buffer again to get a more even flow.

The buffer will not only contain parts for the bearings it will also contain tools and indirect materials, which means that these need to be described as well. An indication of the division between tools, indirect material and direct material is also something that has been requested by the users.

3B1 Product information
Same information as screen display 3A1.2 and 3A2.

3B2 Block product in the buffer
The users wanted a functionality to block products in the buffer with the search function with the following parameters:

- product denomination
- process in cell or machine X during the time interval Y
- ID number
- the measure "Inbyggnadsmått" for combing the inner ring, outer ring and the rollers to get the right clearance in the assembly

3B3 Request product from buffer for control
The operators wanted a function for request out products from the buffer so that they can control the product and secure the quality using the same search functions as for blocking products in the buffer.

3C AGV
According to the process development team at SKF the AGV system will not be possible to implement in the regular screen displays but need a separate one. However it has been asked by the operators to be able to see the AGV placement and if the AGVs are ok or alarming on the machine park overview. If you press the AGV symbol you will see information on the screen display beside it. The following information should be presented on the deep information screen display:

- Show the placement of all AGV:s on a map over its area
- The colour of the AGV on the map should show the status of the AGV, red colour of the AGV means that the machine is alarming. If the colour is light green the AGV is OK.
- If the AGV is transporting material there should be a box placed on the AGV on the map.
- The colour of the box should show if the pallet is clean or dirty.
- The information, which the users wanted of the product on the pallet was:
    - product denomination
    - number of products of the pallet
- Where the AGV is going; to cell X, buffer or charging station X
- Where the AGV have been latest; by cell X, buffer or charging station X
- The percentage, of which the battery is charged

3D Quality
From this screen display the user can monitor the measurement machines' result, analyse the result from first piece- and process measurements, and monitor the Cp-, Cpk-, Pp- and Ppk values. Report and analyse scrap.

3D1 Monitoring measurement machines

In the upper right corner of the screen display the alarms and warnings from the measurement machines in the cells, which have not been reset should be shown with

- which cell is alarming or warning
- an indication of whether it is an alarm or a warning
- the text message describing the alarm or warning
- the time at which the alarm or warning started

The measurement machines should alarm when a measure is outside of the tolerance or if the value of Cp, Cpk, Pp and Ppk are at alarm level. The users have asked for a warning level of the measurement machines when there are measurements over the three sigma-level or a trend is found. The user can press on the alarm and warnings in the upper right corner of the display. A graph over the latest measurements for the chosen measurement will show. How many measurements back in time the graph will show is 20 but can be set by the user. The goal value, the upper and lower warning and alarm levels should show on the graph together with the measurements. If a user makes a change in the measurement machine this should be shown with an X on the graph for the product where the change was implemented.

Histograms of certain measurements of the inner and outer ring should be shown to secure normal distribution of the measurements. A need has been identified to show the graph of the most important measurements, described in Figure 44. But also a search function to choose which graphs should be shown.

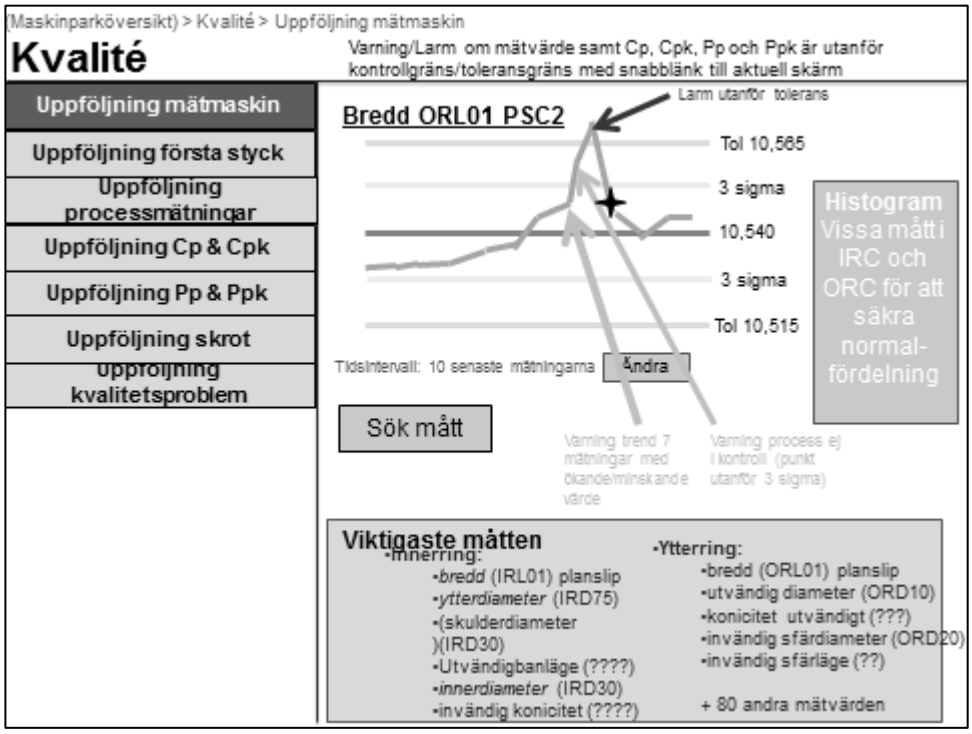


Figure 44: Information that should be visible on the measurement quality screen display.

3D2 Analyse first price
Figure 45 shows which parameters the users can choose to enter in order to analyse the result from the first piece measurements. All parameters do not have to be entered.

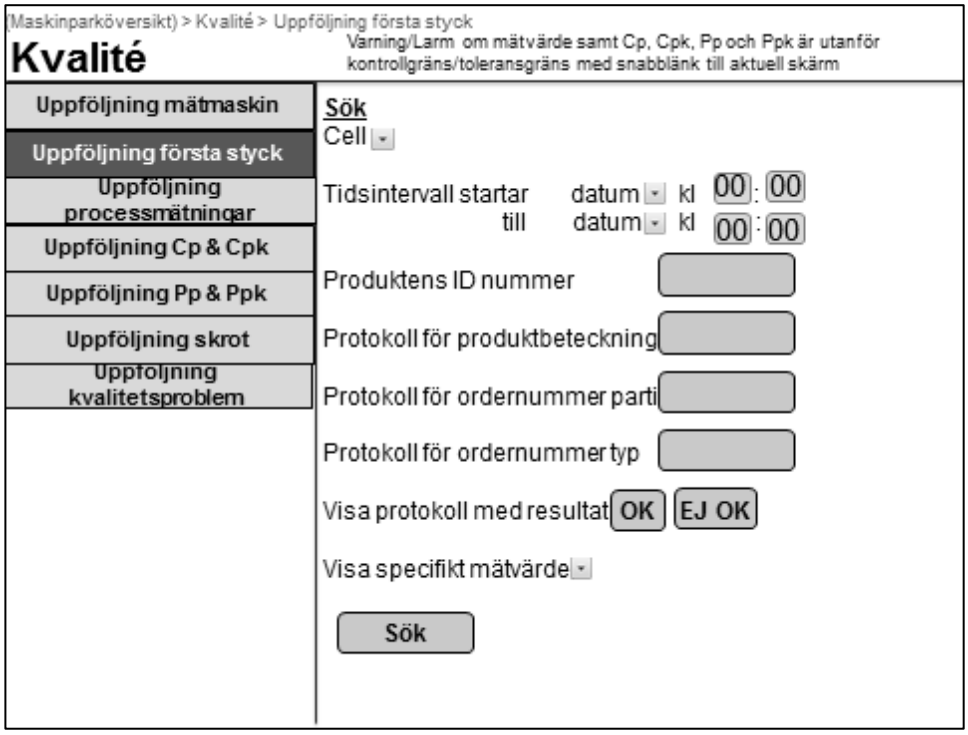


Figure 45: Search display for analysing first piece measurements.

3D3 Analyse process measurements
The user analyses the process measurements by searching with the same parameters as Figure 45.

3D4 Monitor Cp and Cpk
A need to follow up the spread of the measurements and the offset of the measurements from the goal value was identified.

3D5 Monitor Pp and Ppk
A need to follow up the spread of the measurements between product type changes and the offset from the goal value of the measurements between product type changes in the production system was identified.

3D6 Scrap
A need to report scrap and analyse scrap has been identified. On this screen there should be two buttons: one goes to the screen display for reporting scrap and the other for the search function of analysing scrap.

3D6.1 Report scrap

Figure 46 shows the screen display for reporting scrap with the identified parameters that should be reported.

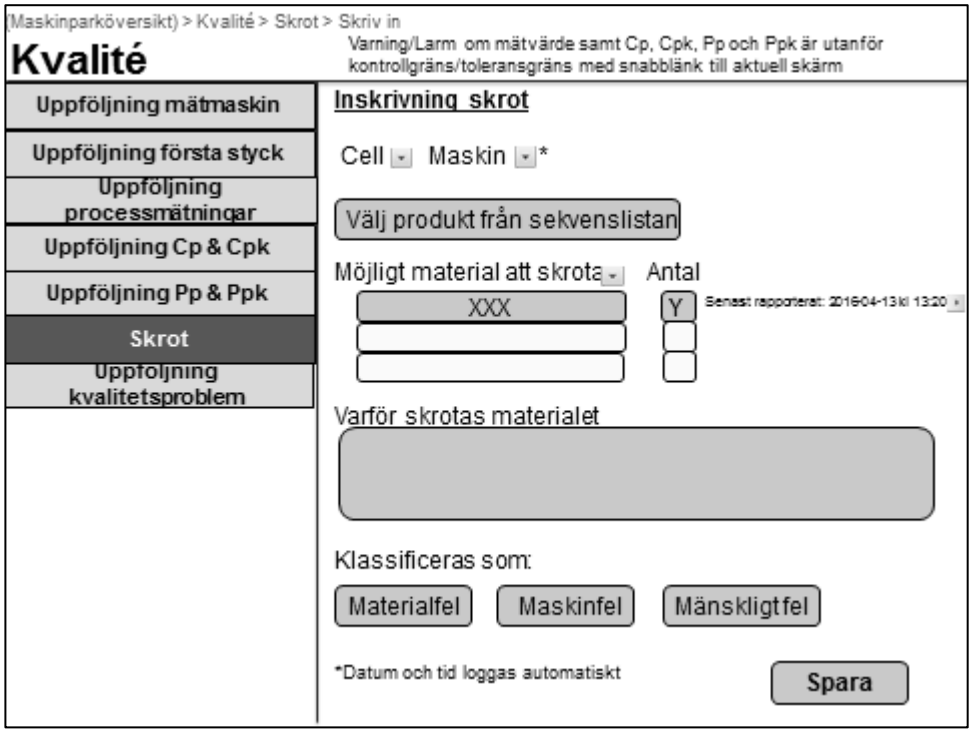


Figure 46: Screen display for reporting scrap

3D6.2 Analysing scrap

Figure 47 shows the screen display for analysing scrap by searching the scrap database with the identified parameters. All parameters do not have to be entered.

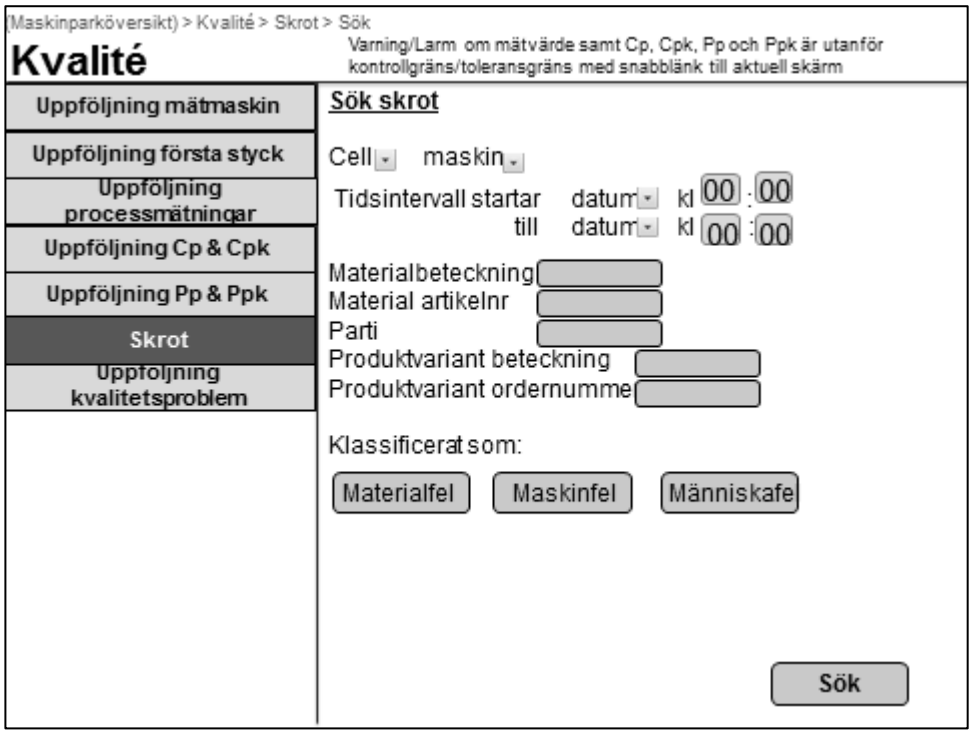


Figure 47: Screen display for analysing scrap.

3D7 "How to" quality problem

A need to gather and present the knowledge the operators have for fixing quality problems has been identified. The operators should write instructions on how different quality problems they have experienced have been fixed. When the user then gets quality problems, which prove to be problematic in solving, the user can search the database to find already reported guides. This screen display should show two buttons were the user choses between reporting a solution and searching for a solution.

3D7.1 Report solution

Figure 48 shows the screen display for writing a guide on how to solve a quality problem written by an operator.

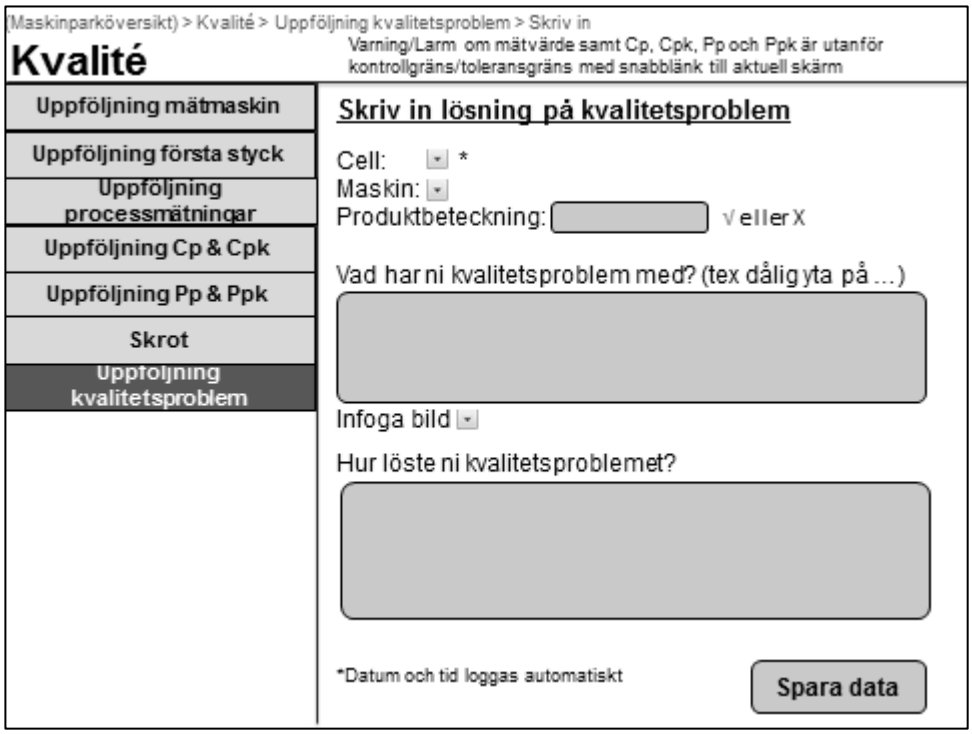


Figure 48: Screen display for reporting an instruction on how a quality problem can be solved

3D7.2 Search solution

Figure 49 shows the screen display for searching in the database for instructions on how to solve quality problems in the production system. The checkmark and X symbol marks whether the product denomination is correct or not.

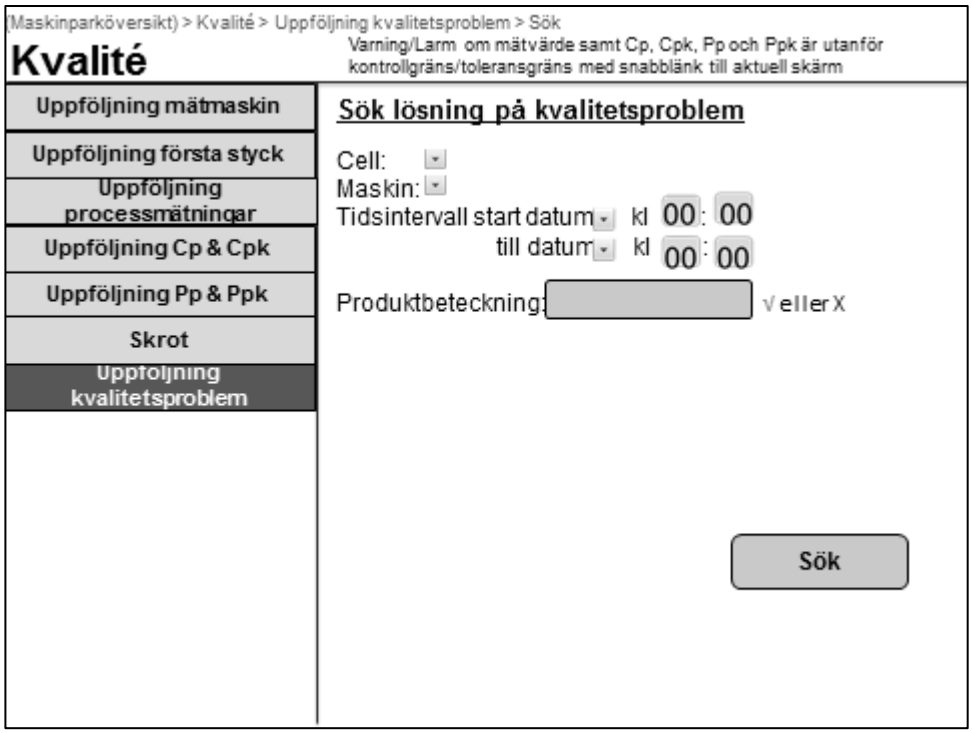


Figure 49: Screen display for searching quality instructions

3E Maintenance

From this screen display the unplanned maintenance can be followed up. A planning and display function of what should be done during the maintenance stops is available. The daily task of the operators is planned and displayed here.

3E1 AUO

The need to have an overview screen on which unplanned maintenance assignments are on cue, which are worked with on now and which assignments have been finished during the last 24 hours has been identified. For each assignment the user needed to know the cell, the machine, the problem and the start and end date and time of the assignment. The user will also have the function on pressing an assignment and get further information. Figure 50 shows the designed overview screen display of unplanned maintenance.

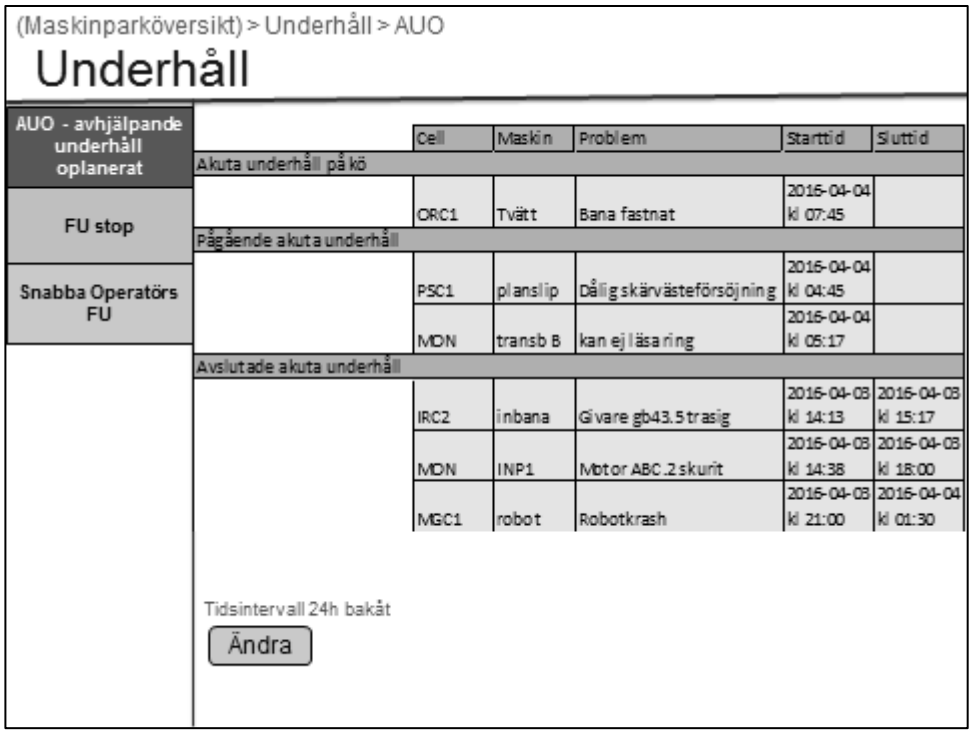


Figure 50: Display of unplanned maintenance

3E2 FU

A need to have a smart planning and display function for preventive maintenance was identified. For preventive maintenance a clear division of what should be done, on which machine, during what time and by who is needed. Today there are situation were maintenance personnel, production technicians and operators have planned to work on the same machine at the same time. A wish was to be able to drag and drop activities to the preventive maintenance schedule from a list, which would show the following activities organized by when they should be finished or if they are already late:

- inspection and control maintenance
- preventive maintenance with a set interval
- condition based maintenance
- the interval set activities the production technicians have
- the interval set activities the operator does during maintenance stops

For each activity the following information should be showed

- date, start time and end time
- cell
- machine
- short description of assignment
- deeper explanation of what should be done, instruction included for frequent assignments
- responsible person
- if the machine has to be shut down
- if there is a certain product type, which needs to be processed
- if they need help by an operator
- the knowledgebase that the operator needs

3E3 Operator task

The operators have daily tasks that they do with a certain frequency. The operators have expressed a need to see which tasks are delayed, not jet started and started for each shift. Figure 51 shows the information that the user needs for the task and the identified functions of signing that the user has started the task, signing that the operator is finished with the task, the possibility to write a comment about the task and a possibility to "sign off" tasks if the list of delayed tasks gets too long.

Operatörs FU	Cell	Maskin	Beskrivning uppdrag	Inst.	Tid måste vara klar	Beräknad tidsåtgång	Ansvarig = uppdrag påbörjat	Uppdrag klart	Kommentar	Skriv av uppdrag
Försenade	PKC1		sopa golv	länk	2016-04-15 kl 02:00	10 min				
	ESK1		tom ettikettlåda	länk	2016-04-14 kl 13:00	5 min				
	IRC2		rengör läsare	länk	2016-04-14 kl 15:00	5min				
Ej påbörjade	PSC1	Mätmaskin	Rengör mätmaskin	länk	2016-04-15 kl 12:00	15 min				
	ORC2	Mätmaskin	Kalibrera mätmaskin	länk	2016-04-15 kl 14:00	5 min				
	ORC3	innerslip	töm spånbinge	länk	2016-04-15 kl 14:00	30 min				
Påbörjade	LAS2		rengör läsare	länk	2016-04-15 kl 10:00	5 min	Lisa Gustavsson			
	buffert2		rengör golv	länk	2016-04-15 kl 08:00	20 min	Tomas Karlsson			

Figure 51: Table for operators' daily task.

3F Administration

Today the operators are presented with a lot of information from the production whiteboards. An identified need is to make these whiteboard digital to make sure that the information is updated and easy to access.

3F1 To do in an emergency

Shows an instruction on how a person should react if an emergency occurs.

3F2 Staffing

A need to both report staffing and to analyse the staffing has been identified. Buttons to the two functions will be available at this screen display.

3F2.1 Report staffing

Figure 52 shows the screen display for reporting staffing.

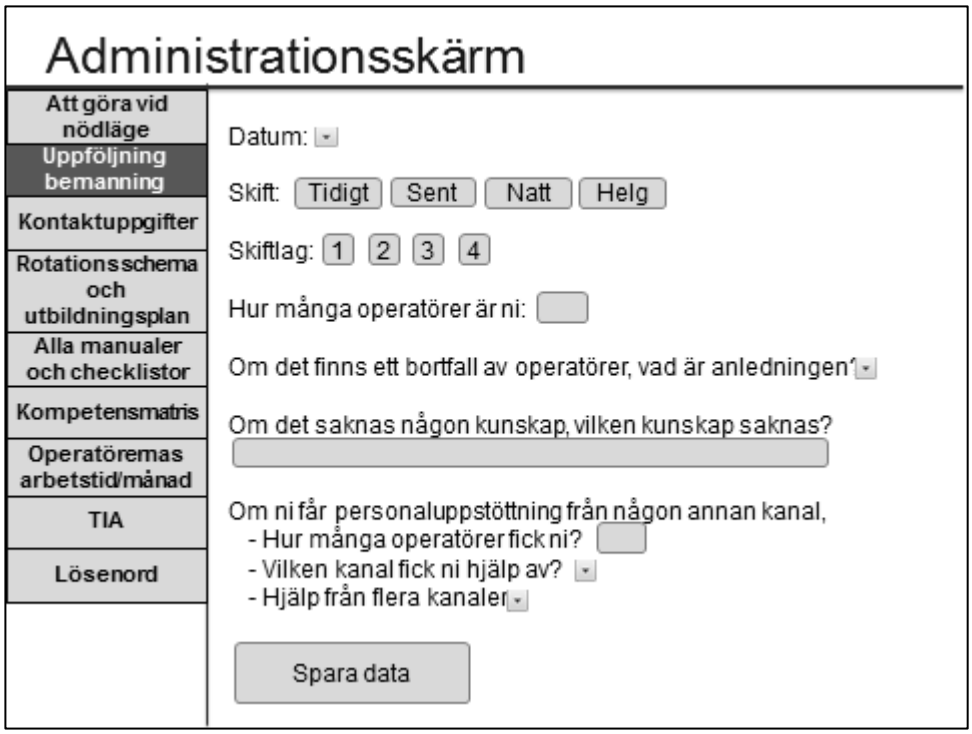


Figure 52: Screen display for report staffing

3F2.2 Analyse staffing

The user can analyse staffing for searching at the parameters that have been entered for reporting staffing.

3F3

Figure 53 describes the contacts' details that have been identified as helpful for the users. The expanded list in the figure shows the different units that the users need contact details on. The dotted list in the figure shows which contact details are useful to show for each respective unit. Note that it is important that the information should be easy to change in order to improve the likelihood of the contact details being actively updated.

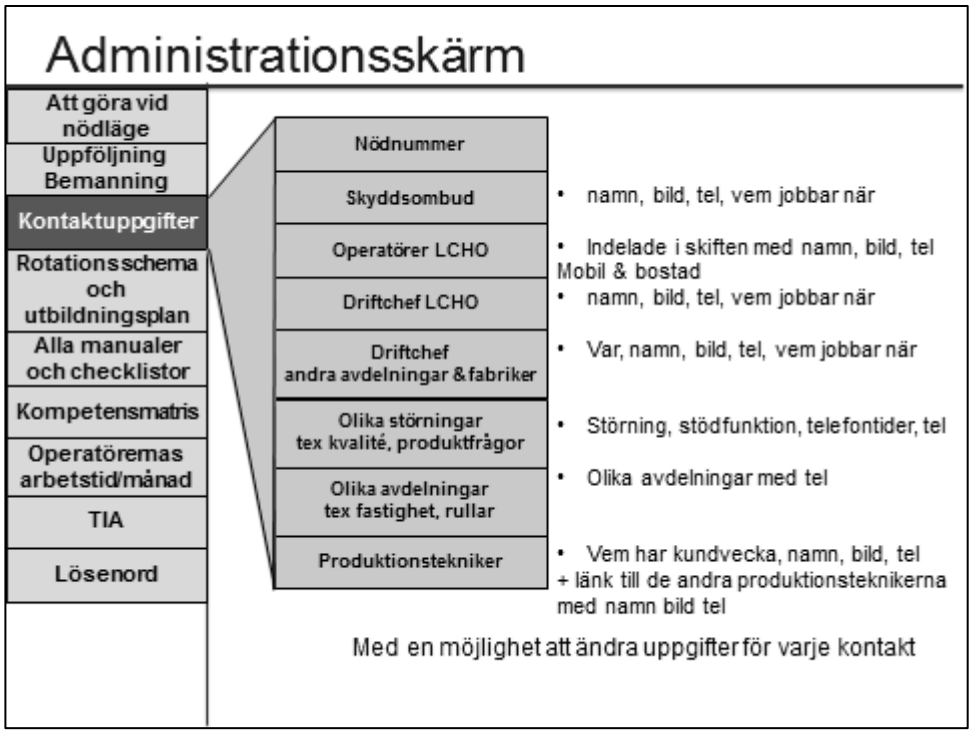


Figure 53: Screen display for contact details

3F4 Rotation schedule and training plan
Today the operators have a document containing a rotation schedule and training plan on the production whiteboard. This should be shown digitally in the control room instead.

3F5 All manuals and checklists
A need to gather and distribute manuals and checklist to the effected units and task have been identified to ensure that the latest edition is used and that instruction for identical machines or tasks are updated by only changing one document.

3F6 Competence matrix
Today there is a paper with the competence matrix on the production whiteboard. This should be shown digitally in the control room instead.

3F7 Operators' hours per month
SKF does not use staffing agencies so instead they vary the employees' work hours over the month. The document of how the shift should work, should be available from the control room.

3F8 TIA
Today SKF uses a program called TIA for accidents reports. The control room should have a link to the program, so it could be seen on the deep information screen display.

3F9 Password
A need for a database where they can put in and reach passwords has been identified, because as it is, the user spends a lot of time with password problems.

3G Improvement
A need to show information about the improvement work of the production system has been identified.

3G1 Production technology
The production technicians have expressed a wish for showing the operator the work that the production technicians have in queue, the work that they are presently working on and the outcome from finished assignments. This has also been identified as required information for the operators.

3G2 A3
The operators work with the Lean tool A3 to found root causes to problem. The result from the A3 documents should be visible in the control room by request from the operational manager.

3G3 Availability alarms
At Volvo Cars in Skövde they use a method where they can see how large percentage of production time each machine is producing and not alarming. This is done in order to be able to prioritize which machine the user should focus on removing alarms from. Figure 54 shows how this is visualized at Volvo Cars. This has been identified as valuable information for SKF as well.

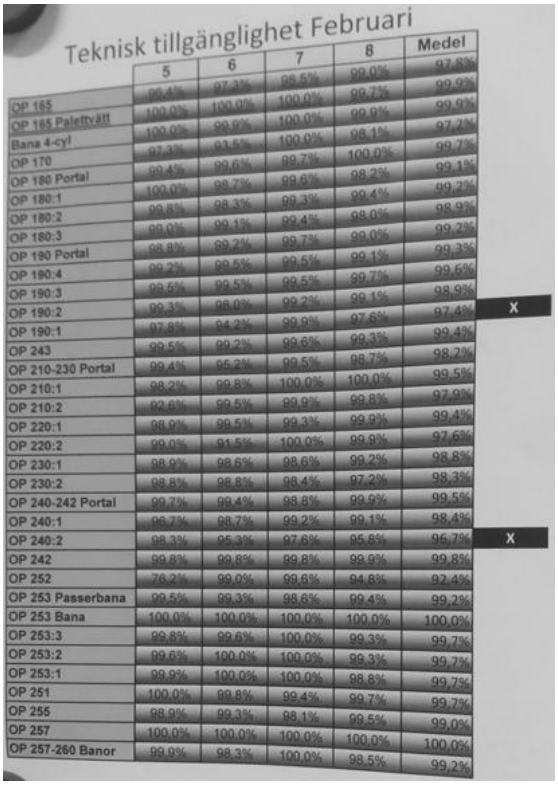


Figure 54: Availability of machines at Volvo cars with consideration to alarms.

3G4 Graph analyse alarms
With this function the users develop a bar graph showing the alarm texts a machine has had during a time period on the X-axis. How many times each alarm text has appeared and the sum of the time it took to reset each alarm text during the same time period are shown on the Y-axis. The graph helps the user to prioritize between the two alternatives; removing short

stop alarms or removing a few alarms, which take a long time to reset. Figure 55 shows the data input by the user needed in order to create the graph. Figure 56 is an example of a graph developed at Volvo Cars in Skövde.

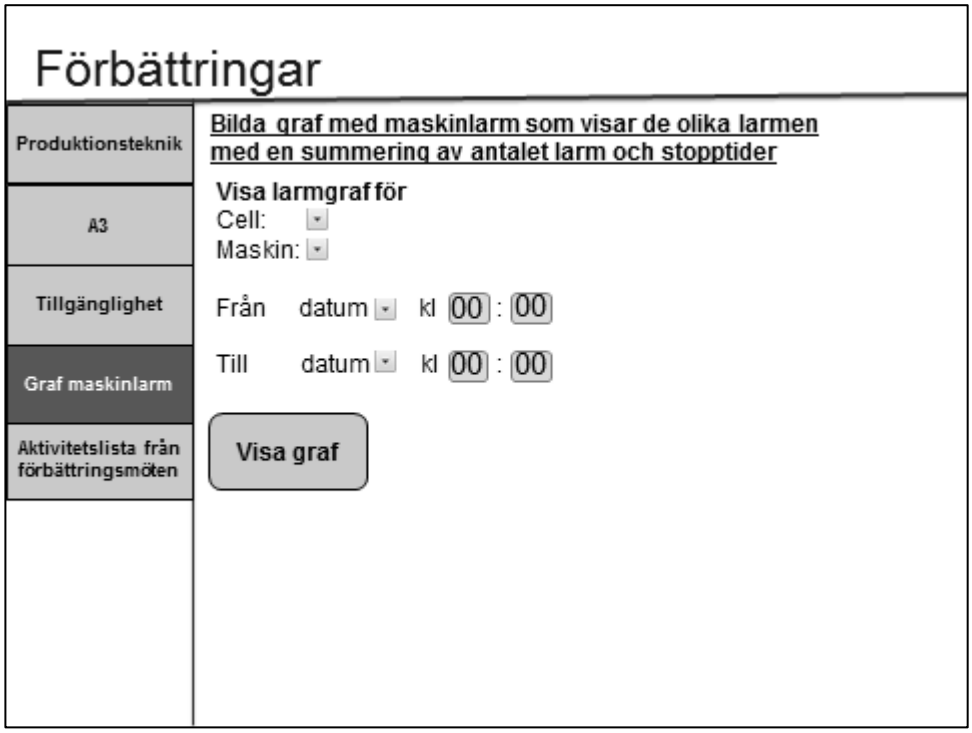


Figure 55: Input parameters needed for a graph over alarms

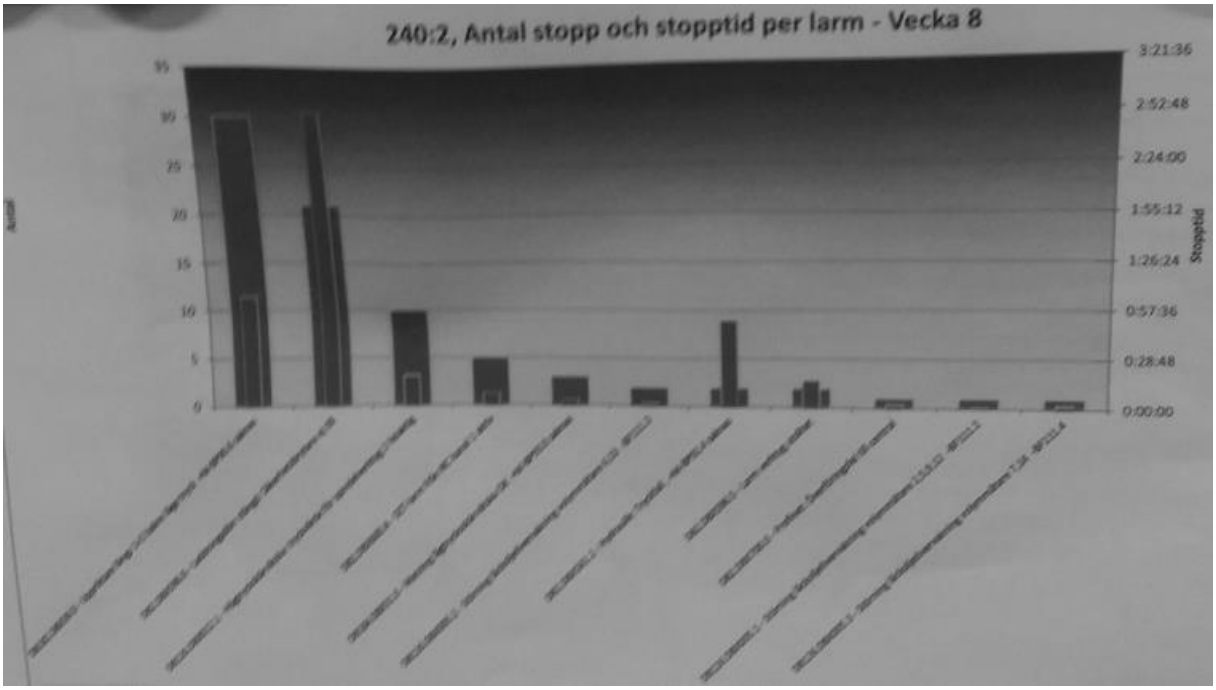


Figure 56: A graph of alarms from Volvo Cars showing the alarm texts a machine has had during a time period, how many times each alarm text has appeared, and the sum of the time it took to reset each alarm text during the time period.

3G5 Activity list
Representatives for the operators and the operational managers have meetings with the production technicians were they go through improvement work that has been done and which should be done. The developed activity list from these meetings should be visible at the control room so that the operators and operational managers can see if they can work with anything on the list while having spare time.

3H Efficiency measure
This screen display is mainly done for the supply chain personnel and the channel group manager so they can analyse what has happened in the production in order to find improvement factors.

3H1 OEE
SKF is currently not using the OEE measure, a measure commonly used in industry. This makes it hard for SKF to compare their availability with that of other companies. A wish is therefor that the OEE measure should be calculated automatically and shown in the control room.

3H2 Cycle time
A need to show the changes of cycle times for the machines over time is identified.

3H3 Setup times
Setup times have previously been monitored at SKF. A need to in the control room show setup times in order to analyse why setup times differ has been identified.

3H4 Pace
The pace of the production system should be possible to follow from the control room.

3H5 Net output
The display should show the number of produced products in the production system compared to the plan.

3I Lab report process media
The screen display should visualise the lab reports from process media. This will help the operators, in ruling out the quality of the process media as the cause of error when problems occur.

3J Operators ID and contact links
When pressing the face symbol in the machine park overview the following information about the operator should show: name and whether the person is responsible for quality, technology or personnel. It should be possible to message the chosen operator without the message being shown to the other users. On the mobile phone the user wants a link to call the user in order to facilitate communication.

Appendix J. The production sequence and material list screen display

This appendix goes into depth on what information should be shown in order for the operators to know what they should produce, when they should produce the products and whether they will get enough material. Figure 57 shows the display for the sequence list and the material list.

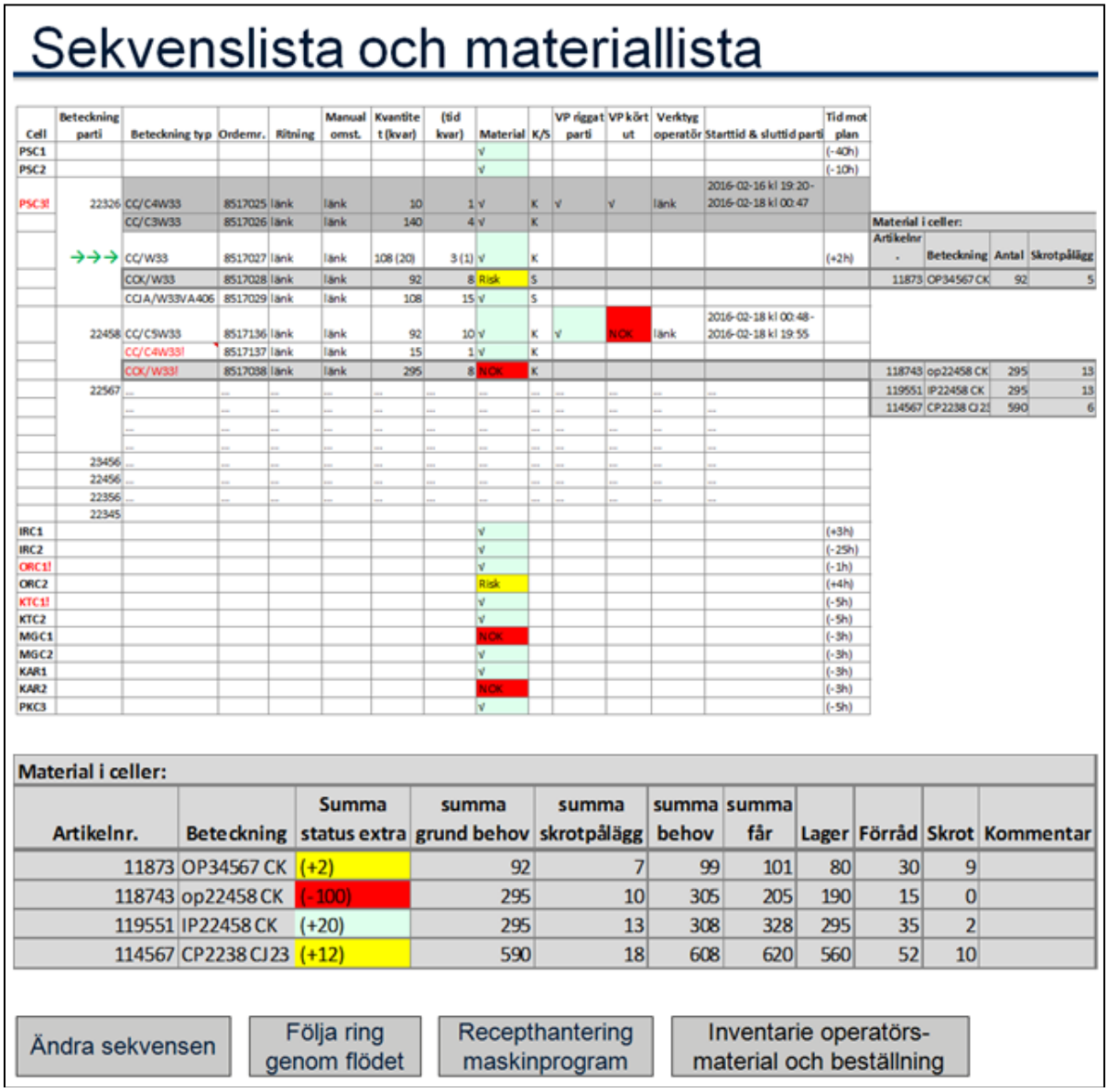


Figure 57: The production sequence list for cell PSC3 and its material list

Sequence table

For each cell the users requested a sequence list describing what they should produce. The supply chain decides what should be produced based on the orders they get. The information that the operators need from the supply chain are:

- A separate sequence plan for what they should produce in each cell. The plans should continue as far into the future as possible, even if they get less detailed.
- The denotation of the product group.
- The denotation of the product type.
- The order number connected to the product type.

- A link to a drawing of each product type in the sequence list. Currently they have a program called windshield with drawings of all the products, which the operator uses to setup the machines. The problem with windshield is that a lot of the users do not have login to the program and thereby no access to the program. The search function within the program is, according to the users, difficult and not consistent in its use. The users are also afraid of missing differences between a special product and a standard product. A wish is therefore to be able to see a special product beside its equivalent standard product with the differences highlighted and a text describing what is special with the product.
- Links to instructions on how to make the setup for each product type in the sequence list.
- How many products of each product type that should be made.
- How long time each product type is calculated to require in order to be produced.
- A colour and symbol or letter indication if they have enough material in the buffer, if there is a risk of having too little or if they know it will be enough.
- An indication of whether the product is to a customer or to stock. If there is a risk of material shortage the operator tries to plan the production so that this happens on the stock orders and not the customer orders.
- Whether the tool technicians have prepared the tool for the product group.
- Whether the tool technicians have placed the tools by the machine or if they are still at the tool department
- A link connected to each product group with a list of the tools that the operators needs for the different product types so they will know what they should order.
- The planned start time and end time for each product group.
- The number of hours each cell is ahead of or behind the plan in their production.
- A function that allows the user to press the rows and get more information about the material needed to make that product to the right side of the table. The article number of the parts needed in that cell, denomination of the article, how many is needed of each article and what has been decided as the scrap mark-up should be shown.

Material table

A summation of the material needed for the cell is showed in the table in lower part of the screen display. There the user should see:

- The article number of the parts
- The denomination of the parts
- A number of how many extra or too few parts the user will get combined with a colour indication of whether the material will be suffice, if the material will cover the base need but not the safety levels of the scrap mark-up or if the delivered material not even will cover the basic need.
- A summation of the basic need, if no scrap would be produced
- The summation of the scrap mark-up.
- A summation of the base need plus the scrap mark-up.

- A summation of how many parts the user will get with the number of product scraped subtracted.
- The user also asked for a description of how many parts that will be delivered are from storage and how many are leftover parts from previous production. The leftover parts are in some cases harder to use than new parts from the storage.
- The number of scraped parts should also be visible.
- The supply chain should have the possibility to make a comment on the supply of each part to the operators.
- A description of where the products are stored. Today they have problem finding pallets with material in the basement, this problem could be solved if all materials were contained in the new buffer. Though if the basement will still be used for material storage a function showing where material is stored will probably be needed.

The buttons

The operators want to be able to communicate to the supply chain whether they have or will make changes in the production sequence and which type they are currently producing. The green arrows in the sequence list show what is currently being produced in the cell. The function to change the production sequence or move the arrow in the list to show should be reached by pressing the change sequence button at the button of the screen display.

The operators, supply chain personnel, operational managers and the production technicians have asked for a function to search for the ID of a product and find its routing. Routing is a function to show in which machine and cells but also the time the product has previously been processed at.

The recipe handling of machine programs button should lead to a database where the machine programs are storage. This to simplify program changes of duplicated machines and highlight differences in the programs if there are any.

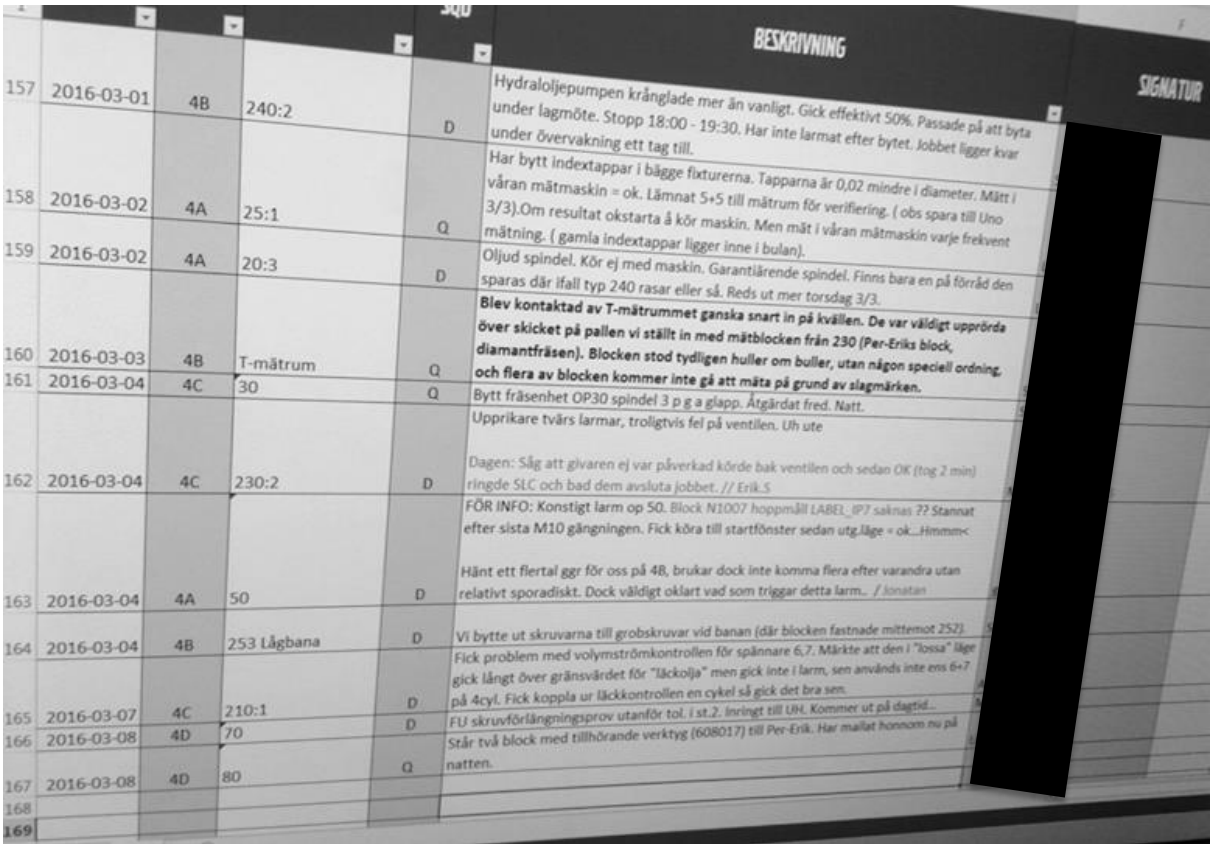
The operators have responsibility to order certain products, like the plastic bags for pallets in packaging, certain grinding wheels, ear protection, gloves and hand cream. The user wants to have an inventory list in order to know how much and when to order more material. Ideally the users want an alarm that they need to place an order for a certain product or that the order goes directly to the supplier. The most important inventory list was for the grinding wheels. Today the operators go through their inventory every day but still they often have to make acute orders to the suppliers. The data of the grinding wheel that they wanted to store in a database automatically was the wheels grinding type and the number of product or time left on the grinding wheel until it had to be changed. The fourth button should also have a link to the material order program.

Appendix K. The communication screen display

This appendix shows deeper information about the operators' diary and the information control document as well as the information about the navigation on the information display.

Diary

The diary for operators is visualized as a table which shows the date someone have written a comment, which shift team that person works at and which cell and machine the comment is connected to and of course the comment itself. By pressing the arrows in each column you choose which comments are interesting for you. It should be possible to add and change information in the excel document. Changed or added information should be highlighted with for example a different colour of the text so that changes are noticed. The idea for this diary came from the company visit at Volvo Cars in Skövde. An example of how a diary looks like at Volvo can be seen in Figure 58.



					BESKRIVNING	SIGNATUR
157	2016-03-01	4B	240:2	D	Hydraloljepumpen krånglade mer än vanligt. Gick effektivt 50%. Passade på att byta under lagmöte. Stopp 18:00 - 19:30. Har inte larmat efter bytet. Jobbet ligger kvar under övervakning ett tag till.	
158	2016-03-02	4A	25:1	Q	Har bytt indextappar i bägge fixturerna. Tapparna är 0,02 mindre i diameter. Mätt i våran mätmaskin = ok. Lämnat 5+5 till mätrum för verifiering. (obs spara till Uno 3/3).Om resultat okstarta å kör maskin. Men mät i våran mätmaskin varje frekvent mätning. (gamla indextappar ligger inne i bulan).	
159	2016-03-02	4A	20:3	D	Oljud spindel. Kör ej med maskin. Garantiärende spindel. Finns bara en på förråd den sparas där ifall typ 240 rasar eller så. Reds ut mer torsdag 3/3.	
160	2016-03-03	4B	T-mätrum	Q	**Blev kontaktad av T-mätrummet ganska snart in på kvällen. De var väldigt upprörda över skicket på pallen vi ställt in med mätblocken från 230 (Per-Eriks block, diamantfräsen). Blocken stod tydligen huller om buller, utan någon speciell ordning, och flera av blocken kommer inte gå att mäta på grund av slagmärken.**	
161	2016-03-04	4C	30	Q	Bytt fräsenhet OP30 spindel 3 p g a glapp. Åtgärdat fred. Natt.	
162	2016-03-04	4C	230:2	D	Upprikare tvärs larmar, troligtvis fel på ventilen. Uh ute Dagen: Såg att givaren ej var påverkad körde bak ventilen och sedan OK (tog 2 min) ringde SLC och bad dem avsluta jobbet. // Erik.S	
163	2016-03-04	4A	50	D	FÖR INFO: Konstigt larm op 50. Block N1007 hoppmåll LABEL_IP7 saknas ?? Stannat efter sista M10 gängningen. Fick köra till startfönster sedan utg.läge = ok...Hmmm< Hänt ett flertal ggr för oss på 4B, brukar dock inte komma flera efter varandra utan relativt sporadiskt. Dock väldigt oklart vad som triggar detta larm.. / Jonatan	
164	2016-03-04	4B	253 Lågbana	D	Vi bytte ut skruvarna till grobskruvar vid banan (där blocken fastnade mittemot 252).	
165	2016-03-07	4C	210:1	D	Fick problem med volymströmkontrollen för spännare 6,7. Märkte att den i "lossa" läge gick långt över gränsvärdet för "läckolja" men gick inte i larm, sen används inte ens 6+7 på 4cyl. Fick koppla ur läckkontrollen en cykel så gick det bra sen.	
166	2016-03-08	4D	70	D	FU skruvförlängningsprov utanför tol. i st.2. Inringt till UH. Kommer ut på dagtid...	
167	2016-03-08	4D	80	Q	Står två block med tillhörande verktyg (608017) till Per-Erik. Har mailat honnom nu på natten.	
168						
169						

Figure 58: Volvo Cars diary for operators. The operators' signatures are censured.

Information control document

At Volvo Cars in Skövde they have a manual method for information control, but the researcher wants to do it digitally. This is done by having a table, figure 59, with all the operators divided into the different shifts and alphabetically ordered in the left column. The reason for this division is to simplify the search for an operator's name. It can also help the operational manager to know which person to remind to read the documents. In the top row, with numbers, every green cell is connected to a separate document with information directed to the operators.

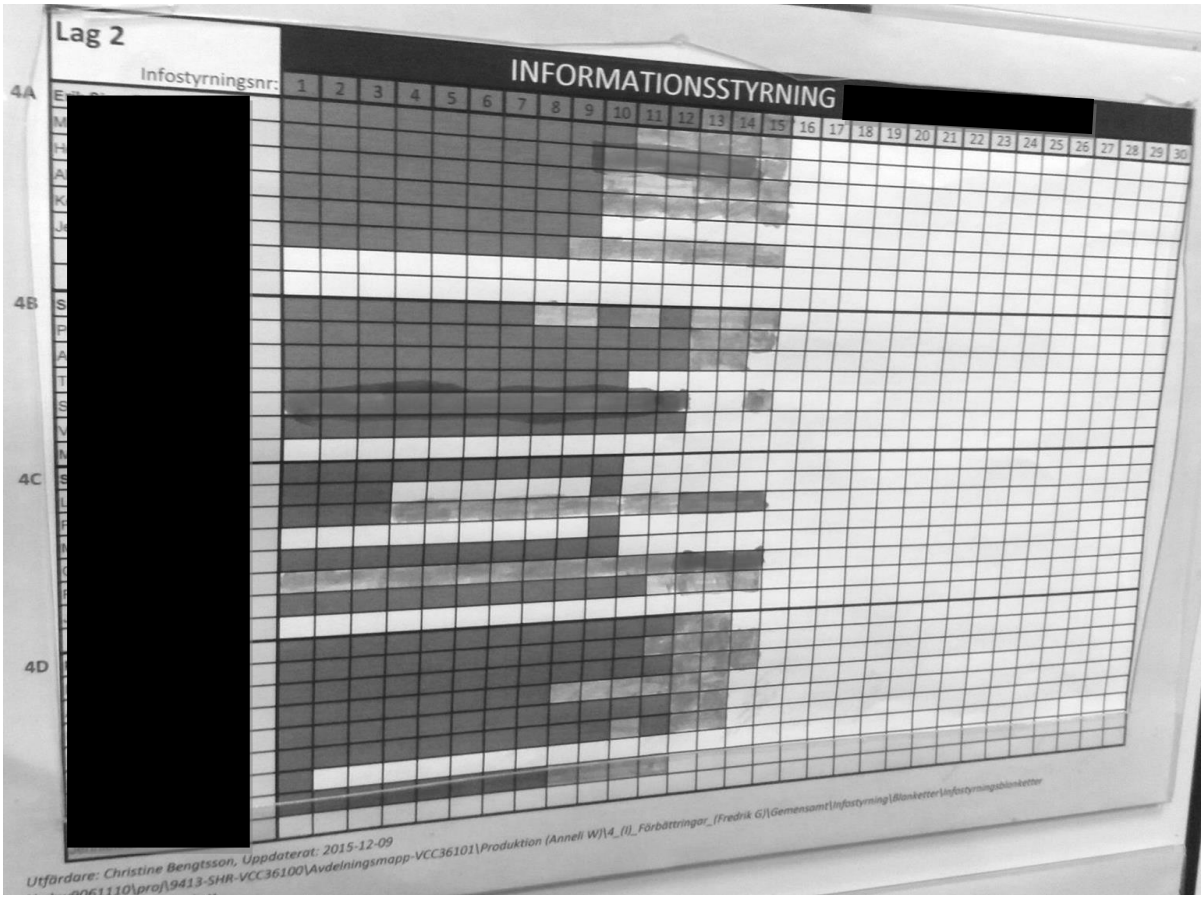


Figure 59: The information control paper at Volvo Cars. The factory's and the operators' names are censured.

If a new information document is uploaded there will be another green cell in the top row. When the operator sees that a new document is uploaded and that the operator's cell, under this new document, is not green the operator presses the cell and the document pops up. In the document the operator should be able to read:

- which area the change is connected to, for example which cell, machine, lift or conveyor in order to know if the information is important for the user to read.
- the date the information document was saved
- contact information to the person who has saved the document if something is unclear
- a description of what have changed or what the operator should think of
- pictures should be able to include to describe the change more deeply

The operator should then at the end of the document have a choice of choosing a button with "OK" written on it or another with "N/A". The "OK" button should be pressed if the worker works in the area the change is connected to. The operator should press the "N/A" button if the operator does not work with that machine, lift or whatever area the change concerns. When the operator has pressed on one of the buttons, does not matter which, the operator's cell connected to that information document, changes colour to green to symbolise that the operator has read the information.

Production technicians will probably be the ones to write the most documents. All users should however have the possibility to write information control documents.

Navigation

The user should have the possibility to change the size and position of the different communication boxes; diary, time limited information, chat and information control to suit the user's work. If a box is pressed it should be able to take up the entire screen display but the three outer boxes should be symbolised on the side and indicate if information is added to them. A home button at the upper left corner should reset the size and position of the boxes to the original configuration.

Appendix L. The active alarm and warning screen display

This appendix starts with describing how the alarms and warnings should be grouped and presented on the active alarm and warning screen display. Further, there is an example of alarm text messages at Volvo Cars, which can be used for inspiration to get better text messages at SKF. The information needed for an alarm and warning log is described as well as the search function for analysing alarms and warnings. The displays of writing and searching "how to guides" for alarms and warning are describe in this appendix. The displays of hiding false warnings and finding the list of already hidden warnings are described.

Grouping alarms

The reason for grouping the alarm and warnings after its cell with respect the third corresponding cell is sine the user arrives at the display via the layout picture where the user can see whether a cell is alarming or warning. The reason for pairing the alarms and warning from the same cell and machine together is to help the operator fix one machine at a time. The third prioritizing rule is order the machines placement in the cell group should be chronological order with the most recent alarm or warning at the top in order to make it easier for the user to see why a machine or cell changes colour from for example a warning to alarm.

Poor alarm and warnings messages

A problem that the operators described was that the text messages for alarms and warnings for the present machines at SKF consist of just a code. The operators wished for a more clear description of what was wrong. The researcher found the alarm text of Volvo Cars quite clear, an example is shown in Figure 60.

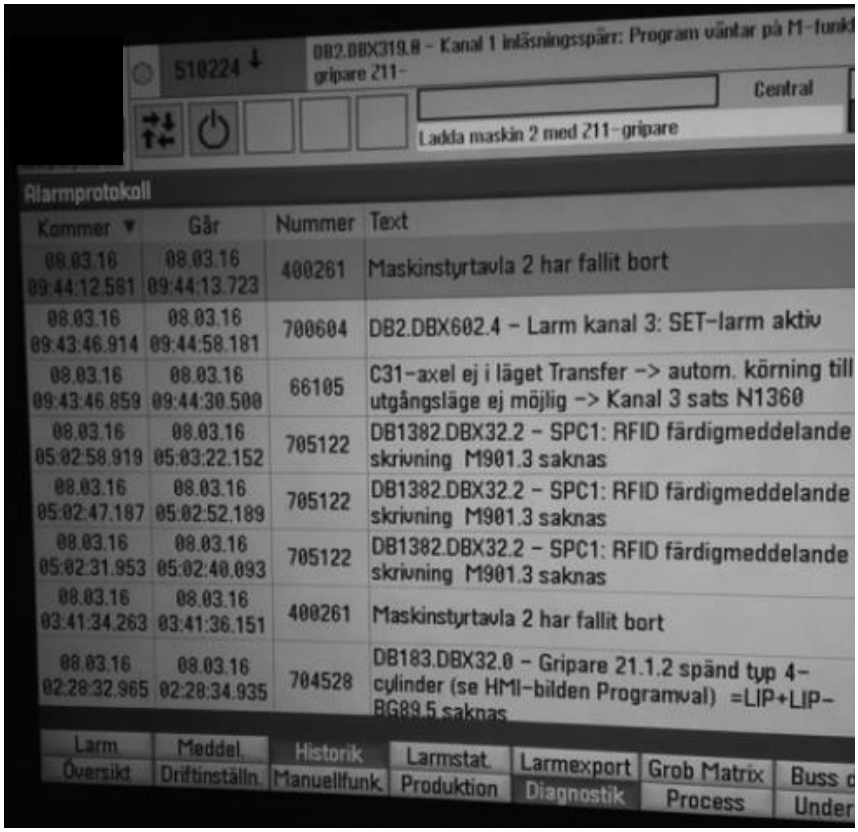
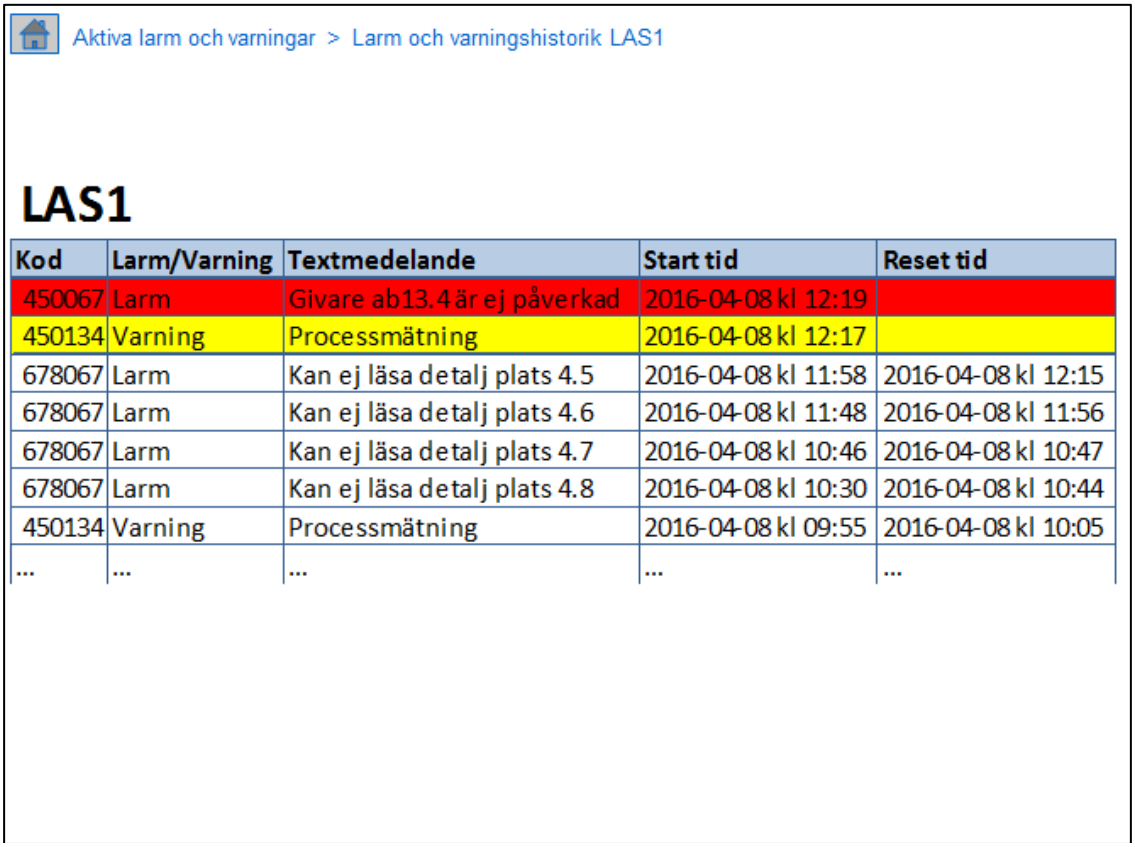


Figure 60: An example of alarm and warning messages from Volvo Cars. The machine name is censured.

Alarm and warning log

Figure 61 is an example of a machine's alarm and warnings log which the user could get as an output from the search function if the user wanted to know the latest warnings and alarms of laser machine one. A quicker way to reach this screen display is by clicking on the text message for the laser machine row in the active alarms and warnings screen display.



Kod	Larm/Varning	Textmedelande	Start tid	Reset tid
450067	Larm	Givare ab13.4 är ej påverkad	2016-04-08 kl 12:19	
450134	Varning	Processmätning	2016-04-08 kl 12:17	
678067	Larm	Kan ej läsa detalj plats 4.5	2016-04-08 kl 11:58	2016-04-08 kl 12:15
678067	Larm	Kan ej läsa detalj plats 4.6	2016-04-08 kl 11:48	2016-04-08 kl 11:56
678067	Larm	Kan ej läsa detalj plats 4.7	2016-04-08 kl 10:46	2016-04-08 kl 10:47
678067	Larm	Kan ej läsa detalj plats 4.8	2016-04-08 kl 10:30	2016-04-08 kl 10:44
450134	Varning	Processmätning	2016-04-08 kl 09:55	2016-04-08 kl 10:05
...	...	...	...	...

Figure 61: The Laser 1 machine alarm and warnings log.

Search and analyse alarms and warnings

If the search alarm and warning history button is pressed the user is able to use a search function of analysing warnings and alarms by these parameters:

- Cell
- Machine
- Conveyor belt
- Kitting stations
- Buffer
- Time period
- A specific warning or alarm text
- Time interval from message to the alarm or warning being reset
- Number of alarms
- Number of warning
- Show only alarms
- Show only warnings

How to solve alarm and warning
If the user presses the "how to" solve alarms and warnings button on the alarm and warning screen display two buttons are showed. One button for creating a new "how to" instruction of how the operators have solved an alarm or warning in the past and one for searching for already written instructions.

If the user presses the "create a new instruction" button, Figure 62, shows what the user should input. The product description is needed since different product types can have different solutions. The varying size of the bearing can for example lead to the need for different kind of actions. The user reaches text message by pressing the arrow and choosing from the machine log shown in Figure 63.

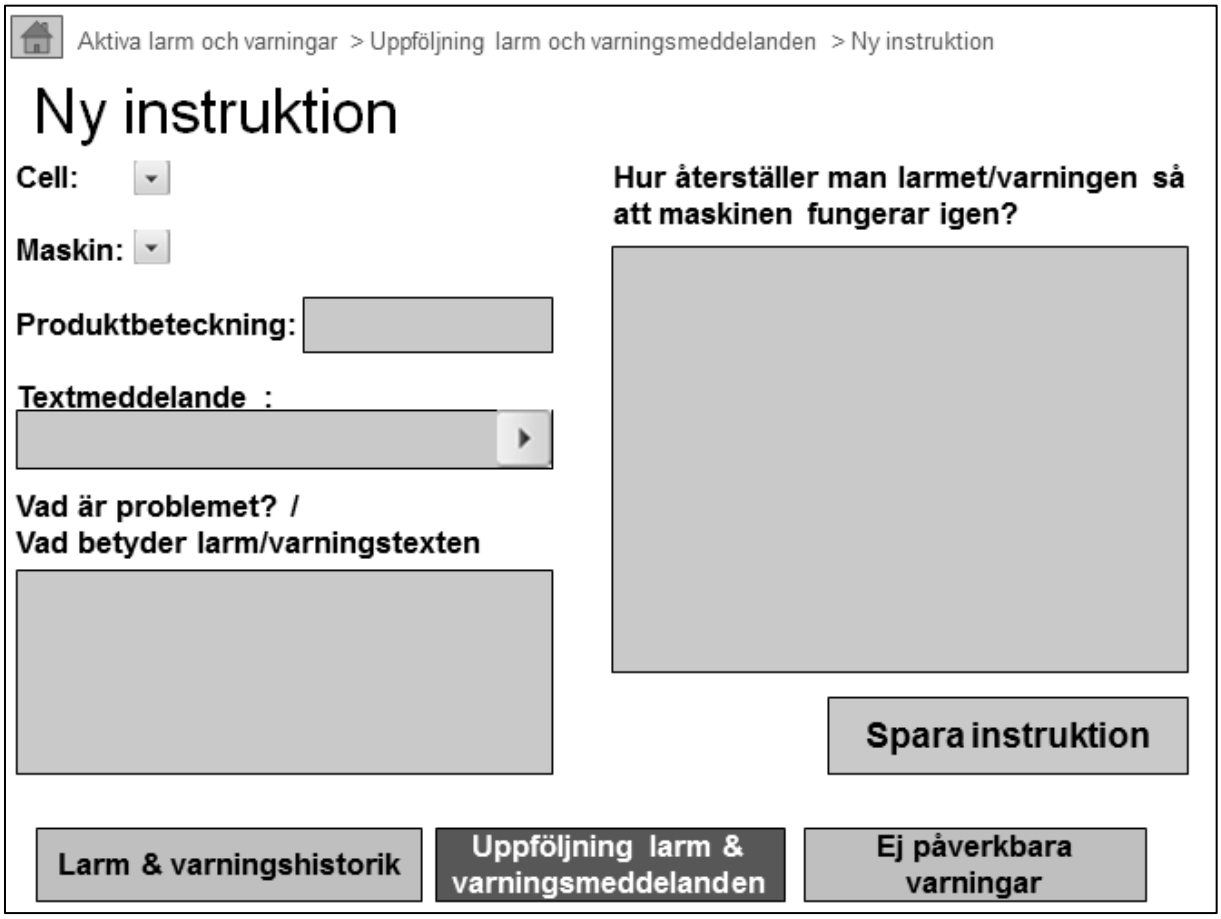


Figure 62: Creating a new instruction for how alarm and warning are reset

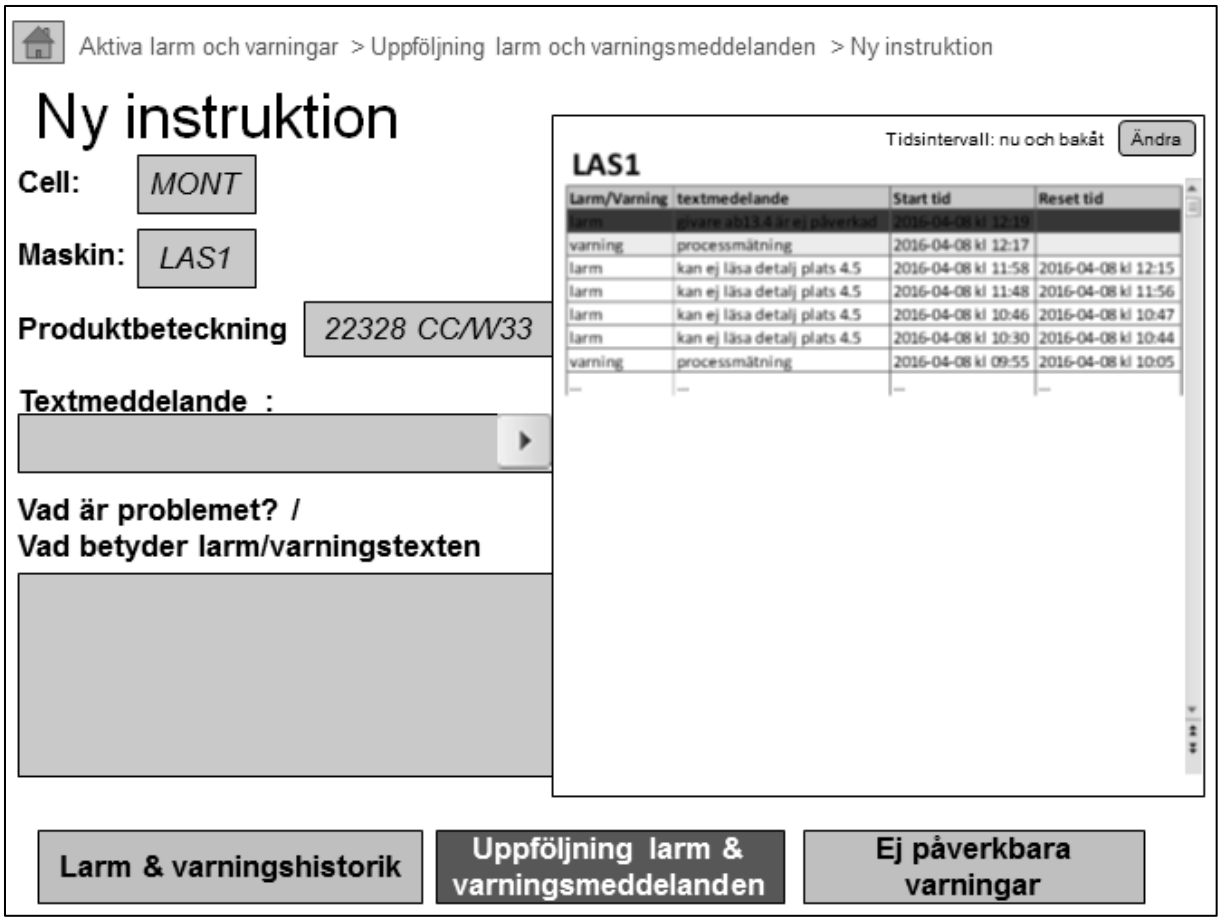


Figure 63: How it can look when you chose the text message of a machine.

If the user chose to search for an instruction for how to solve an alarm or warning the user inputs in the information showed in Figure 64.

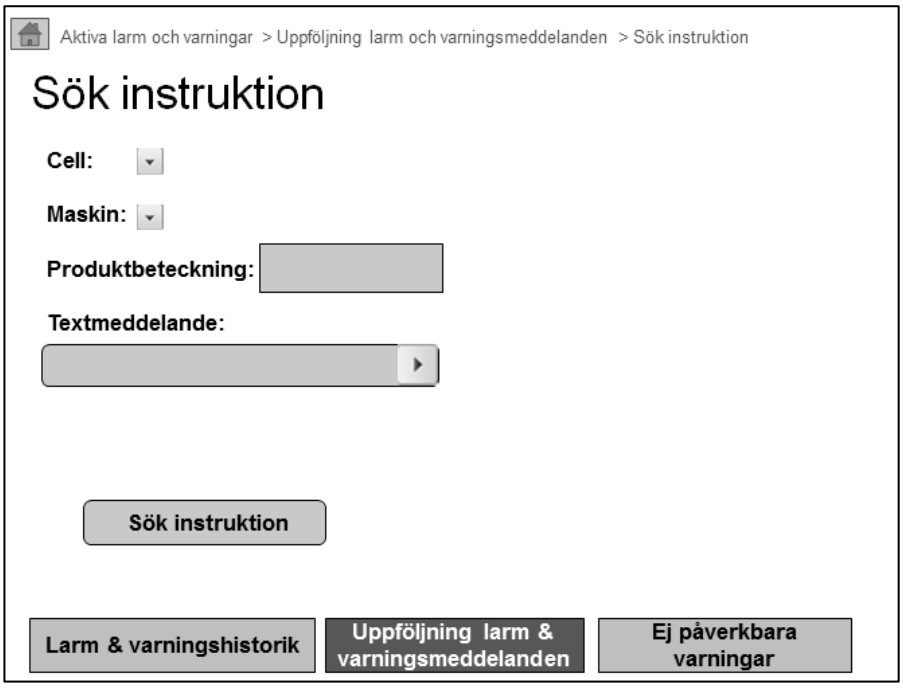


Figure 64: The search function for finding a how to guide to reset a warning or alarm.

Hide warnings
There should be a function for hiding warnings from the active alarm and warning screen display that the user cannot affect besides pressing the reset button at the machine. No false warnings should be visible, a warning should mean the user can react and do something to reset the machine like change a setting or clean the machine. The inspiration for this function came from the seminar at In Use where a participant worked full time with these kinds of functions at Volvo trucks in Gothenburg.

If the user presses the "hiding unresponsive warning" button on the active alarm and warning display two buttons are shown. One button for hiding a warning and one button for seeing the warnings that are already hidden.

If the user's want to hide a warning the information showed in Figure 65 should be entered.

Figure 65: The data to put in to hide a warning.

Figure 66 shows the table for warnings that already have been hidden.

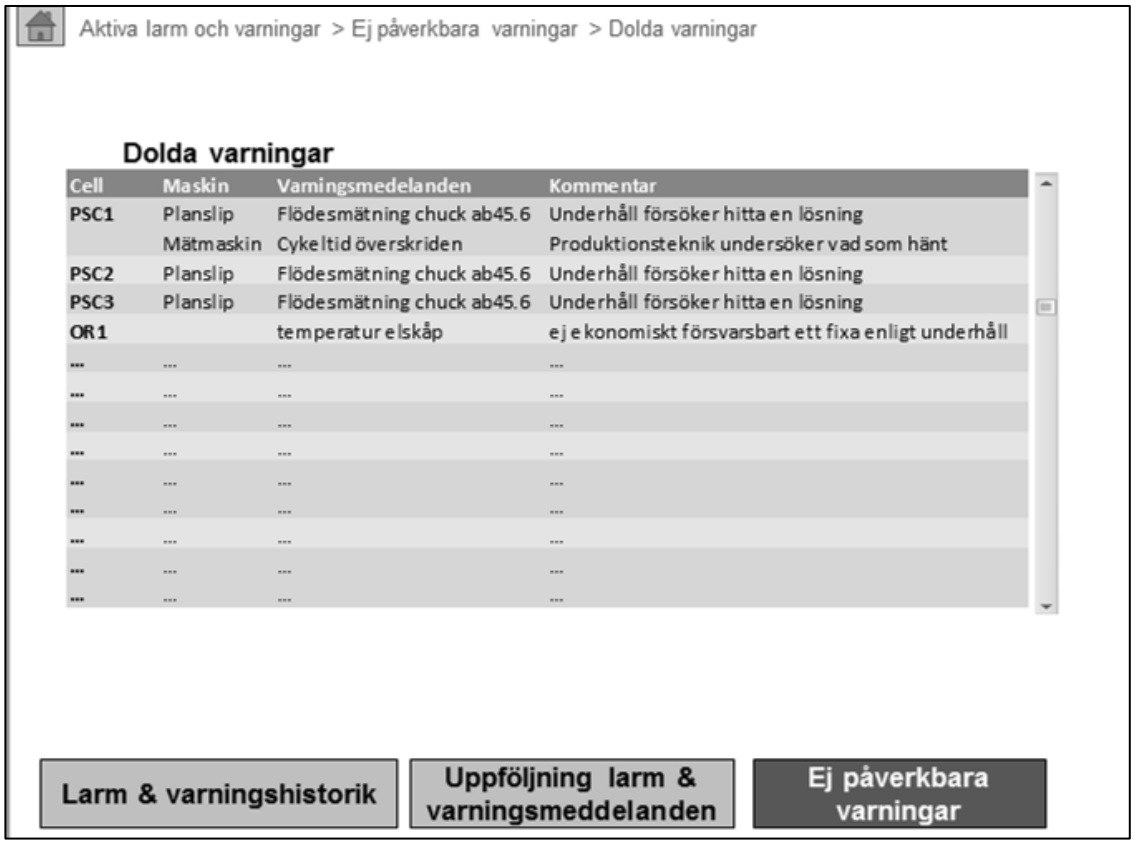


Figure 66: The hidden warnings display

Appendix M. The prioritizing screen display

In this appendix the prioritizing box, the bar chart and the tables of the main prioritizing display are further described.

Prioritize cell information box:

The operational manager has to be signed in to the information system on the computer or put in a password to be able to write in which cell should be prioritized. The information will only be shown a certain time. The time limitation should secure that outdated information is not followed during a too long time. How long time the data will be shown have to be decided between the operational manager and the operators.

The bar chart:

- The blue bar shows how many hours each cell is behind or ahead plan. The reason for having time as the variable is that the different products have a high variation of cycle times in the machines.
- The red bar is for how many hours they have materials for each cell. "Having" material for each cell is the sum of the material that is ready, waiting in the buffer, on an AGV to the cell or waiting to be processed in the cell. The reason why the material supply is important is because it is often no point in prioritizing a cell if you will have a material shortage soon.
- The last bar, the green one, indicates if the products being made in the cell at the moment are for a customer order or a stock order. A customer order means that the bearings will be delivered directly to the customer, a customer has ordered it. A stock order means that a SKF stock has ordered the bearing since they are running low of that type. If the operator has a choice the order that goes directly to the customer will be prioritized. The reason for this is because with a customer order a customer is waiting for the bearing, and that does not have to be the case with a stock order.

The tables:

- In the table "process mätning", the process measurement, the measurements conducted with certain frequencies are shown. In the table you can see a list of cells connected to:
    - How long time it is left until a measurement will stop the machine
    - How many products are left to be produced until the machine will be stopped.

    The reason for having both time and the number of product as units is because the number of products is sure to be correct in comparison to the time. But the number of products does not tell the operators how long time it could take because of the high difference in cycle time between products. Therefore both units are useful for the operator.

    The machine has a counter, which keeps track of how many products have been made since the last measurement. When the counter reaches the amount decided by the frequency a product is put in the place for measurement. After a product is placed in the place for measurement a decided number of products can pass in the flow before the measurement has to be approved. If the measurement has not been approved when these products have passed, the machine is stopped.

- The second table shows a list of cells connected to
    - How long time is left until next setup
    - How many products are left to produce until the next setup should start
    - The setup time

    The setup time is important since some setups consist of just pressing a button while others require rebuilding of the machine.

- The third table shows a list of cells connected to when a tool change is calculated by
    - How long time there is left until the tool is calculated to be changed
    - How many products are left to produce until the tool is calculated to be changed

- The fourth table is showing a list of cells connected to material that the operator needs to refill.
    - How long time is left until the material will the empty
    - How many products are left to produce until the material will run out

    The process development team has design the material level control system with only two sensors. One sensor indicates a warning level that the material will soon run out. The other sensor will give an alarm when the material is empty. Before the warning level is reached the system only knows that the material level is above the warning level. This means that the table for material will only show the time and products remaining after the machine has given a warning for material supply.

    In comparison to the other three tables the operators cannot use this table before a long break to know whether the material will run out, whether it is not already warning for material.

All the tables show the activity that will happen first at the top of the table and the activity that will happen latest at the bottom of the table. This will simplify for the user when he/she compares the time and number of products between different warnings to know which warning should be taken care of first. Two examples are:

- The operator has a warning for low material in cell MGC1 and a warning an impending process measurement in cell PSC1. The tables show that the process measurement will stop the machine in 5 minutes while the material supply is calculated to be in 10 minutes. The measurement is therefore done before the material refill and no machine has to stop.
- The tables could also be used to plan for a longer time period, for example before a break. The user can then see what will happen during the break and tries to do the activities before the break or change the time of his/her break to better fit the production.

Appendix N. Mobile information

This appendix is written in Swedish because the work is not connected to the goal of this thesis but it is included since the information is interesting for SKF.

Skärmar från kontrollrummet som operatörer har uttryckt att de vill ha på mobilen
Maskinparkens översikt

- Samma skärm förutom att vissa länkar som i kontrollrummet går till djupare information har bedömts ge för lite information jämfört med ansträngningen det är att designa om bilderna så att de ska kunna ses på en mobil. Operatören måste i vilket fall ta sig till maskinen som larmar eller varnar för att återställa larmet/varningen och då kan de lika gärna kolla på den djupgående informationen på maskinens skärm istället för mobilen. Informationen från länkarna som operatörerna ansåg vara värdefulla att ha på mobilen var:
    - Kvalitetsskärmen
        - Rapportera kassationer.
        - Söka lösning på hur kvalitets problem har lösts tidigare.
        - Kunna skriva in instruktioner för hur de löst ett kvalitetsproblem. Dock anser undersökaren att detta endast ska kunna ske i kontrollrummet med inloggning av den kvalitetsansvarige operatören så att informationen verkligen är korrekt.
    - Underhållsskärmen
        - AUO skärmen.
        - FU lista av vad som ska göras under ett FU stopp, men inte kunna lägga in jobb, det får göras i kontrollrummet.
        - Skärmen över operatörernas dagliga jobb.
    - Administrationsskärmen
        - Vad man ska göra vid en nödsituation.
        - Kontaktlista
        - Rotations- och utbildningsplan.
        - Lösenord.
    - Förbättringsskärmen
        - A3 skärmen.
        - Skriva i aktivitetslistan ifall de har ändrat någon punkt på en robot eller flyttat en bana.
- Kalenderskärmen
    - Ska vara samma med alla funktioner som skärmen har i kontrollrummet.
- Aktiva larm och varningar
    - Samma huvudskärm som i kontrollrummet.
    - Kunna söka efter larm- och varningshistorik.
    - Kunna söka instruktioner på hur larm och varningar återställts tidigare men inte kunna skiva in instruktioner.
- Sekvenslista och materiallista
    - Samma huvudskärm som i kontrollrummet.
    - Samma sekvenslista och materiallista som i kontrollrummet.
    - Kunna följa en produkt genom flödet.
    - Kunna se inventarier men inte kunna beställa material som operatörerna ansvarar för.
- Prioriteringsskärm
    - Samma information som i kontrollrummet.

- Kommunikationsskärmen
    - Samma men med pop-up funktion för ny tidsbegränsad information, chatt, osignerade informationsstyrningar samt dagboks information.

Operatörerna ska skriva in följande information i mobilen:

- signera aktiviteter under FU-stopp
- signera dagliga operatörsjobb
- skriva in skrot
- skriva i A3 för förbättringar
- uppdrag underhåll
- uppdrag produktionsteknik
- möte som stoppar produktion
- oplanerad omställning som stoppar produktionen
- oplanerat verktygsbyte som stoppar produktionen
- oplanerad materialbrist som stoppar produktionen
- övrig anledning som stoppar produktionen
- signera att man tar larmet eller varningen
- signera att man har läst informationsstyrningar
- skriva i chatten
- skriva in tidsbegränsad information
- skriva i dagboken
- ställa in vilken zon de vill ha information ifrån
- ställa in vibration och ljudnivå på mobilen
- logga in på mobilen så att man kan se vem användaren på maskinparksbilden är och så att operatören slipper skriva sitt namn på alla signeringar utan istället endast behöver kryssa i en box
- följa produkt genom flödet

Information som bara kan skrivas in på mobilen och inte kontrollrummet är följande:

- till VP
    - bytt verktyg
    - bytt planslipsskiva (truckförare)
    - problem med ett verktyg
    - fylla i ett dokument när operatörer hämtat reservdelar från verktygsteknikernas förråd
- förstabits kontroll och frekvensmätning ska rapporterads med hjälp av att läsa en QR-kod innan produkten kan plockas ut ur sin låda.

    Data som sparas automatiskt är:
    - vem mäter
    - datum
    - klockslag
    - produktens id nummer
    - beteckning produkt
    - cell
    - mätvärden mätmaskin

    Data som operatören själv behöver skriva in vid förstabits mätningar och frekvensmätningar är:
    - mätvärden från manuell mätning
    - visuella kontroller i form av att kryssa i OK/NOK
    - möjlighet att lämna en kommentar

- omställning
    - klickar in startar omställning
    - klar med manuellomställning
    - omställning godkänd