Project Deliverable 1.2

First version of requirements of workers and organisations

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About this document

Executive Summary

This document is entitled "First version of requirements of workers and organisations" and represents Deliverable 1.2 of the H2020 project "FACTS4WORKERS - Worker-Centric Workplaces in Smart Factories" (FoF 2014/636778).

Building on a deep understanding of industrial workers' individual practices, embedded in the contexts of six industrial partners (elaborated on in Deliverable 1.1), we present the first suggestions (in the form of requirements) for sociotechnical solutions that are intended to support their daily work and encourage smarter work.

We structure the identified requirements as:

1. **23 problem scenarios** that describe how the actors currently perform their work in a described context and highlight especially critical issues in their daily activities that yield improvement potential, next to …
2. **23 activity scenarios** that pick the identified issues and constitute suggestions of how the workers could be supported with sociotechnical solutions, incorporating …
3. screen illustrations of **8 prototypes**.

The artefacts mentioned above are embedded in 8 contexts-of-use at 6 industrial partners (four industrial partners with one context-of-use each and two industrial partners with two contexts-of-use each).

This document also provides a detailed illustration of our methodical approach, which primarily describes the aforementioned types of boundary objects as the best possible way to avoid inconsistencies in the requirements and thus to provide a high level of transparency to all the readers.

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BPMN .... Business Process Modelling and Notation

CNC .... Computerized Numerical Control

EMO .... EMO Orodjarna d.o.o

HID .... Hidria TC d.o.o

HIR .... Hidria Rotomatika

HVAC .... Heating, Ventilation and Air-Conditioning

ICT .... Information communication technology

IP .... Industrial Partner

MES .... Manufacturing Execution System

OEE .... Overall Equipment Efficiency

OEM .... Original Equipment Manufacturer

QA .... Quality Assurance

Tab. .... Table

SCA .... Schaeffler AG

SBD .... Scenario-based Development

SME .... small and medium enterprise

THO .... Thermolympic S.L.

TKSE .... ThyssenKrupp Steel Europe AG

1 Introduction

This document is the result of the HORIZON 2020[1] project FACTS4WORKERS. In FACTS4WORKERS, we explore how individuals work and learn, how they interact with new technologies and how we can create attractive and challenging work environments that will increase employee satisfaction and motivation.[2]

As part of our mission to implement successful sociotechnical solutions for production processes, we recently published Deliverable 1.1 (D 1.1: Captured and structured practices of workers and contexts of organisations), in which we report on the first steps of working package 1 (WP 1): *The identification of workers' practices and the contexts of organisations at our six industrial partners*. The focus in D 1.1 is on the individual practices that emerge when workers carry out their daily routines, as opposed to previously top-down specified processes to optimise business. We argued that a deep understanding of workers' individual practices will help to define the requirements for an ICT solution that supports smarter work.

Figure 1: The steps to define the requirements

[1] See http://ec.europa.eu/programmes/horizon2020/.

[2] For a more detailed overview of the project, see http://www.facts4workers.eu.

The present deliverable, D 1.2, offers the first version of requirements of workers and organisations, and in putting it together we have adhered to our envisaged approach of

1. analysing, structuring and communicating the specific requirements in the eight identified contexts-of-use at six industrial partners (IPs),
2. using a collection of artefacts as boundary objects to facilitate communication between the partners (Levina and Vaast 2005) and to elicit and capture the required information,
3. following an iterative and agile development approach to processes by building on the assumption that the "wicked problems" (Pries-Heje and Baskerville 2008) in our project cannot be solved in a linear fashion,
4. and applying the Design Research's process model (Hevner et al. 2004; Peffers et al. 2007) as our guiding principle.

As mentioned earlier, this deliverable (D 1.2) is an important step towards clarifying and illustrating our vision of a "smart factory" in which smart workers play a central role in the production process and smart ICT infrastructure support them in the best possible way. We do so by recounting the individual stories of smart workers (as the focus of attention) who are empowered by a smart ICT infrastructure that continuously improves knowledge sharing and effective knowledge acquirement in the workplace. Storytelling is a well-known knowledge transfer strategy in intra-organisational settings and is also an established practice in software projects (Wende 2014).

To apply the storytelling approach in this deliverable, we opted to use the form of context-of-use-comics, which we have adapted for this project, to represent the identified personas, problem and activity scenarios. Our approach not only allows an overview of the requirements but also shows how the smart infrastructure will contribute to reducing stress levels, cognitive overload and monotonous, error-prone work for production workers (cf. D1.1.).

In total we illustrate 23 problem scenarios that create the existing challenges in the industrial workers' daily work routines and 23 activity scenarios that show how a smart ICT infrastructure can contribute to better decision-making ability, increased participation and more autonomy. Moreover, we introduce the performing actors in form of 23 personas.

As part of the presented requirements per contexts-of-use, we will also provide insights into the development of 8 prototypes.

In short, the content of this document comprises the following:

Based on a brief recapitulation of our general approach in WP 1, which was explained in detail in D 1.1, we expand the list of artefacts we use as boundary objects in the project to communicate the requirements (Chapter 2) and explain the artefacts that are highlighted in the deliverable.

Subsequently, we present a more detailed picture of the problem scenarios, activity scenarios, personas and prototypes embedded in eight identified contexts of use (Chapter 3).

An analysis carried out across the contexts of use allows the reader to compare them with each other and understand their commonalities and differences (Chapter 4).

Please bear in mind that this deliverable is only the first draft of the requirements for the envisaged ICT infrastructure to support smarter work. By the time this document was finalised, we had already developed some of the presented prototypes even further, which will soon undergo further evaluations at the IPs. Thus, we will continuously sharpen our picture of the ICT infrastructure that supports smarter work.

Please note that D 1.1 contained an impact analysis of the planned interventions. Since we have followed the proposed approach, we anticipate the same impacts.

2 Method and Solution Design

The goal of work package one (WP 1) is to establish a shared understanding of the context-of-use and its embedded work practices across all the partners and the stakeholders that are concerned as well as to identify requirements for an ICT infrastructure that supports smarter work.

In deliverable (D 1.1), we already pointed out that the requirements for sociotechnical solutions intended to support industrial workers' daily work cannot be collected in a decoupled form (like a table) but should always be kept in the context-of-use of the industrial partners (IPs). We are therefore collecting specific requirements for each context-of-use.

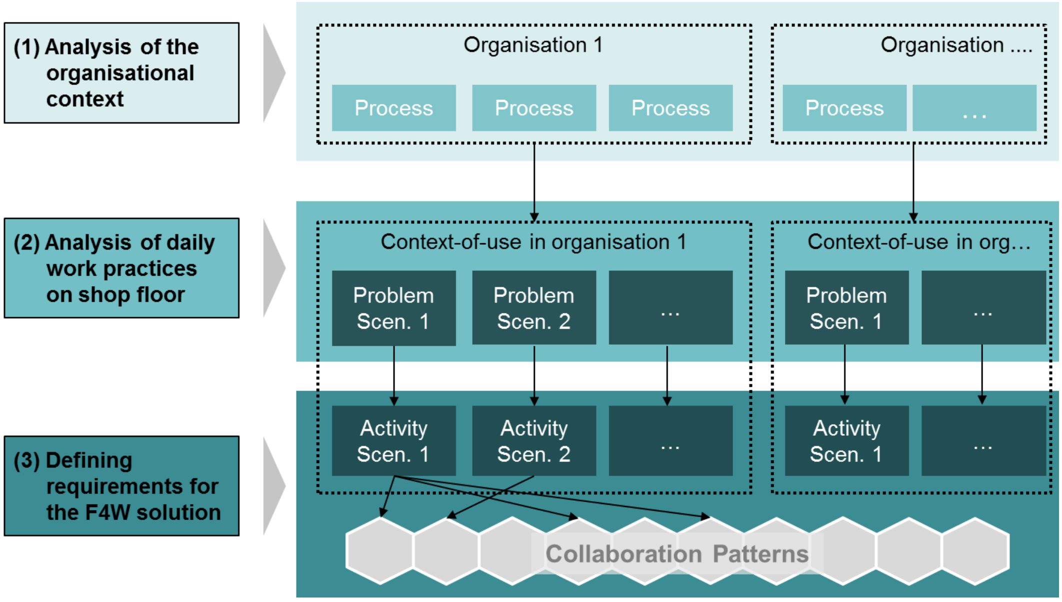

Figure 2: F4W layer model

Having analysed the organisational context (1) and the daily work practices (2), we are now in a position to formulate the requirements (3). We proceed by developing solution approaches for the identified problems (problem scenarios) in the form of activity scenarios. Both types of scenarios will be illustrated with texts and figures in that deliverable. In both types of scenarios, so-called "personas" are the main actors. The personas describe fictional worker role models and help us to understand workers' thinking, goals and reasons for striving to achieve them.

This approach will be explained further in the following sections.

2.1 From "as-is" to "should-be"

D 1.1 features a detailed description of our general approach as human-centric, iterative and agile, and it has been inspired by well-known and widely accepted frameworks and models from the domains of Design Research and Scenario-based Development.[3]

Scenarios as boundary objects

Instead of describing a future system only in terms of its pragmatic dimensions (i.e. functions), scenario-based development (SBD) focuses on the perspectives regarding how the system "**is**" and how it "**should be**" used by the relevant stakeholders (Rosson and Carroll 2002). Scenarios describe how the relevant stakeholders act in the current situation (problem scenarios) and how the envisioned system can be used in the specific context to improve the situation (activity scenarios). In written text form, the scenarios enabled us to convey the vision of the solution at the very early stages of the project and validate it with the IPs. Once evaluated, the scenarios formed the bases for the upcoming design of the first mock-ups (i.e. clickable screen mocks). This procedure of alternating between building and evaluating cycles was repeated in the subsequent steps. Consequently, scenarios play an important role in the context of this deliverable. D 1.1 already illustrated their role with an overview of the project artefacts and their relations[4] (cf. the figure below).

Besides illustrating the practices and requirements in a way that acknowledges that they always have to be seen in the context of individual workers' practices and the organisational context (i.e. scenarios, personas), we use prototypes on different maturity levels. The beauty of prototypes is that these artefacts, as opposed to lists of requirements, cannot be inconsistent among themselves. Of course, it is possible for a prototype not to incorporate all the information, or to incorporate information other than the scenarios, and this is why we are continuously validating the prototypes.

In a nutshell, our approach to describe a rich context (in the scenarios) and to have several different types of boundary objects is the best way to avoid inconsistencies, as these rich descriptions would very quickly point to any inconsistency. By the time of writing this deliverable, the illustrated artefacts existed for each of the eight identified industrial partners' contexts -of-use.

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[3] As mentioned in D 1.1, FACTS4WORKERS includes the collaboration of more than 60 individuals from 6 industrial and 9 academic partners as well as experts from various domains, like software engineering, production management, knowledge management and engineering. To consider these diverse backgrounds and to allow the highest possible degree of collaboration and interaction between the partners, we did not specify the detailed methodological design up front but developed it as we went along. The continual feedback from the partners regarding the information (formats) they would need allowed us to ground the project progress in the knowledge gained with each step.

[4] We call this overview "artefact ontology" and use the term artefact whenever we refer to any kind of digital and non-digital products that we create to support our development process.

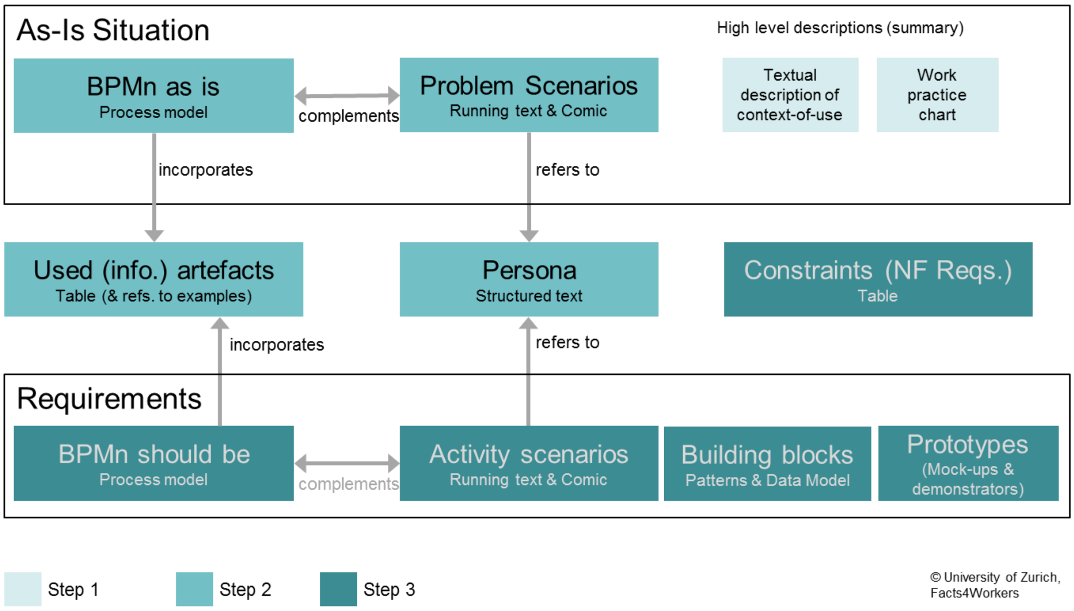

Figure 3: F4W artefact ontology

2.2 The artefacts in this deliverable in more detail

Persona

Personas are user models that represent a fictional, aggregate character based on the information gathered during the contextual inquiry. These characters' thinking, goals and reasons for striving to achieve them were mapped to the persona (Cooper, Reimann, and Cronin 2007).

Problem scenario

A problem scenario shows how the actors perform their work in a particular context and the activities in which they are engaged (Rosson and Carroll 2002). Not only is the factual knowledge (such as the decisions that are made) described, but the individual's intentions and considerations are also shown.

Activity scenario

Whereas the problem scenario provides a starting point, the general aim is to maintain or even enhance positive consequences for the actors while minimising or eliminating the negative ones (Carroll & Rosson, 1992). Thus, we transformed the problem scenarios into activity scenarios through a combined process of brainstorming about design ideas, reasoning from previous claims and working through the general concerns of activity design. Activity scenarios provide solution ideas about how existing technology might support these activities and help to explore shared work. "Even if a scenario focuses on the goals and experiences of one individual, it contains information about the setting and about the actor's motivations and responsibilities [Ultimately, they] illustrate the functionality proposed for a system in the context of specific uses" (Carroll & Rosson, 1992).

During the first few months, the scenarios were communicated in the project as text documents and collaboration diagrams (in BPMN - Business Process Model and notation) to capture the coarse processes in order to embed the scenarios in the organisational context. Both representations were used to disseminate the knowledge within the project consortium. In this deliverable (D 1.2), we further supplement the textual descriptions with comics to raise the level of detail and to communicate background and context information about these workplaces.

Prototypes

As a refinement and further detailing of the third phase, we use mock-ups and demonstrators. Mock-ups are smart means to present a draft software look and feel to the prospective users (workers) in order to receive quick feedback about the requirements. Demonstrators go one step further by showing a proof of concept and taking test data into account, which provides feedback both in terms of requirements verification and in terms of the feasibility of a software or implementation concept with dummy data. This approach enables fast iteration loops to adjust and refine the solution proposal[5] and is shown in the following table.

	Objective	Functionality	Hardware
Mock-up	Proof of **feasibility** of workflow and handling	none - functions are faked, e.g. ppt, Balsamiq or HTML-Click mock-ups etc.	Standard hardware, e.g. standard tablet (OS not critical) or non-digital device (paper-based)
Demonstrator	Proof of **concept** (of technology building blocks involved)	Key functions, such as input/output functions, are working	Designated hardware type, e.g. tablet or SmartGlass, but not necessarily final hardware or OS
Validator	Testing user acceptance, proof of **value**	Some functionality of context-of-use is covered; building blocks are working	Designated hardware
Pilot	Onsite evaluations of project targets, proof of **use**	Context-of-use functionality is fully covered; measurement of productivity and attractiveness possible	Designated (off-the-shelf) hardware

Table 1: Prototypes on different maturity levels

[5] The next maturity step is proof of value with a validator. This step requires working building blocks and designated hardware as well as test data for verification. Requirements have to be completely defined in advance. The final step, namely the onsite pilot implementation, covers full functionality.

2.3 Comics

We opted to use comics to represent each context-of-use at a high level, in order for the information to be comprehensible to all project partners and interested persons beyond the project. The comics are not intended to replace other boundary objects, such as the collaboration diagrams introduced in D 1.1, but rather as companion objects.

The comics are part of the descriptive stories representing both activity and problem scenarios. Storytelling is a generally well-known knowledge-transfer strategy in intra-organisational settings and has recently been adopted to offshore outsourcing IT projects (Wende 2014). The collaboration demands in F4W are comparable to outsourcing settings, as our project team also comprises partners from different geographical locations and from different domains and backgrounds. By using a storytelling approach (i.e. scenario text and comics), we are able to transmit context-enriched information, build a bridge between implicit and explicit knowledge components (Wende 2014) and describe the interaction with the intended software system.

Wende et al. (2014) have found that channel capacity seems to be an important factor and that video-based methods perform better than purely textual descriptions of stories. We have chosen an intermittent way of using comics to transport that background and implicit knowledge. We evaluated the comics with the IPs to verify that they can identify themselves with the situation described. Short textual stories in the form of scenarios from the employees' perspectives are intended to facilitate this knowledge distribution process throughout the project, while they offer details even to those project partners that have not been on site at the IPs.

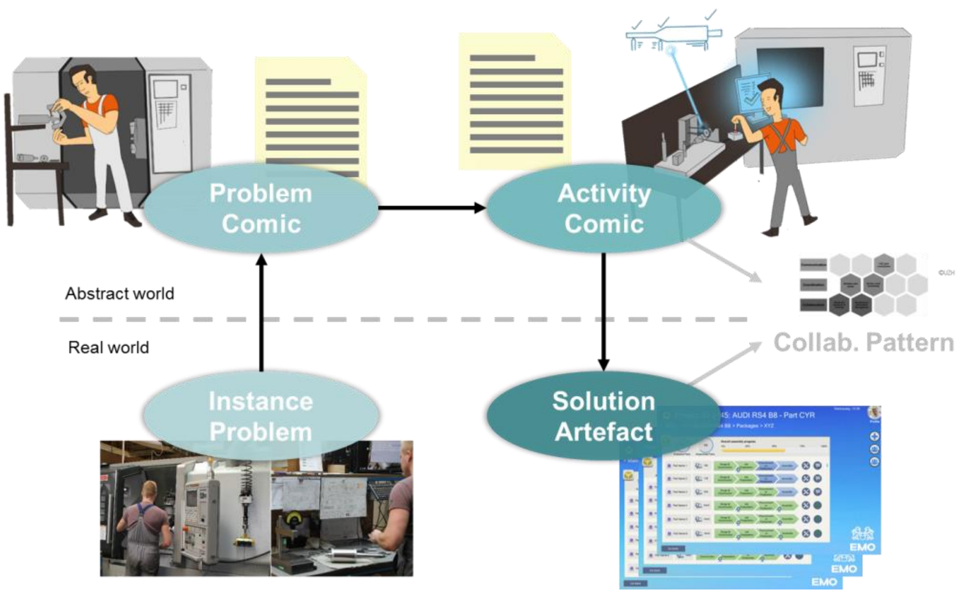

Figure 4: The role of comics in this deliverable

2.4 Feedback and validation

All the artefacts that we present here have been validated with the industrial partners (IPs). We received constant feedback from the IPs via regular phone calls and in the form of mark-ups and comments in the text documents. Moreover, and even more importantly, we presented four of the prototypes in face-to-face meetings with workers at the IPs' sites. We received a wide array of positive and constructive feedback that enabled us to improve the prototypes constantly, and we will continue to do so in the future.

The feedback that we have received from the IPs so far shows that we have not only built a solid trust basis but also found ways to communicate on a level that enables effective feedback and progress.

A word on privacy

FACTS4WORKERS sets very high standards with respect to guaranteeing privacy and all related personal rights of the individuals concerned.

Before we start data collection, all responsible stakeholders (like the working council) are involved, and we keep them informed throughout.

Whenever we introduced the project to individuals and discussed the project details, we informed them that their participation in any data collection was part of research activities carried out within the context of the EU-funded project "Facts4Workers - Worker-Centric Workplaces in Smart Factories". We further informed them that their data would be stored and used anonymously for the project and that the raw data would remain confidential and would not be disclosed to third parties, including their factory. In addition, we informed them that reports and publications based on these data would not contain any personal data. Most importantly, we made very clear that their participation was voluntary, and they could refuse or withdraw consent at any time.

At the end of this briefing, every individual involved in data collection (whether for interviews, photos or workshops) signed an "informed consent" document.

3 Requirements in the Contexts-of-Use at the Industrial Partners

We now describe the workers' and organisations' requirements separately for each industrial partner's context-of-use. As explained before, our understanding of workers' individual practices helped to build the problem scenarios that would form the basis for activity scenarios and prototypes.

3.1 EMO Orodjarna

EMO Orodjarna d.o.o. (EMO) produces (progressive and transfer) tools for metal stamping. The company's main customers are the automotive and aviation industries and their suppliers to which EMO delivers tools for large presses. Most of the tools' components are manufactured in-house. These components are later assembled into the final product (progressive and transfer tools) that is delivered to the customer. The company aims for maximum production quality and works in close cooperation with its customers from the stage of the simulation and design activities to the actual manufacturing process and, finally, to the quality control and shipping phases.

3.1.1 EMO1: Personas

The main characters in the following scenarios are an assembly worker, a machinist, a group leader and the project manager. The assembly workers carry out the complete assembly process of the stamping tools produced, while the machine operators work on the various traditional, NC and CNC machines to produce parts from stock material. Assembly workers work in small teams and are responsible for the assembly process and facilitate coordination of the work. The project manager is responsible for the entire end-to-end production process from engineering and design activities to the procurement, manufacturing and assembly of the parts produced.

Ivan is a 32-year-old toolmaker who likes his job but is also frustrated that a lot of things remain unchanged. He no longer even shares his ideas for improvement, because he has no faith that any change would result from them. In his job, he likes the challenges that come up during the assembly process. Whenever possible, he always tackles the complex parts first. He likes the dynamic nature of his job: He hardly ever has to build the same tool again. On a typical work day, he spends most of his time assembling tools. However, numerous support tasks like searching for missing parts or correcting defective parts require a lot of time.

Anton works as a machinist at EMO, where he makes various parts for the tools the company produces. He works in a three-shift system and operates a CNC machining centre. One of his main activities is setting up the machine and the tools required to perform the machining operations. He has to take special care whenever he downloads new CNC programmes from the servers and ensure that the programme runs error-free and carries out all the required steps. Sometimes he has to alter the programme to facilitate smooth production. During the day he does the setup procedures several times and handles tool and work piece changes. This can be a demanding job if he works alone. He is also responsible for the condition of his workplace, which means he has to ensure that the machine is in good condition and sufficiently clean. When working on a shift where the production manager is not around, he sometimes has to make decisions on his own (like the adaption of a CNC programme or a tool change) based solely on his experience and knowledge.

Andrej is one of the project managers. He is responsible for keeping track of the schedule and interacting with the company's clients to plan all relevant production steps, client updates and client audits. He likes being in control, although he also wishes he had better tools to do the daily planning activities. Andrej is a very communicative person who likes to keep in contact with the people who work with him.

Ivan	Anton	Andrej
Assembly worker	Machine operator	Project manager

Figure 5: Relevant personas in this context-of-use

3.1.2 EMO1: Problem Scenario 1: "Missing awareness during assembly"

When Ivan comes to work and wants to start the assembly, he first checks that all the parts he needs to complete the task are available. Some (but not all) of parts are stacked beneath the machined cast iron frame, waiting to be assembled. He walks around the shop to find the rest of the parts he needs, but some of them cannot be found. Where are they? Who knows something about them? On his way across the shop floor, Ivan collects the relevant information from various sources and talks to his colleagues who are busy assembling other tools and to the machinists that machine the parts (Figure 6, top-left). One of the parts he needs seems to be lost. No one knows anything about it, and he has to bring in others, including Andrej, the project manager, if necessary. Ivan is now prevented from working on his tools and moves on to another tool in production.

With the new tool, this information gathering task starts all over again! With the help of other co-workers, he has to quickly obtain an overview of the current status of the tool and its related parts that have to be assembled. Everyone involved has a bad feeling about the situation, and Ivan inevitably takes over responsibility for other employees' work. If mistakes are made during the assembly process, it is difficult to identify whose fault it was afterwards, as the information about who has assembled which parts is only in the assembly workers' heads.

Figure 6: EMO - Problem Scenario 1: Where is the information?

3.1.3 EMO1: Activity Scenario 1: "Mutual awareness re-established"

EMO Orodjarna has been successful in its introduction of the novel Facts4Workers solution, and Ivan has just obtained his personal tablet computer. When Ivan arrives at the shop, everything looks the same as before: The tools and parts are waiting to be assembled, and some of the parts are already stacked beside the machined cast iron frame. Ivan powers up his tablet and logs in. The first thing he does is to check the status of the build process, especially which parts are still waiting to be assembled. He uses the tool to find the parts grouped into logical compartments according to the sequence in which they can be assembled. At a glance, Ivan sees the packages that are ready to be assembled and those that are still waiting for parts (figure 7, left). Now Ivan can start to assemble the listed parts (figure 8). When Ivan has finished, he documents his progress in the system (figure 10). He cannot work on the tool any longer, as the next important part is still in production. The system tells him who is working on the part and when to expect the completion of the machining processes. As it takes too long to wait for the arrival of the parts, Ivan decides to switch to another tool. Ivan uses his tablet to inform the group leader about the problem and of the need to switch to another tool (figure 8, right). This takes only a matter of minutes, even though Ivan does not know where his group leader is.

Arriving at the other tool, Ivan uses his tablet again and retrieves information on the other project. He uses the same functionality to find out the current status of assembly, the parts he could work on and who worked on the tool before, if he notices any problems (figure 9).

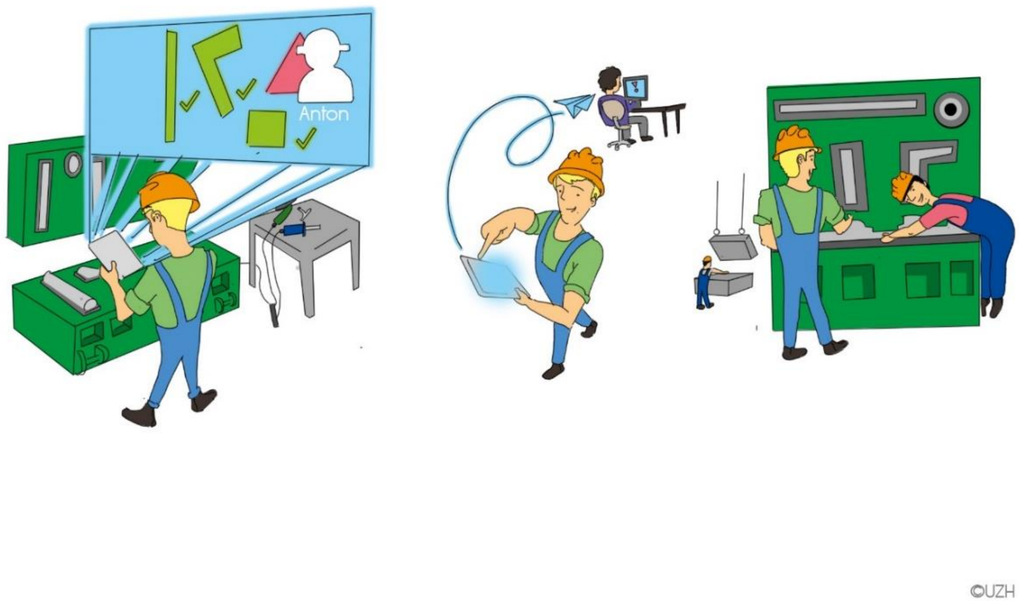

Figure 7: EMO - Activity Scenario 1: The information is always with you!

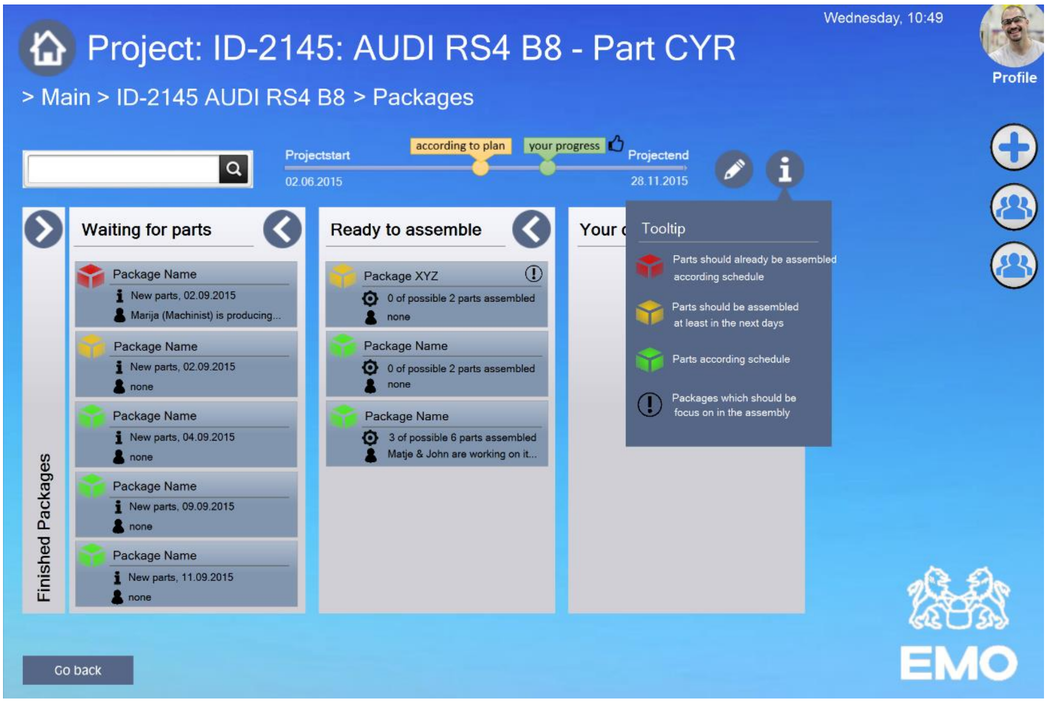

Figure 8: Mock-up of package overview

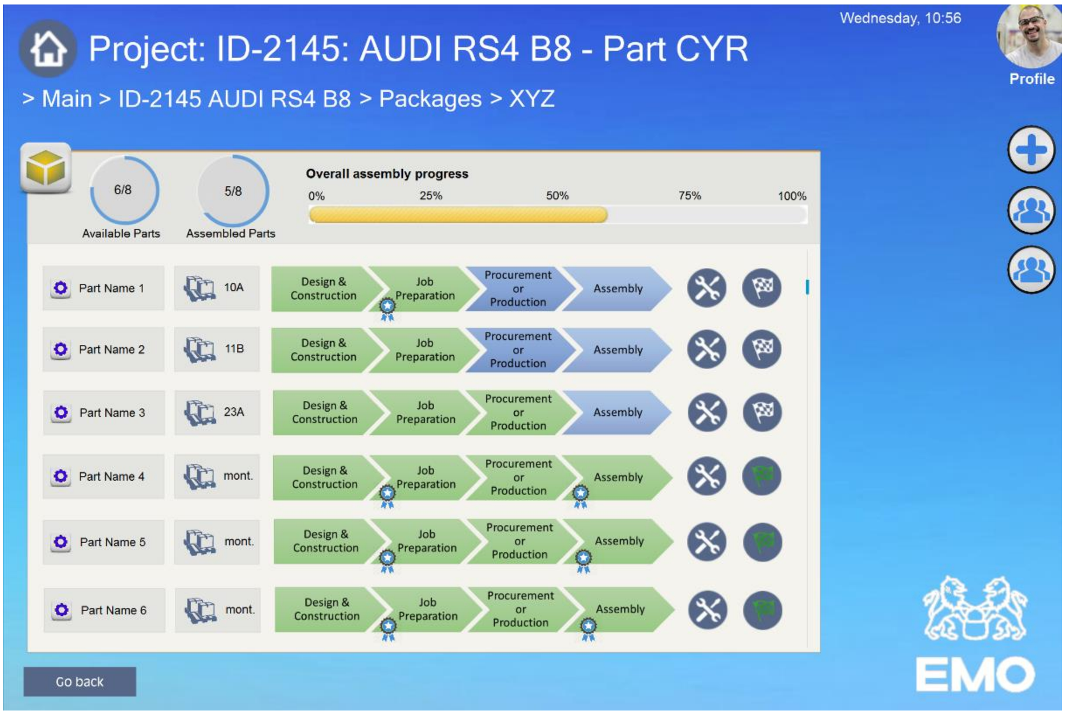

Figure 9: Mock-up of real-time package details

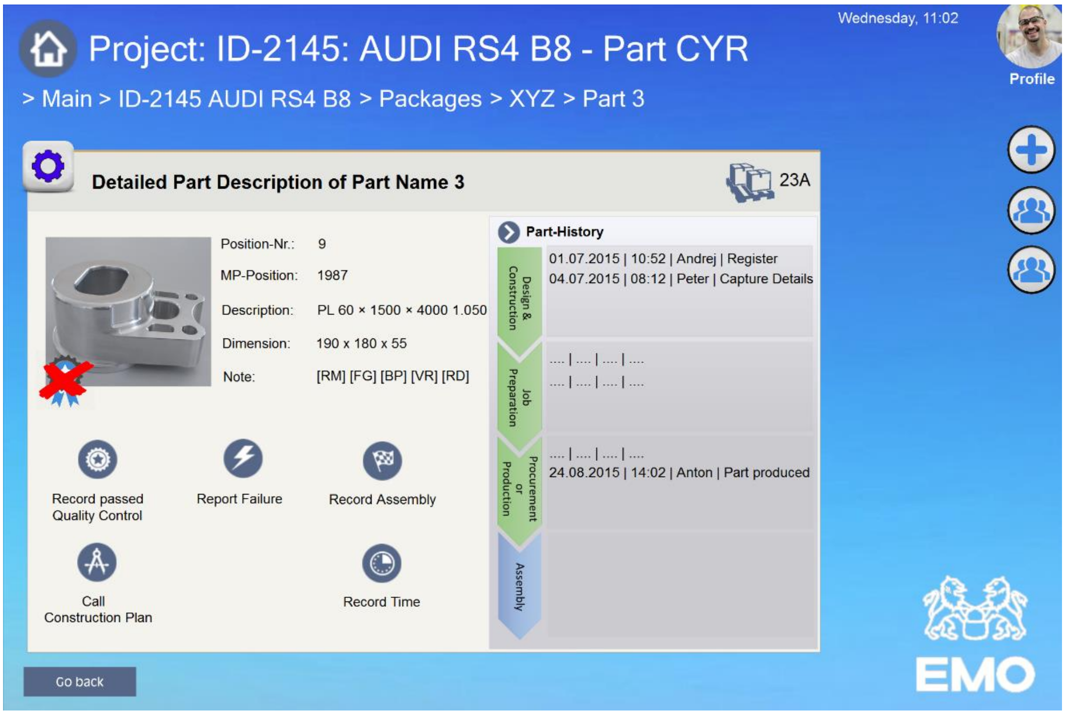

Figure 10: Mock-up of real-time parts details screen

3.1.4 EMO1: Problem Scenario 2: “Unclear QS responsibilities”

Ivan is in the middle of a crucial assembly step as he realises that the part he wants to mount does not have the correct geometry. Only through experience was he able to notice the mistake that would have created greater damage if the tool had been tested for the first time. Using his callipers, he proves a deviation from the part’s drawing that he cannot fix by himself (Figure 11, left). Whenever this happens, he wonders why there is no strict quality control process in place. By chance, Ivan knows that Anton has produced this part; otherwise, he would have needed to identify the person who could help him with that. He takes the faulty part to Anton. In a face-to-face conversation (Figure 11, right), he explains the problem to Anton and asks him whether he could rework the part immediately. Luckily Anton has a bit of time in his otherwise tight schedule and places the part right into the three-axis CNC milling machine. After the part’s surface has reached its final dimension, Ivan takes the part back to his tool and assembles it.

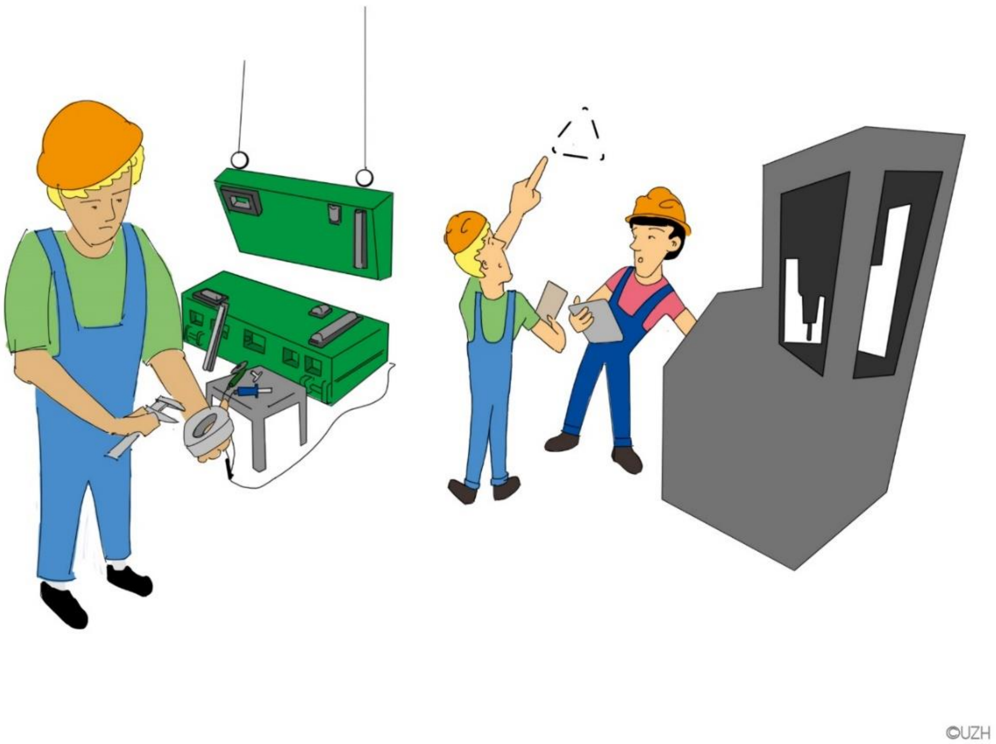

Figure 11: EMO - Problem Scenario 2: It doesn't fit – who can help?

3.1.5 EMO1: Activity Scenario 2: "Documented QS and fast problem intervention"

Ivan is in the middle of a crucial assembly step and is preparing to mount the next part. As this part's dimensional properties are critical to the machine operation, Ivan uses his tablet to check whether a full quality check has been performed. On the part's details view (Figure 13), he can clearly see that no quality check has been performed on that part. Hence, using his callipers to get a rough indication of whether the part is in good condition, Ivan performs the check by himself. As it turns out, the part's geometry is not correct, but Ivan cannot rework the part by himself. He looks up the responsible person on his tablet. This is an easy task, as the machine operators working on that part are listed on the part's details screen. Ivan sees that he has to speak to Anton. Instead of walking across the entire shop floor, Ivan uses the "report failure" and chat function to document the error and to get in contact with Anton. Anton says it is no problem to rework the part within the next hour. When the part returns from Anton, Ivan quickly assembles it. Now it fits perfectly, and thus Ivan ticks off the "quality controlled" flag as well as the assembled flag in the software.

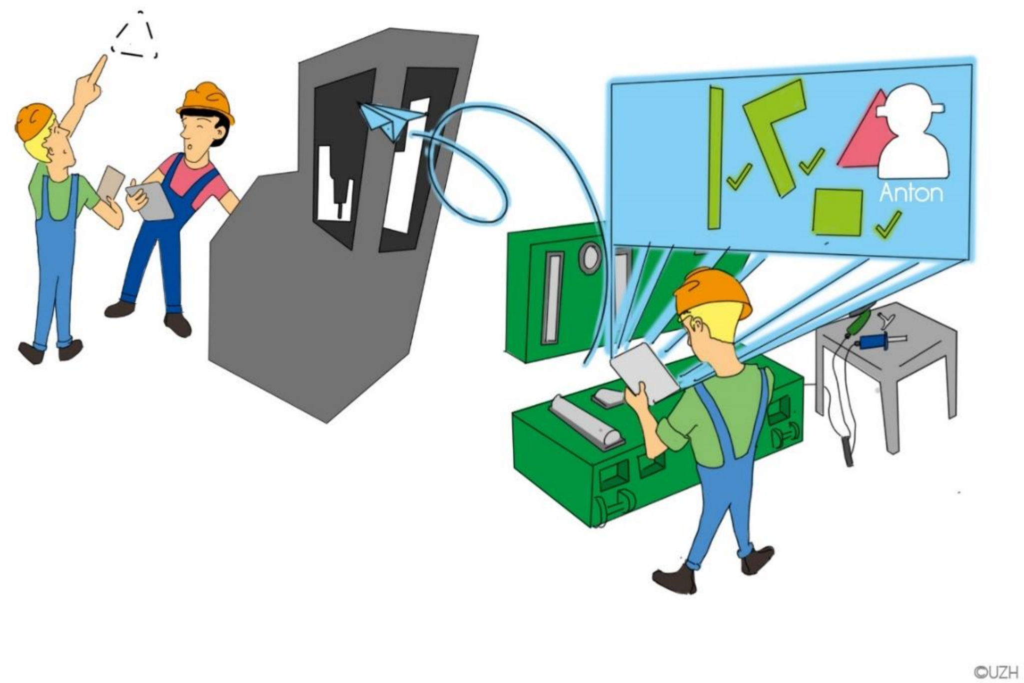

Figure 12: EMO - Activity Scenario 2: Anton can make it fit!

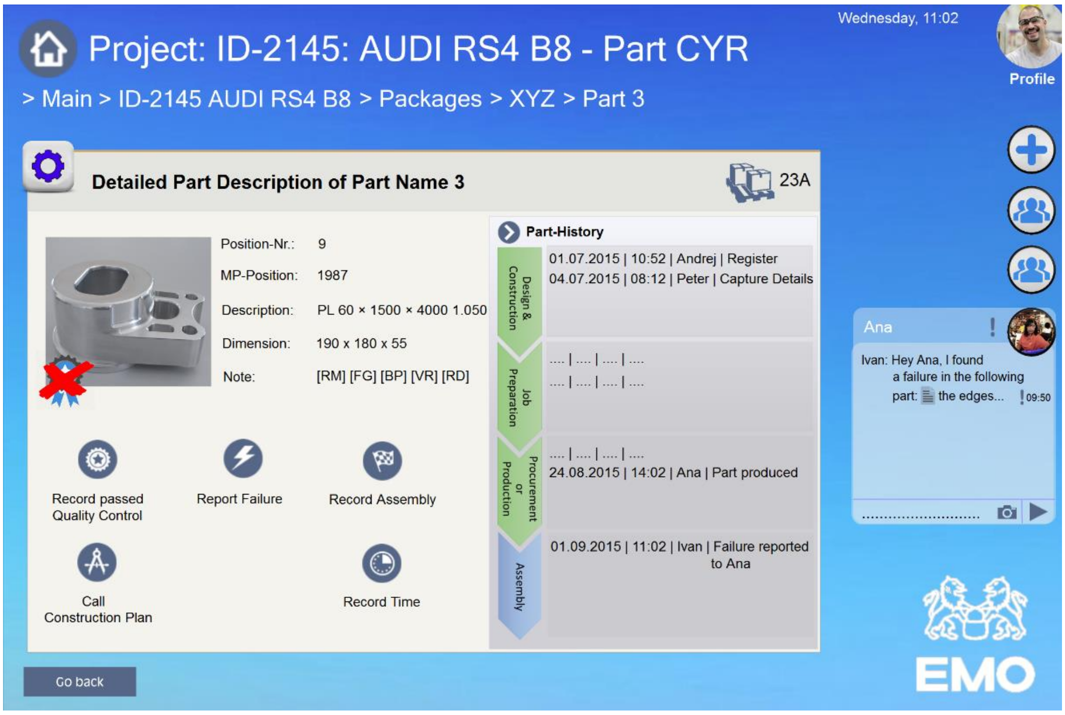

Figure 13: Mock-up of error reporting

3.1.6 EMO2: Personas

Marko is a maintenance worker and takes care of all the machines in the shop. He works in a small team, but he is able to perform all maintenance tasks on the machines. Marko has a solid understanding of mechanics and enjoys tackling complex problems. He feels like he plays a very important role in the company. Sometimes he even gets called in after the end of work, because his colleagues cannot fix a problem. Besides machine maintenance, his main activity is the procurement of spare and replacement parts.

Anton works as a machinist at EMO, where he produces various parts for the tools the company builds. He works in a three-shift system and operates a CNC machining centre. His main activities involve the setup of the machine and the tools required to perform the machining operations. He has to take special care whenever he downloads new CNC programmes from the servers, as he has to ensure that the programme runs error-free and includes all the required steps. Sometimes he has to alter the programme to ensure smooth operation. During the day he does the setup procedures several times and handles tool and work piece changes. When he works alone, this can be a demanding job. He is also responsible for the condition of his workplace, which means he has to ensure that the machine is in a good state and sufficiently clean. When working on a shift where the production manager is not around, he sometimes has to make decisions on his own (like the adaption of a CNC programme or a tool change), solely based on his experience and knowledge.

Franc is a 40-year-old maintenance employee. He has been working at EMO for several years and has plenty of experience with all the machines. He is able to service all the machines from classic hand-operated machines to CNC and LASER ones. Every new problem is also a learning opportunity for him, and he likes this flexibility in his job. Besides the actual repair process, Franc also organises the stock of spare parts. He especially enjoys working on complex problems, as this makes him feel important to the company. At the same time, however, Franc is a team player. He believes in strong team bonds as a way to solve problems efficiently.

Marko Machine operator (LASER)	Anton Machine operator (CNC)	Franc Maintenance worker

Figure 14: Personas of second EMO case

3.1.7 EMO2: Problem Scenario 1: "Too many unpredicted problems"

It is 9 o'clock in the morning, and Marko is in the middle of an unexpected problem that requires a maintenance procedure on the laser cutter. A parabolic mirror has become dirty and must be cleaned. The machine has triggered a corresponding warning. This requires that Marko partially disassemble the laser head. The laser cutter is an important machine, and the shop only has one machine of its kind. Incoming orders to the machine are piling up.

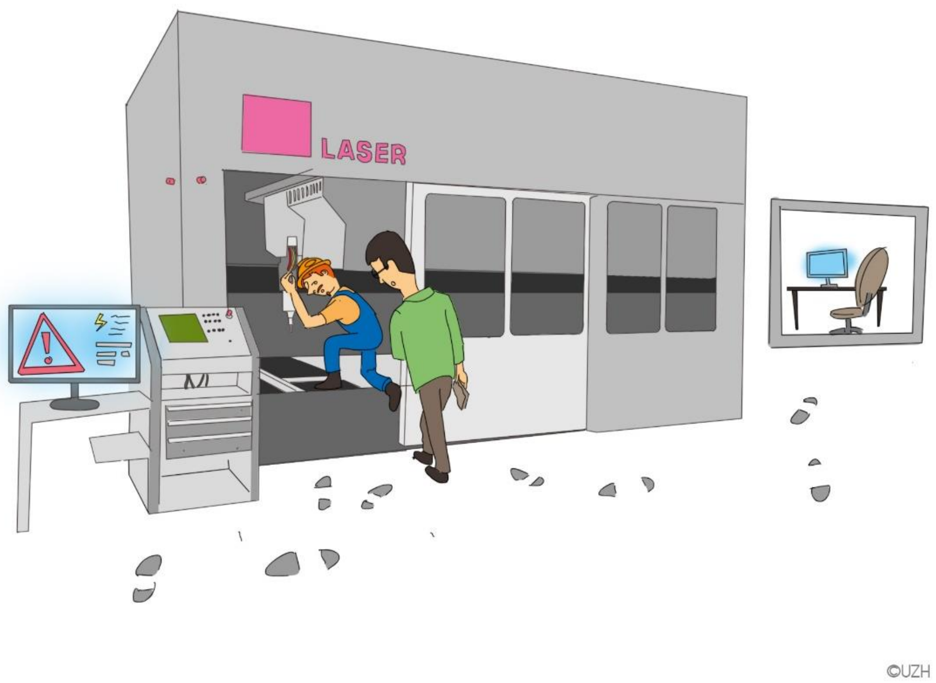

Figure 15: EMO2 - Problem Scenario 1a: The laser cutter has stopped working and must be maintained.

While he is busy with this machine, Anton passes by, as his CNC machine has also just broken down. His remote controller has stopped working. This is very annoying for Anton, as he now has to work only with the main control panel, which is fixed in place. Marko feels stressed, because he has a precise idea of the problem, and he knows that Anton could easily fix it by himself if he only knew how to do it. Putting the laser head back together, Marko notices another part being damaged that also needs to be replaced immediately. He looks up the part number in the corporate procurement system. There is no replacement part on site, but Marko knows a distributor 100 km away, where he can obtain the part directly. He phones up the distributor, gets into a car and drives to the distributor. Back at the shop three hours later, he installs the part, and the laser cutter goes back into normal operation. But he has certainly not forgotten Anton nor his broken controller. Marko visits his workplace. A quick look confirms his thoughts on the problem: It is just a loose electrical connection in the remote control terminal. He switches off the machine and tightens all the screw terminals to ensure a decent electrical connection. After switching the machine back on again, they try out the basic functionality of the remote controller to verify the success of the repair. Marko immediately notices that the illumination of the working area is very dim: The light bulb has burnt out. This is easy to fix. He just has to remove the protective glass and replace the bulb. It is a standard bulb, and they have plenty in stock. After a busy day, Marko is looking forward to a relaxing evening with his family.

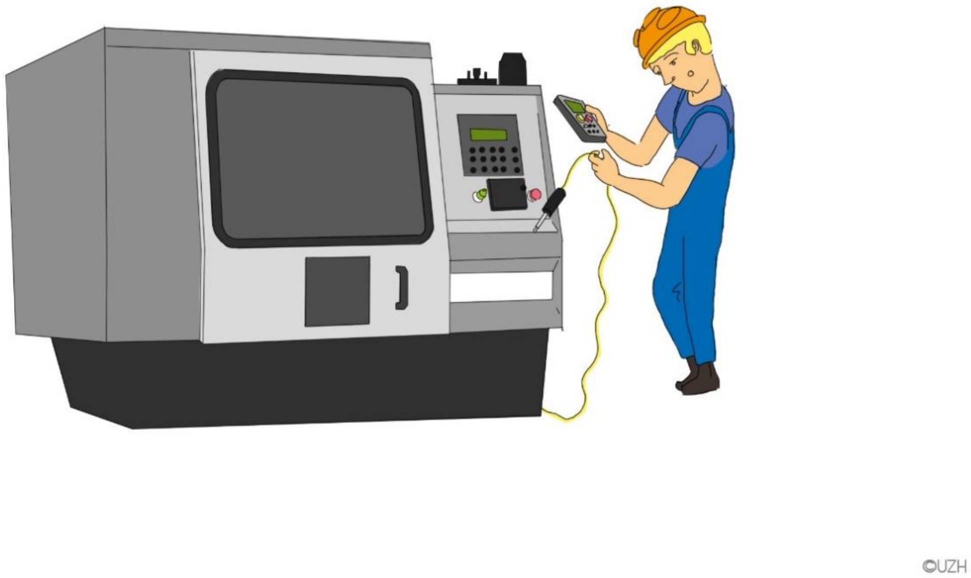

Figure 16: EMO2 - Problem Scenario 1b: The remote control on this CNC unit has just failed.

3.1.8 EMO2: Activity Scenario 1: "Preventive maintenance"

It is 9 o'clock in the morning when the laser cutter issues a warning that the parabolic mirror has to be cleaned. Franc, who is operating the laser, notices this warning, takes out the Facts4Workers tablet system and looks up the error in the database. This normal, preventive maintenance procedure prescribed in the machine's handbook is not a big deal. He quickly retrieves the necessary procedure from the tablet. A detailed step-by-step guide, which Marko prepared as part of the preventive maintenance routines the last time this error was triggered, gives him confidence that he can manage the repair on his own. During the mirror cleaning operation and the reassembly of the laser head, Franc notices that another part appears to be damaged as well. His tablet system does not contain any information about this issue yet, as this is the first time the fault has ever occurred. He calls in Marko by pressing the "request maintenance staff" button on his tablet. Marko promptly joins him and confirms the suspicion that the part has to be replaced immediately. Marko takes the car to buy the missing part at a local distributor 100 km away. Upon his return to the shop, he installs the component, and the laser goes back into normal operation. Marko thinks it would be worthwhile to check the part more often in the future, so he adds it to the list of periodic maintenance checks that the machine operator would do on a three-monthly basis from now on. At the end of each shift, Franc (as well as the other machine operators) uses the tablet and work from the list of suggested maintenance tasks to avoid unexpected interruptions like this one.

Anton is producing parts as usual, because his machine did not break down. Everything is working smoothly. His remote controller is also in perfect condition, as he has recently tightened all the electrical connections, as the tablet system suggested.

The light bulb burnt out a week ago. Anton realised it immediately, and there was no need to call in Marko, because he could follow the simple procedure that the tablet system provided. At the end of today's shift, the system requests the cleaning of some fluid filters. Anton follows the steps and cleans and reinstalls the filter. When he has completed the task, he ticks off the procedure to mark it in the system as done.

Marko is now much more relieved than during the unexpected workloads, and he can focus on other work. There is also a benefit to the production, as the machines fail less often. He leaves the building in the evening, confident that everything is in good condition and that he will not get called up at home to assist with an emergency repair.

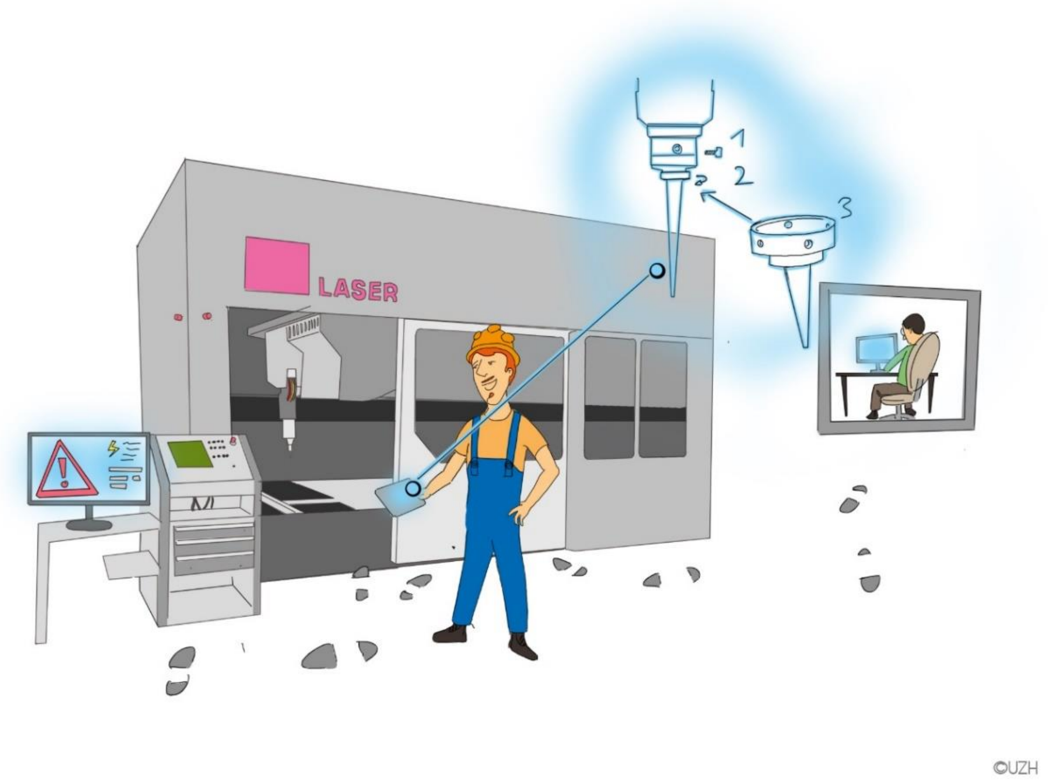

Figure 17: EMO2 - Activity Scenario 1a: A step-by-step manual helps Marko to perform the maintenance procedure autonomously

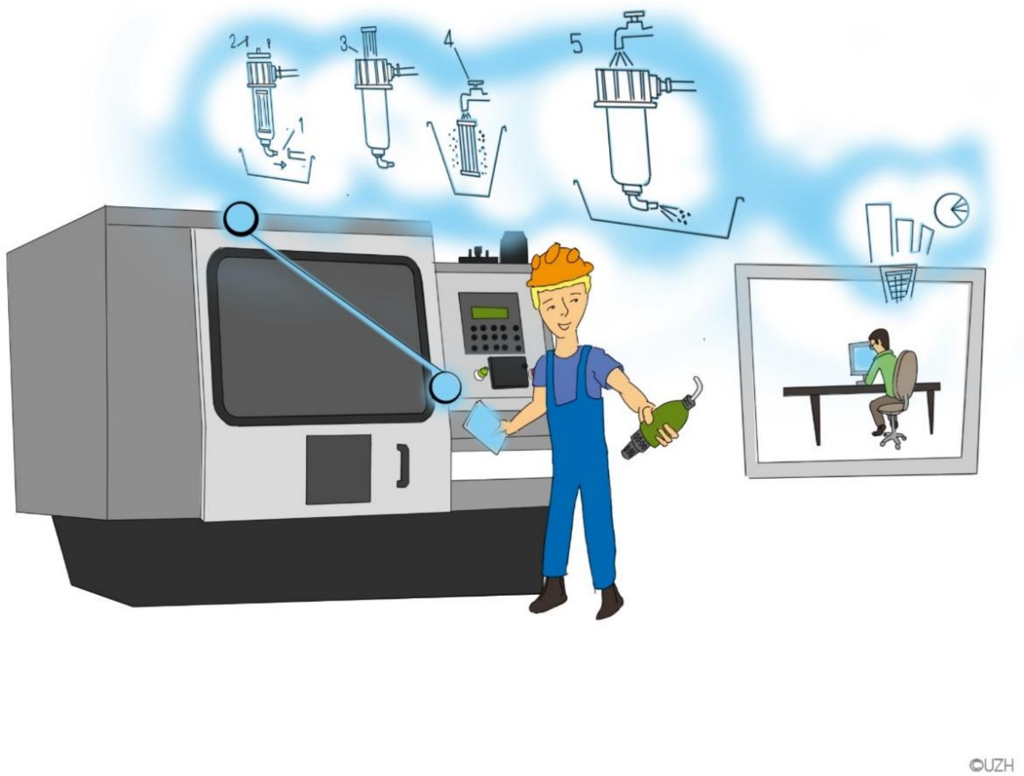

Figure 18: EMO2 - Activity Scenario 1b: The system provides step-by-step guides on how to perform the maintenance activities

3.2 Hidria Technology Centre

The Hidria Technology Centre d.o.o. (HID) designs and manufactures a wide spectrum of partially or fully automated assembly lines, ranging from simple conveyer belt designs that support manual assembly to fully automated lines equipped with state-of-the-art instruments that ensure the products will meet their specifications. These sophisticated machines are tailor-made: They are designed from scratch for specific customer needs (engineer to order).

Since the machines are equipped with programmable devices to control the process, the development is a co-design effort by mechanical, electrical and software engineers. However, once installed at the customer's site, these assembly lines show a typical efficiency of only 65% (overall equipment efficiency, OEE). The loss in efficiency is due to either time-consuming setup and maintenance activities or lacking supplies. In such cases, the line comes to a halt or produces parts that have not been specified. The reduction of setup and maintenance time is the focus of this context-of-use.

3.2.1 Personas

In the following scenarios Mihail, the 31 year old supervisor of the assembly line operators and Robert, the 42 year old member of the maintenance team, are the main characters in this context at the customer's site (Hidria Dieseltek plant). Mihail's main responsibility is to keep the automated assembly line running for the orders and the production plan, and Robert is responsible for maintaining all the machines in the production area. Mihail and his team members are experts when it comes to resolving smaller problems in assembly lines, but in the case of larger or more complex problems, Robert and his internal maintenance team help to bring the production up to speed again as quickly as possible.

Mihail is a 31-year-old line operator who keeps the automated assembly line handy for the orders and the production plan. He also prints out maintenance sheets, participates in audits once every 14 days or once a month, and he helps to cover other operators when needed. His work includes a lot of manual documentation, which he does not like, as he thinks that all this paper work takes too much time. He likes his job and thinks that it is a good day when there are no surprises, but it is even better if he gets a challenging task for the day.

Robert is a 42-year-old member of the maintenance team, which also comprises five other workers. Robert and the team maintain all the machines in the production area. He takes care of all service orders and orders spare parts for maintenance. Robert also builds procedures, prepares check lists on the machines and draws up timetables for the team. He enjoys challenges that need more attention and more knowledge to solve. Robert also likes to be involved in different kinds of development projects.

Figure 19: Relevant personas in this context-of-use

3.2.2 HID: Problem Scenario 1: "Tricky machine setup and complex fault condition"

When Mihail comes to work, he first prints out the (maintenance) checklist to check the production for the coming week. This is how the operators ensure the machines are running smoothly, as they get instructions on what needs to be checked on each machine. Then he calls a morning meeting with the operators to go through everyone's tasks. Checking operations includes a lot of manual documentation and correcting mistakes (updating various things) in the current IT system.

Right after the morning coffee break, a machine in the assembly line triggers a warning that something must be checked immediately. Mihail knows how to fix the machine, as he has worked on all the lines in his past and gained a lot of working experience. The information he needs in this repair situation is in his head. One operator in the team attempts to fix the problem directly by replacing a defective pneumatic actuator. When it is finished after half an hour's work, Mihail writes down the replaced part in the machine book. In the case of larger or more complex problems, the internal maintenance team helps to bring the production back to speed again as quickly as possible. Sometimes Mihail needs to call the product technologist or an electrician for help. Product technologist knows the machine the best and is responsible for the quality of the pieces being made.

In the afternoon, as per the production plan, it is time to prepare the assembly line to make another product (part). This requires very accurate work phases, and many things need to be checked before the machines are adjusted and calibrated so that the new products will be produced according to their specifications. Besides the switching tasks, machines sometimes require accurate special adjustments when there are deviations in incoming components. "We have to set the production according to these deviations in this component" (Mihail).

After a day filled with many different tasks, even though they were completed successfully, Mihail once again considers how the worn-out machines could be replaced with new ones. They would be more reliable and also have a lower noise level than the current ones. Although it takes time to learn how to use them, they would be better for everyone in the end.

Figure 20: HID - Problem Scenario 1: A complex assembly line, where many things have to be checked and adjusted

3.2.3 HID: Activity Scenario 1: "Automated fault prediction and guided checking procedures"

As his first task for the day, Mihail checks all the recent production events with his new F4W tool. He and his operator team each use their own F4W tools to get the automatically updated instructions on what needs to be checked on each machine for the coming week in the assembly line. Those on the operator team allocate tasks for themselves to check. Each operator documents all the activities performed on each machine in the new F4W solution. It is easy to update machine information and correct mistakes. Mihail is happy to get rid of all the manual paper work and to have all the information about the machines in his new electronic machine book.

Right after the morning coffee break, a machine in the assembly line triggers a warning that something must be checked immediately. In his new electronic machine book, Mihail checks the early warning indicator, which was the cause of the warning, and how to fix the problem. In this case, the fault was indicated to be a defective pneumatic actuator, as the sensor in actuator triggered a warning that it is over the limits of the acceptable measurement value. An operator in the team replaced it directly. When it was completed, within 10 minutes, the operator Mihail writes down the details of the replaced part in the new electronic machine book.

In the case of larger or more complex problems, the line operator team first documents its knowledge in the new F4W solution, which helps Robert to make a proposal as to how the problem could be solved. The solution is based on the knowledge of line operators and on a proactive process fault analysis about real-time machine-run data by applying machine learning and big-data analytics or analysing product quality trends and deviations. Robert and his maintenance team also help to bring the production up to speed again as quickly as possible based on this information.

In the afternoon, as per the production plan, it is time to switch another product on the assembly line. Mihail and his line operators are preparing for the switch task by utilising a new smart ‘hand-held’ F4W tool in addition to the special gauges and devices. The procedure of switching to a new product requires data to be put into the machine, as well as product information (pulled from specifications, tolerances, drawings) and knowledge of the whole assembly workflow. Product information is in the i4 software system that Mihail uses five to six times per shift for different checks.

After a day filled with many different (successfully completed) tasks, Mihail can now share his knowledge of the assembly line through the F4W solution to train other workers. He feels that it is really good to have manageable data and information helping man and machine, and he is now a knowledge worker.

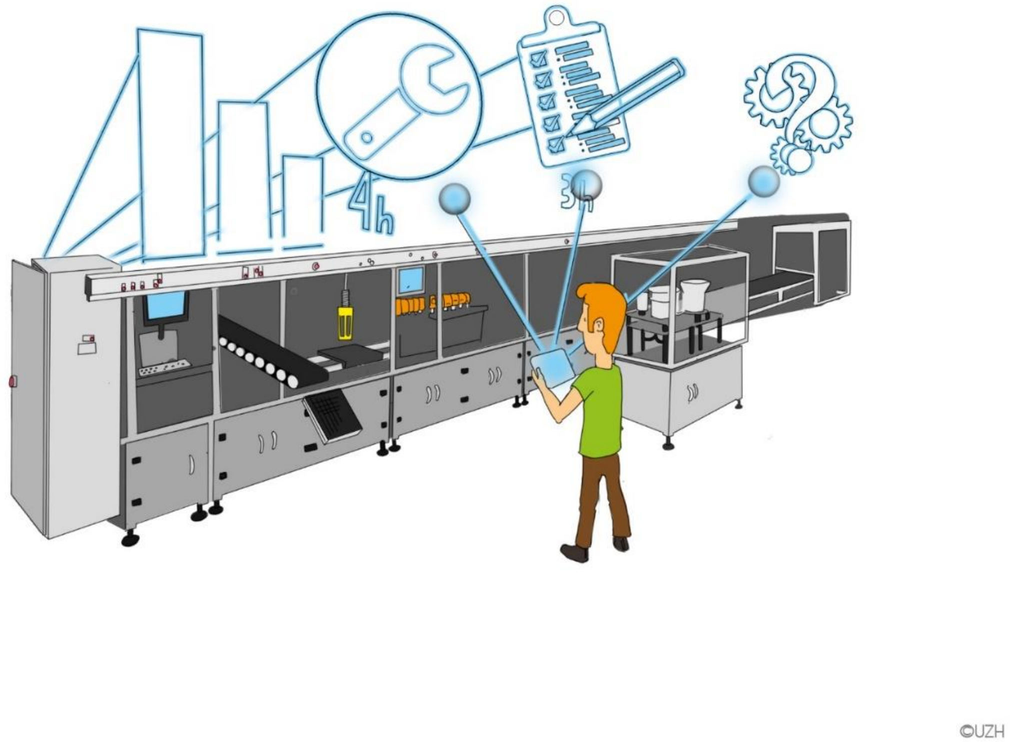

Figure 21: HID - Activity Scenario 1: Mihail now has everything in sight; the system offers real-time machine status as well as future projections of the machine performance

3.2.4 HID: Problem Scenario 2: "Scattered information and event-driven maintenance"

When Robert first arrives at the workplace in the morning, he checks whether anything has gone wrong with the machines. He walks around the production area and checks whether there are any service orders. After a couple of minutes, the production leader brings him a service order. There has been a major breakdown in one of the machines, and it has been stopped, so Robert gets the request to fix it. He goes to the machine and talks to the line operator, who tries to find a solution to the problem and seeks information in his machine book, but without any success. Then Robert makes a phone call to the product technologist, who is responsible for the machine and knows the machine the best.

Robert and the technologist have a meeting to discuss possible solutions to fix the problem. Robert calls the machine manufacturer (Hidria TC) to get more information about the problem and find a possible solution. After the meeting, a solution is found based on information from the manufacturer and a common understanding with the line operator and the technologist. After the meeting, Robert uses his laptop (using the Hidria-wide system for ordering spare parts) to order the special parts from the machine manufacturer and receive them in the shortest possible time. On the service order, he also makes a note of some of the information that can be used in the future.

Robert gives the service order papers to his team's maintenance worker. Robert knows that when he sees a paper on the table, there is still work to do. The maintenance worker performs the necessary maintenance actions with the machine and also writes down on this document all the hours spent and the spare parts used. When the work is finished and the machine is running, the document is given back to the technologist, who is responsible for documenting the case in the electronic LN software system (includes e.g. requests, service orders, accounting system). The system gives Robert a cost breakdown of the service orders, including all the bills, hours and materials.

In the afternoon, Robert is preparing a check list and timetables on the machines for preventive maintenance. He has received feedback (event-based intervention schema) from one of the line operators that one of his machines is making an unusual noise. Another line operator has informed him that a sensor of the machine is showing that one of the measured values is outside the permissible limits. Robert decides to prioritise these two maintenance activities at the top of the maintenance check list. He gives the service orders to his team's maintenance worker and operates the machines himself. After a long day, he feels happy that all the machines are working and the production is in good condition. However, he feels a little nervous about what will happen the next day.

Figure 22: HID - Problem Scenario 2: Robert has to deal with a lot of media discontinuities and distributed information sources during his repair work

3.2.5 HID: Activity Scenario 2: "Shared documents and integrated human-machine information"

When Robert first arrives at the workplace, he checks where anything has gone wrong with the machines. He checks from his laptop whether there are any service orders for him and his team and is happy that no service orders were generated during the evening or night shifts.

After a couple of hours, Robert gets a message through his F4W tool that an urgent new service order has arrived. At the time, he was in the coffee room, so he leaves immediately to get more information about the breakdown from the new F4W solution. He discovers that the specific machine has been stopped and requires immediate action from his team. The line operator has just documented his grasp of the problem in the F4W solution without any success in solving the problem himself. Robert goes through the machine data. The F4W solution has detailed information about the machine, when and where it was purchased, the recorded tolerance deviations of past production runs and carried out maintenance activities. In addition, Robert goes through all the notes in the system that the line operators have made concerning this specific problem.

The new F4W solution helps to predict certain errors based on an analysis of the machine data in the system. Robert discusses the solution approach with the technologist, and they agree on the actions to be taken regarding the machine. In the F4W solution, he also documents some information about the problem and the solution they found, which will help the line operators or the maintenance team to resolve similar problems in the future.

Robert assigns one of his team members the task of fixing the problem. The maintenance worker gets the message to the F4W tool that a new service order has arrived, and he checks the assignment from the F4W solution. The maintenance worker takes the necessary actions with the machine, and in the system he documents how many hours were spent and some information about the spare parts. In the F4W solution, the maintenance worker also makes a few notes about the special tasks or things that have to be taken into account when fixing the problem in similar situations in the future.

In the afternoon, Robert is preparing a check list and timetables on the machines for preventive maintenance. He analyses the production and machine data in the F4W solution to predict upcoming maintenance work. The F4W solution gets the data that one of the sensors of the machine is near the limit of the acceptable measurement value. Robert adds the task to the timetable in order to react to this problem during the week.

After a long day, Robert is happy that all the machines are working and the production is in good condition. He likes that his work time has been reduced significantly in relation to reactive maintenance tasks. The line operators are able to predict and solve most of the minor problems in the production line with the help of the new F4W solution. Therefore, Robert can concentrate more on the preventive maintenance and development projects. He really likes analysing the machine and production data from the new F4W solution and thus preventing many potential breakdowns.

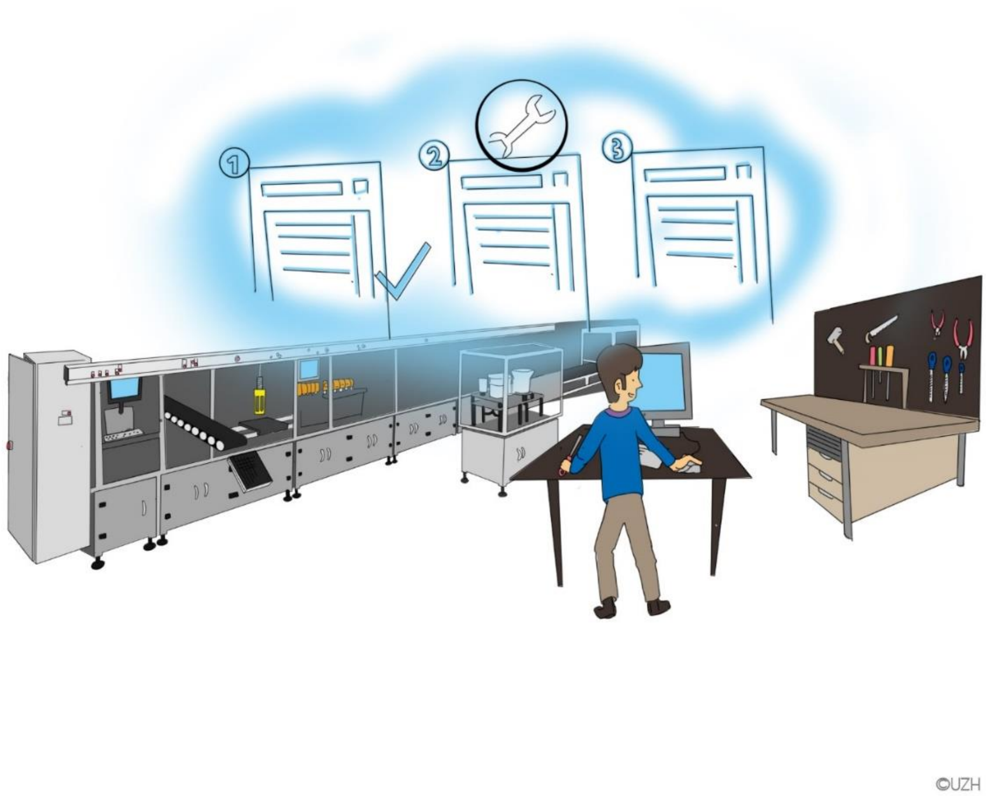

Figure 23: HID - Activity Scenario 2: The F4W system offers Robert centralised access to all the data he needs; the assembly lines are now in perfect condition, as Mihail does a lot of the maintenance work himself

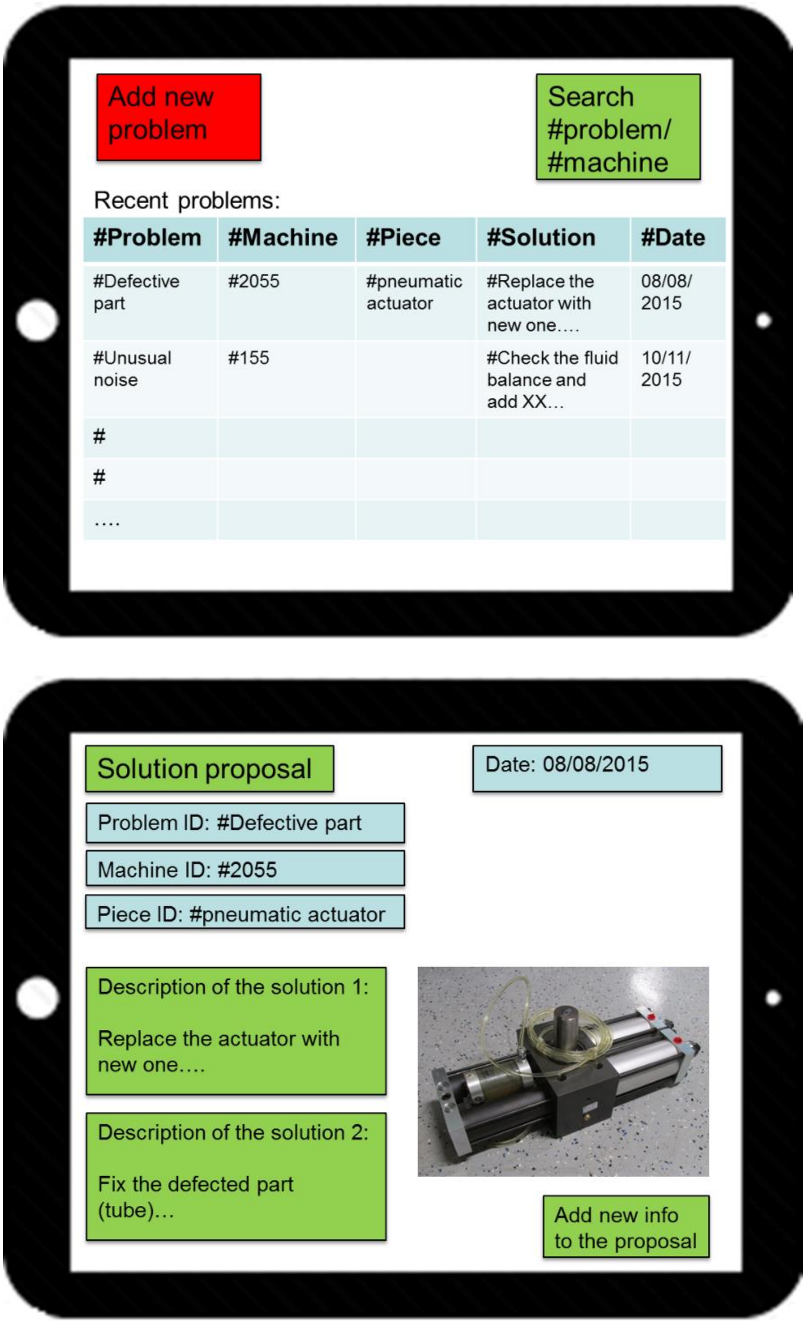

Figure 24: Mock-up of the electronic machine book for Mihail and Robert

3.3 Hidria Rotomatika

Hidria Rotomatika d.o.o. (HIR) produces electrical steel laminations and die-cast rotors for automotive and other industrial applications. The company produces parts in the desired quantity according to its customers' designs and specifications. One stream of products are die-cast rotors with shafts that are used in electric motors. These die-cast rotors are compound components consisting of electrical steel laminates and aluminium that form the basis of these squirrel-cage rotors of electric motors. In a later processing step, a precision-machined steel shaft is inserted into the rotor to complete the assembly. The process from raw material to completed product is spread out over the plant, as it involves numerous processing steps at the factory's different workplaces, including steel stamping, laminating, die-casting of aluminium and the final assembly.

3.3.1 Persona

Janez is a 28-year-old machine operator. In the past few years, he has gained experience at several work places inside the factory and is currently working at the rotor assembly workplace. He has more than a year of experience and thus can already instruct new workers how to perform their tasks. He likes it most when production is running smoothly and he can achieve his production goals without major interruptions. But he also likes the challenges that arise from time to time when he has to fix problems or do smaller repairs. Janez has a lot of bright ideas and likes to communicate them to his supervisors. During breaks, he meets with the other guys of his work unit. They share a table in the cafeteria. He also likes the advances in production technology that make his work easier, for example the installation of a helping robotic arm to help move the heavy rotors around.

Janez
Machine operator

Figure 25: Relevant persona in this context-of-use

3.3.2 HIR: Problem Scenario 1: "Tedious manual quality control and machine setup"

As usual, when Janez starts his shift, he talks to his colleague from the previous shift. After their talk, he rearranges his workplace to suit his needs. A part of the batch from the previous shift is still left over, and therefore Janez immediately starts running further parts. For this operation he has to press the shaft into the die-cast aluminium rotor before mounting it in the chuck of the CNC turning machine. This CNC lathe runs a predefined program and machines the part to its final dimensions. After the machining, Janez takes the part out and carefully measures all the relevant dimensional parameters. He knows the allowed tolerances from the CAD drawings and uses several measuring gauges to guarantee that the part is within its specification. Every part is measured. If a part fails, it is either re-machined or thrown away if reworking is not possible. If the case is the latter, the reason has to be identified. Typically three sources of errors are considered: The raw material was not within its specification, there is a fault on the machine or the parameters of the CNC programme are incorrect. But, as is true most of the time, the part he just measured is in order, so he continues producing the parts. An hour later, the batch runs out. Janez knows that he now has to setup the machine to produce a different and bigger rotor. Bigger rotors tend to be heavier, which means greater physical strain when moving the part around. The most important step now is to dial in the CNC programme parameters to meet the parts' target specification. Janez has to be very careful here, because when setting up the machine, wrong machine parameters could destroy the part and also damage the machine itself. His aim is to set up the machine correctly while minimising waste. Wasting a lot of parts would put him in trouble because of the bad workplace efficiency that would result. Today's setup procedure is unusually tedious and has already taken three hours. He struggles with a deviation of one dimension that he is unable to compensate for reliably. Nonetheless, the parts coming out are not within specification. He knows that one of his colleagues has faced this challenge before. He told him about the problem two weeks ago during the coffee break. But Janez does not know the solution, and the colleague is not on duty at the moment. Janez is exasperated. Normally such a procedure takes less than two hours. It is a complex system with many parameters such as the condition of the cutting knifes, fluids or the condition of raw material, and all of these have to fall in place to ensure production quality. To compensate for these deviations, Janez edits the CNC programme variables again to approximate to the target dimensions with precision. Finally, after more than three hours, the setup is completed, and the batch can be produced.

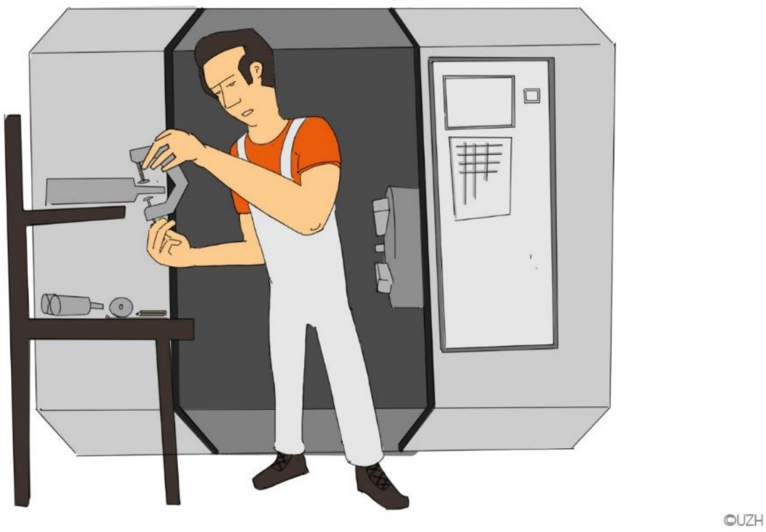

Figure 26: HIR - Problem Scenario 1a: Tedious measurements of every part

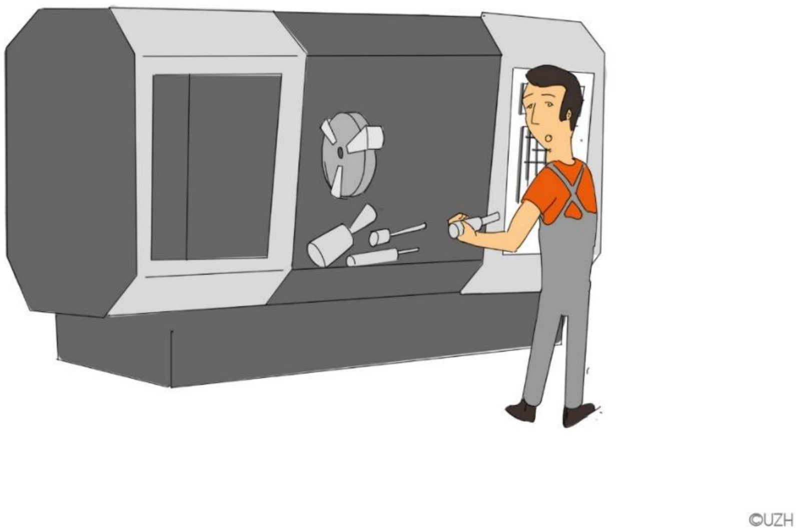

Figure 27: HIR - Problem Scenario 1b: Complex machine setup process

3.3.3 HIR: Activity scenario 1: "Automated quality control and guided machine setup"

As usual, when Janez starts his shift, he talks to his colleague from the previous shift. A part of the batch from the previous shift is still left over, and therefore Janez immediately starts running further parts. To monitor the production, Janez puts on his AR glasses. He also has a tablet version of the system, but usually he likes to have both hands free while he is working. Therefore, apart from data entries made into the system, he prefers using the glasses. Right away he sees the system is telling him that everything is running very smoothly today and that he is perfectly on schedule. Janez puts a new part into the CNC turning machine. After the program has finished, he takes the part out and places it in an automated measuring rig. This rig can probe the relevant dimensions in a fully automated manner. In contrast to the simple pass/fail quality control scheme applied before, the new system can record and track all the dimensions as absolute values on a per part basis. The system automatically retrieves the dimensions and tolerances from the database and also provides Janez with the CAD drawings to guarantee that the part is within its specification. As before, every part is measured, but now Janez can save a lot of time as the tedious measurements have been fully automated. He uses the time to press the next shafts into the rotor blanks. A couple of minutes later, Janez is notified by a blinking symbol in his glasses that the last parts produced are slowly drifting towards the limits of the specification. The system recommends updating a specific CNC parameter to compensate for tool wear. However, this simple approach does not solve the problem. Janez remembers that he talked to his colleague two weeks ago about a similar issue. He uses his tablet to look up the problem. Quickly he finds the report on what his colleague did. He follows the instructions, solves the problem and produces the rest of the batch without any further interruption. An hour later, the batch runs out. Janez knows that he now has to set up the machine to produce a different and bigger rotor. The most important step is to dial in the CNC programme parameters to meet the parts' target specification. As he downloads the programme, the system automatically displays the suggested initial setup values. These values are conservative estimates on the first trial, as neither the machine nor the work piece will be put in any danger. He tries these parameters out on a new rotor blank. As expected, the target dimensions are not met on this first pass or parameterisation. After placing the rotor into the measuring rig, the system assesses the different dimensional properties and calculates the next estimations for the parameters. Janez enters these parameters and runs the programme on the same rotor again. After three cycles, all dimensions are met. He tries out the final programme on a new rotor blank to verify that the target dimensions can be also achieved in only one machining pass. The whole procedure takes Janez just about one hour. He is very happy, as the new approach allows him to be more productive. Janez likes it a lot when he can contribute to the success of his company. Today he has done more than he had planned for, which makes him leave the company with a smile, and he is looking forward to coming to work tomorrow.

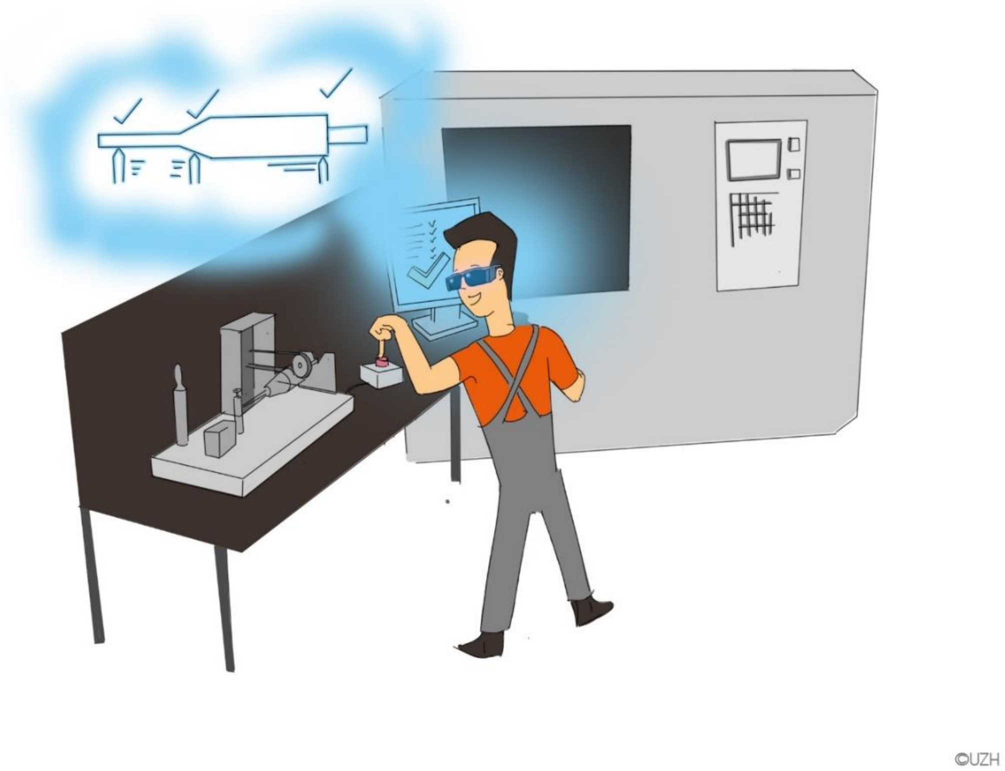

Figure 28: HIR - Activity Scenario 1a: Using the measuring device in combination with AR glasses, Janez can see the measurement results immediately

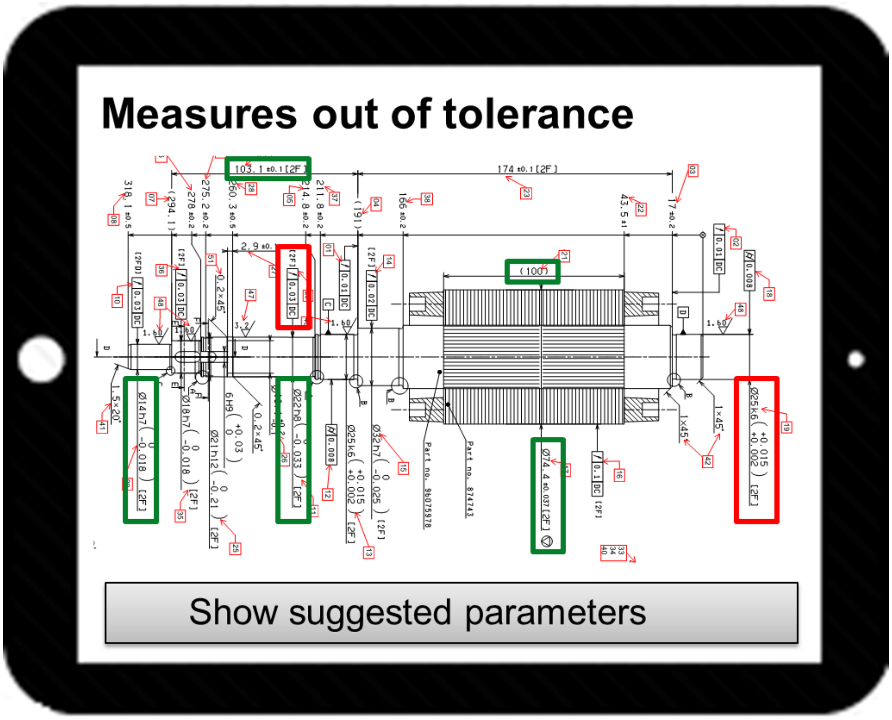

Figure 29: Example screen of the measurement solution

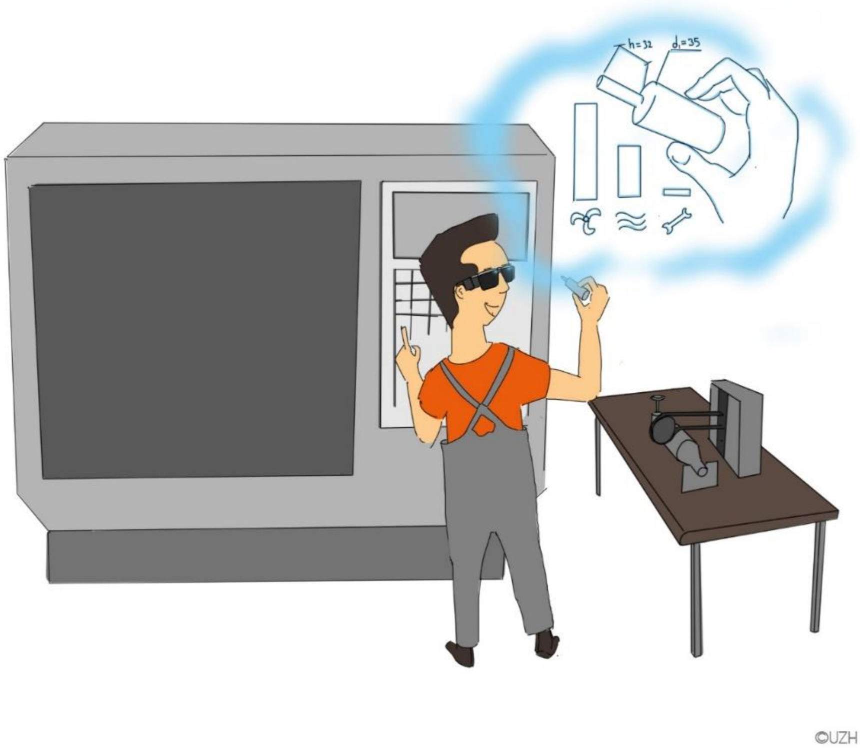

Figure 30: HIR - Activity Scenario 1b: Janez uses his AR glasses to get the parameter suggestions based on the last measurement

3.4 Schaeffler AG

Schaeffler has more than 82,000 employees and is one of the world's largest technology companies in family ownership. Operating in approximately 170 locations in 50 countries, it has a worldwide network of manufacturing locations, research and development facilities and sales companies. As a global development partner and supplier, Schaeffler maintains stable long-term relationships with its customers and suppliers.

The specific SCA factory in focus produces various engine components. In recent years, the factory has changed its production from one that is separated by workshop areas to value stream-based manufacturing. This change, inter alia, led to a redesign of existing quality management and operational quality assurance (QA). The orientation towards value stream means that a production area takes responsibility for its QA. Thus a QA department is organisationally subordinated to a production area and acts as a service provider in this context. As such, the QA department supports the production staff with daily problem solving, for example, the troubleshooting of a station malfunction. In addition, the QA department supports new launches of product types, for example new settings on machines tested and approved in a timely manner, without forgetting other regular tasks with which a QA staff is entrusted, such as the review and archiving of all relevant inspection documents, the creation of action plans (including actions to shut down measures) for defective equipment and to resurvey possibly incorrect measurement devices. Therefore an ICT platform supporting task planning and centralised documentation of problem-solving processes is desirable and simultaneously leads to a reduction of paper-based documents.[6]

3.4.1 SCA1: Personas

In the following scenarios, an employee of the QA, a tool setter and an assembly operator are the main characters.

[6] This context-of-use has also been published in German in Richter et al. (2015).

Hannes QA employee | Marc Tool setter | Martin Operator

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Figure 31: SCA1 Personas

QA employee Hannes, who is 27 years old, has been working at Schaeffler since 2003, when he started his apprenticeship. He switched to QA three years ago. Prior to the switch, he had worked as a main tool setter in the field for the new MultiAir system. He likes challenging tasks, and for him it is important that there be variety in the things he does. His day as an inspector of the QA normally starts with daily tasks like default measurements and the collection of inspection documents. But during the day he has to do a lot of unplanned support jobs where his colleagues from assembly or production have problems with faulty parts on their machines. Consequently there are many unplanned tasks to perform, which prolongs his daily routine. The main problem is the lack of qualifications of the workers on the shop floor to use the measurement equipment correctly and the lack of experience in solving quality problems on their own. Therefore he cannot foresee what the day will bring. So a good day is when everything is running smoothly, and there are no unresolvable problems.

Marc, 41 years of age, is a trained industrial mechanic like his team leader. He has been working as a tool setter at Schaeffler for five years. He is happy when there are no problems during the day and he can concentrate on his work, because it is important that production targets be met by refusing to tolerate any errors. He is usually assigned to one or more machines where he is responsible for technical support. Furthermore, he has to take care of the regular maintenance and retooling of the machines.

The 22-year-old Martin came to Schaeffler two years ago. He is an operator at an assembly line and does not have a lot of experience with different kinds of machines yet. He has only been trained for a few of them. His day starts with him checking to which machine his team leader has assigned him. At this machine he has to do the shift handover with the operator from the shift before. This is normally done via a face-to-face talk, because the handwritten shift log is not very comprehensive. Looking towards the future, he wants to be qualified to use more machines, because he loves his job and the personal communication with his colleagues.

3.4.2 SCA1: Problem Scenario 1: "Boring start of the day – recurring default measurements"

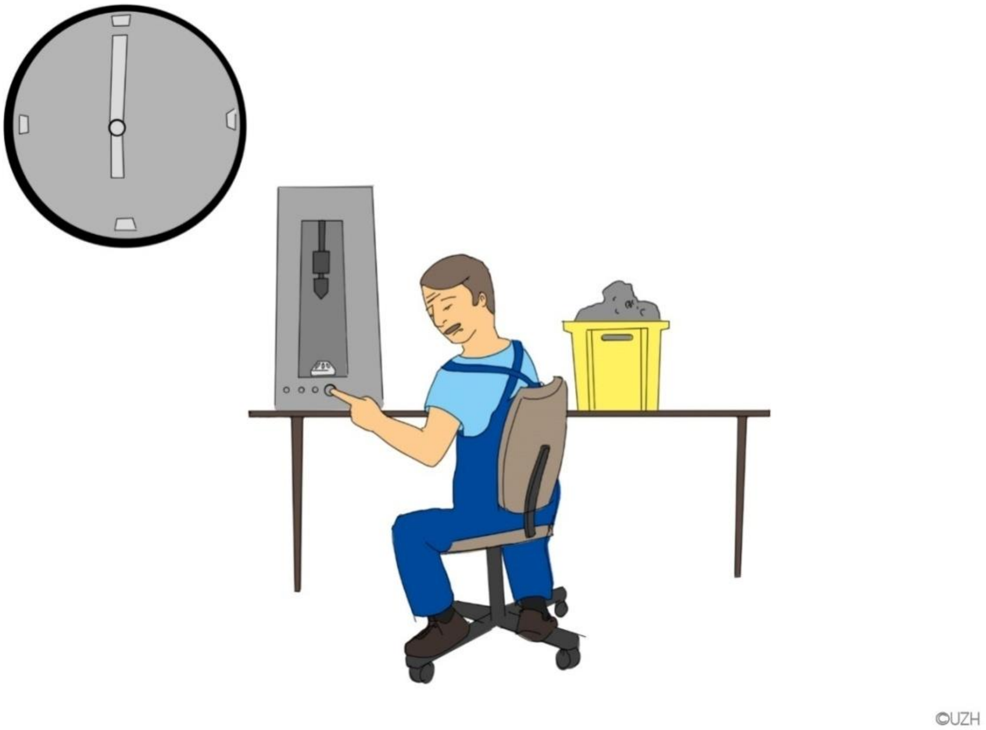

Figure 32: SCA1 - Problem Scenario 1: Recurring default measurements

6 a.m.: For QA employee Hannes, the day starts with the measurement of a set of 60 RSTOs (small rolling elements) by using an optic line. These periodic default measurements are quite boring and not challenging at all. He would prefer to see this task carried out by the responsible department instead. But because his colleagues in production and assembly often lack the qualifications, the QA unfortunately has to do this task. There are many efforts underway to train the workers on the shop floor, but there are also numerous problems with the short-term availability of the particular individuals for these training courses. Furthermore, trained workers will

be assigned to other machines with other qualification requirements, and in the long run they would not benefit from what they have learned. So Hannes has to spend a portion of his working time carrying out these tasks.

3.4.3 SCA1: Activity Scenario 1: "Challenging start of the day - preventive measurement tasks"

Figure 33: SCA1 - Activity Scenario 1: Supported delegation of default tasks to departments

6 a.m.: Operator Martin measures the RSTO test set from the night shift, because he has all the required information and instructions accessible via his new tablet. Hannes and his colleagues have provided the necessary knowledge to the overall available knowledge base before. Many short training videos and commented photo galleries are also available to illustrate how to use the measurement equipment. This helps the workers on the shop floor to carry out simple tasks on their own.

Hannes inspects the faulty parts from yesterday to find possible maladjustments or defects originating in the assembly process. Consequently, he can eliminate problems on machines before there is an outage.

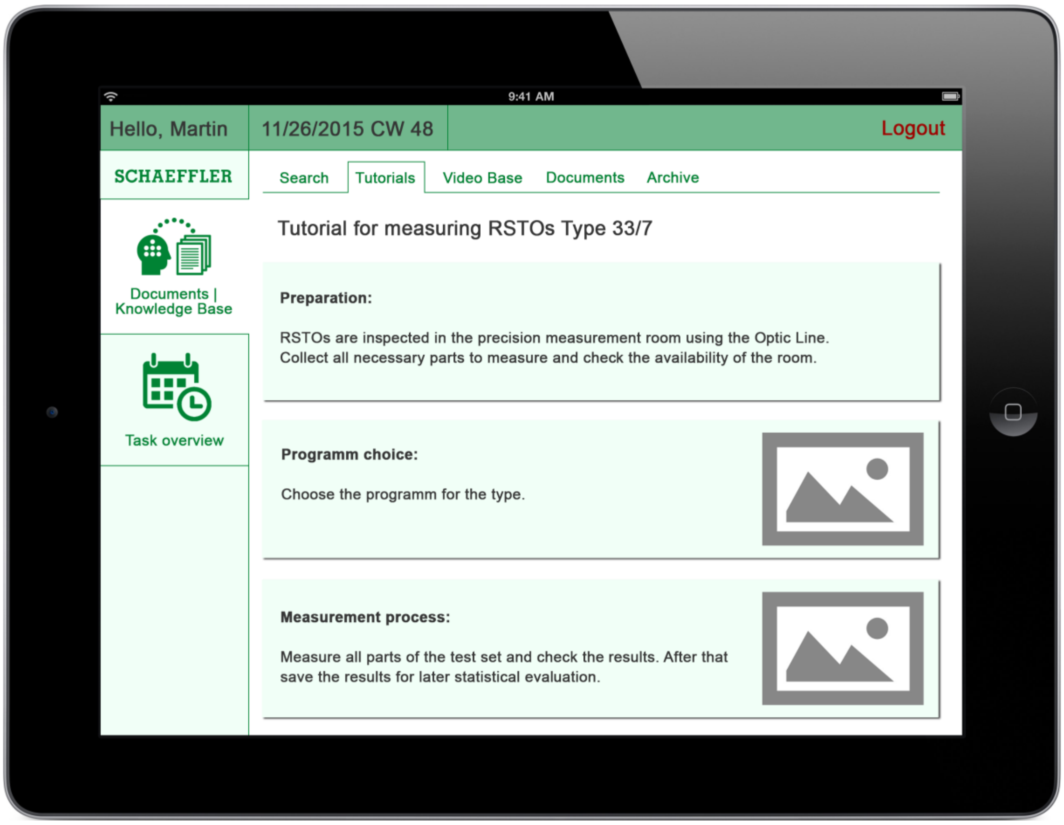

Figure 34: SCA1 - Prototype: Knowledge base with photo gallery

3.4.4 SCA1: Problem Scenario 2: "Collecting inspection documents"

Figure 35: SCA1 - Problem Scenario 2: Long walk across the shop floor

The collection task is unnecessarily time-consuming but has to be done every day. The responsible team leader has to attach a bar code for each document. This is necessary for the archiving process, as all documents are scanned and presented in an electronic system. Finally, all the hard copy documents are destroyed. A digital document version could be much easier to handle, and Hannes's walk would no longer be necessary.

3.4.5 SCA1: Activity Scenario 2: "Digitised inspection documents"

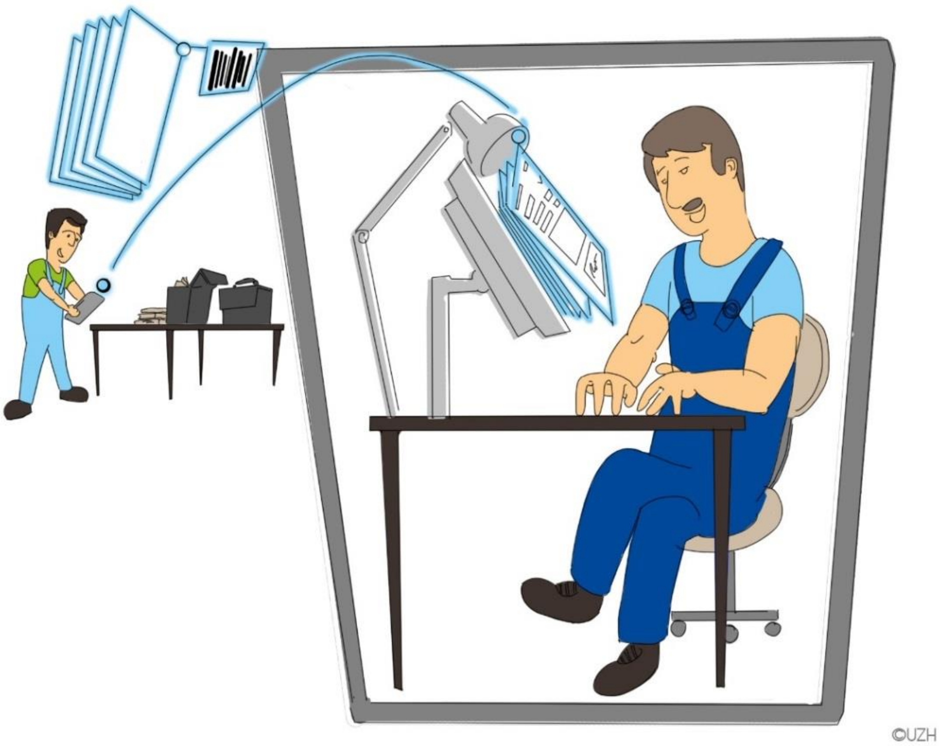

Figure 36: SCA1 - Activity Scenario 2: Digital preparation of inspection documents

Since the QA is responsible for the preparation of the inspection documents, this will be done directly with the F4W software using the QA employee's workplace PC. So there is no need to print a version in hard copy for the workers on the machines, because they have access to the digital version, too. That means the responsible individuals, using the F4W software on a tablet or a separate client on the machine, provide all inspection documents digitally. Operator Martin can fill in the required information directly into a digital form on the machine and save it in the new system. Hannes simply has to check the completeness and archive all the documents. This task does not take much time, and he can plan and prepare the workspace audit for tomorrow, without feeling rushed, using the task-planning component of the new software.

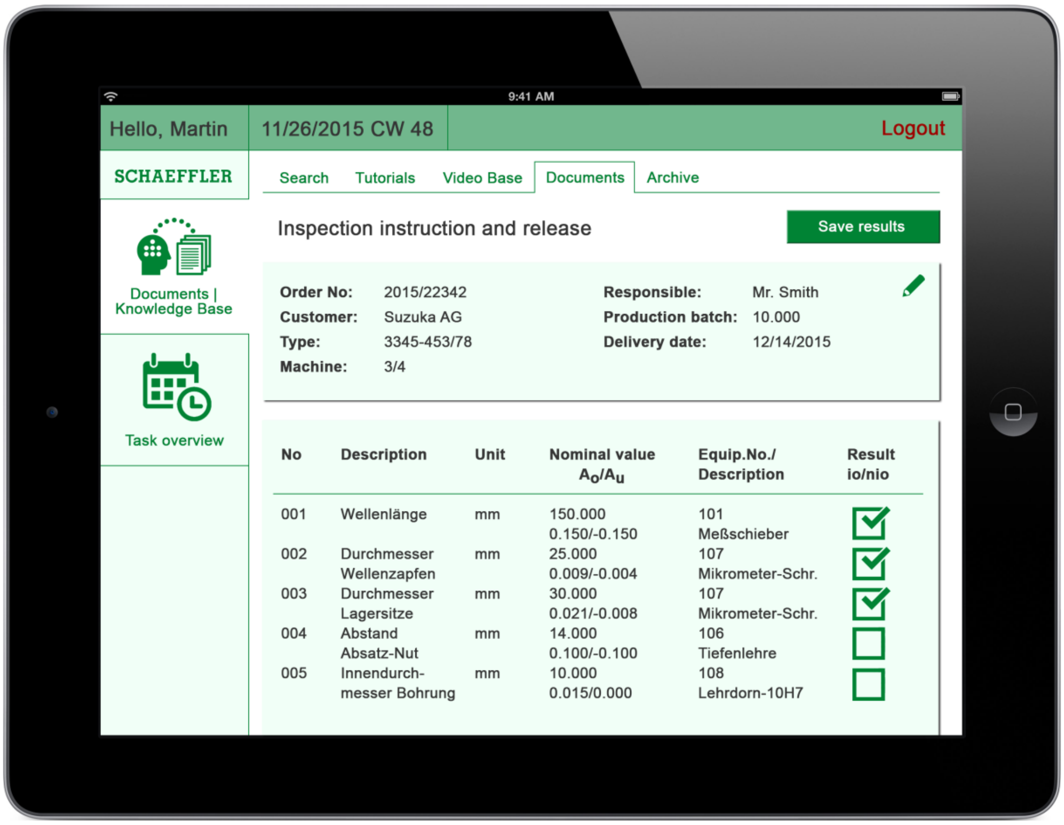

Figure 37: SCA1 - Prototype: Inspection document form

3.4.6 SCA1: Problem Scenario 3: "Processing way to many support jobs"

Figure 38: SCA1 - Problem Scenario 3: Interrupt daily tasks for support jobs

After lunch, Hannes has a call from Marc, his colleague from the assembly line. An assembled product is not working as expected. Neither Marc nor his team leader have an explanation. Hannes has to walk to the machine to analyse the problem by doing his own re-measurement of the product and inspecting the machine. He discovers a technical problem with the measurement device. Hannes retrieves a new device from storage and replaces the defective one. It was not the first support job today, and Hannes has had to interrupt his current tasks once more. With a bit more qualification, his colleagues would be able to solve these problems on their own.

3.4.7 SCA1: Activity Scenario 3: "Enable the production employees to solve problems"

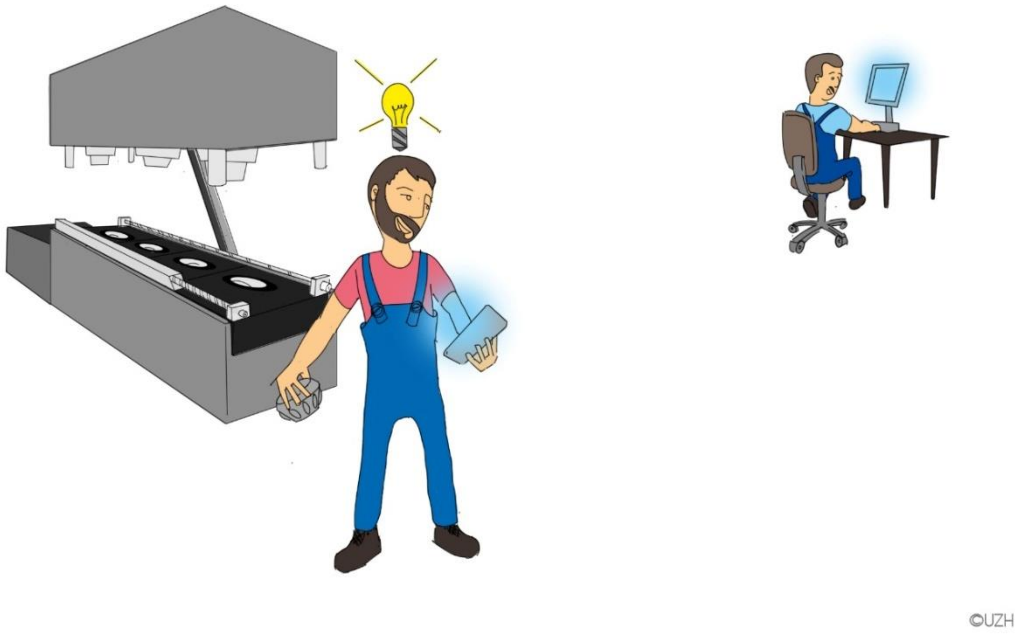

Figure 39: SCA1 - Activity Scenario 3: Problem-solving support via checklists and live chat

Marc detects a problem with the measurements of the final product. He uses his new tablet to access a checklist provided by the QA as part of the F4W application. In this way, Marc can investigate the problem by himself. The checklists describe several steps regarding how he can check, find and eliminate problems. If these lists are not sufficient to deal with the problem, he can easily make contact with Hannes via the F4W live chat component. Hannes points him to the knowledge base, as it contains several possible approaches. Hence Marc can solve his problem on his own and initiate further steps. Hannes, in turn, only has to deal with those problems that are challenging to resolve and does not have to leave his workplace. In more difficult cases, he has to pay attention, because he can access all the required information (like settings sheets and the engineering drawing) via his new portable device. All of these documents can be found in the document base, and it is not necessary to walk back to his workplace to find and print out these documents on the workplace PC.

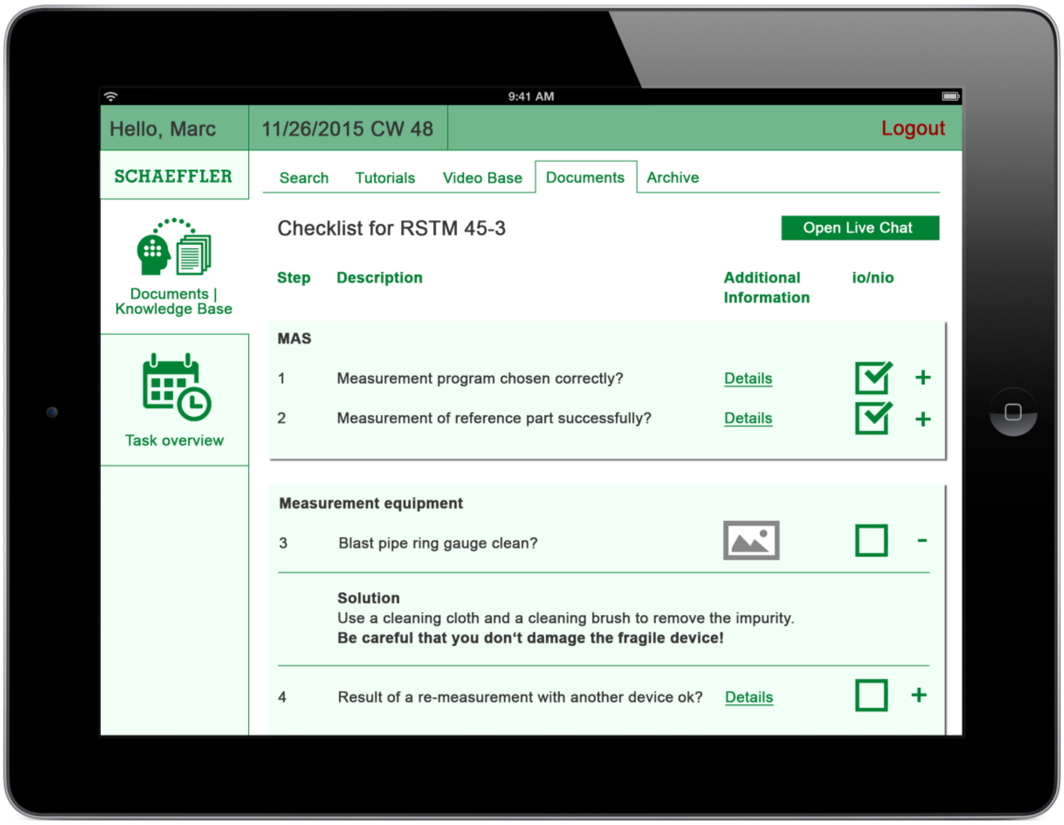

Figure 40: SCA1 - Prototype: Checklist to inspect a problem

3.4.8 SCA1: Problem Scenario 4: "Missing preventive support"

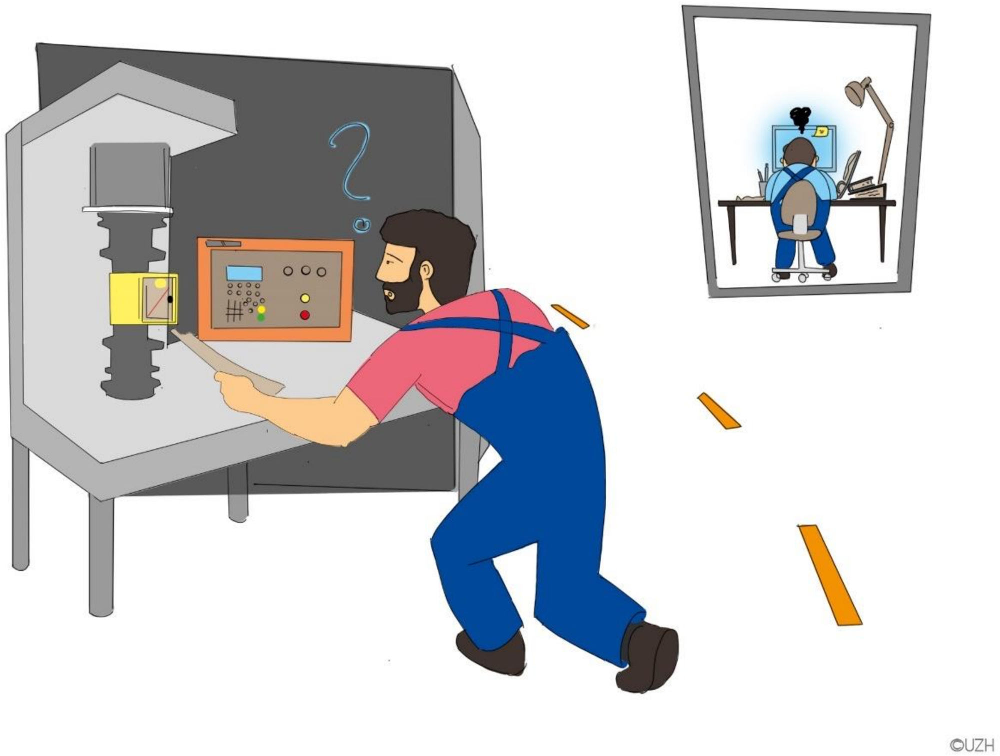

Figure 41: SCA1 - Problem Scenario 4: Unsolved small problems

Hannes wants to make the rounds frequently to offer preventive support and to be available to answer his colleagues' questions, so that they can talk to him and he can solve small problems directly on the machines. These tours also provide an opportunity to train the colleagues how to use measurement equipment, because it is often difficult to schedule training for a group of people, as they are not planned long in advance. Unfortunately, Hannes rarely has the time to do these round tours, because he tends to have many other things or firefighting jobs to do during the day.

3.4.9 SCA2: Activity Scenario 4: “Regular preventive support on the shop floor”

Figure 42: SCA1 - Activity Scenario 4: Round tour with documentation

Because the F4W solution saves so much time, Hannes can make a round tour every day. His supervisor can plan this as a task for him using the task planning part of the F4W application. In this way, he can receive additional instructions, information and required documents for his tour. He can enter into a dialogue with the author to get answers to questions. He can also document the problems that are identified and the answers to his colleagues’ recurring questions in the new system or show them how to use measurement devices as part of a small training course. Finally his knowledge and comments will be available for all the others to use.

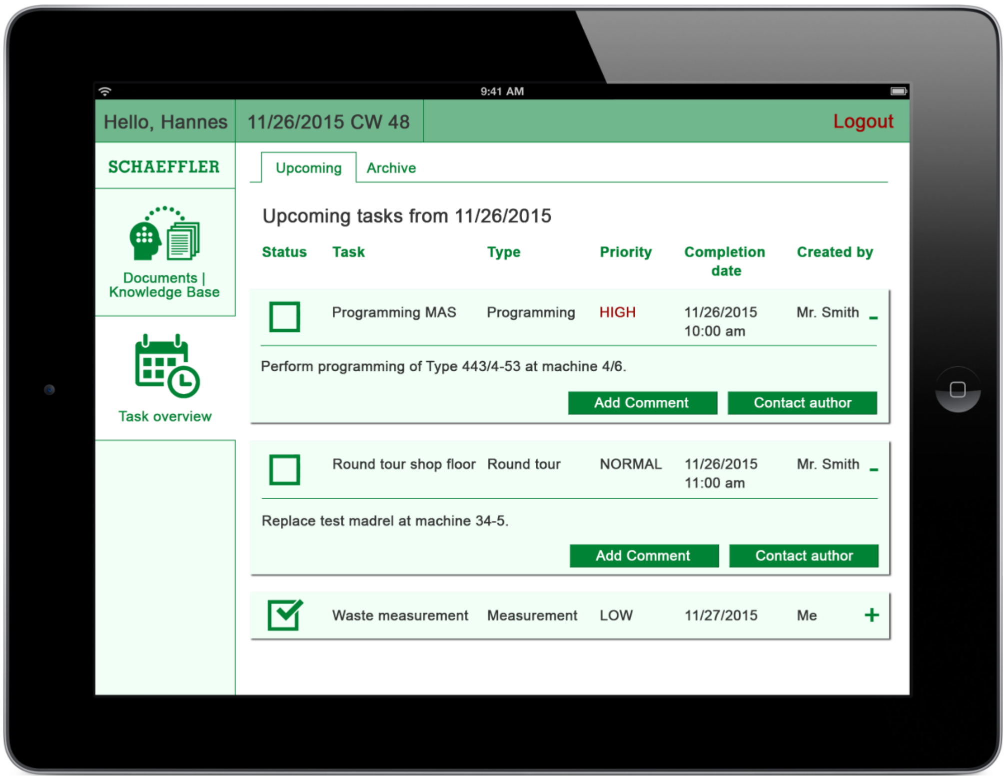

Figure 43: SCA1 - Prototype: Task planning

3.4.10 SCA2: Personas

The second SCA context-of-use focuses on the value stream of chain spanner production processes. The production is divided into several groups, each of which creates components for the final product and is part of the value stream. One of the main challenges is the just-in-time production or establishing compliance with quantities and timelines without creating large stocks. In the following scenarios, a team leader, a tool setter and an operator are the main characters.

Team leader Jürgen is 32 years old and has completed an apprenticeship as an industrial mechanic at Schaeffler. He has been working at Schaeffler in various positions for over 15 years. Before he became team leader, he worked as a tool setter on the assembly. Therefore, he knows the different kinds of machines and his team members' procedures very well. For Jürgen it is essential that all his team members do their work and that they are satisfied. A typical working day includes the following activities: He does the shift handover with the team leader of the previous shift by reading the entries in the shift log as well as discussing unusual situations during the previous shift; then, he has to check whether all the employees in his team can work as planned in the workforce management. Both the tool setter and the operator inform him orally about the current status of production on the shop floor. The rest of the day is usually unstructured. He is continually checking whether the target number of pieces can be reached; if not, he plans and executes some actions to get the production back on track. If problems occur, he is the first level of support for his team members and, if necessary, he organises help from other departments, such as QA.

Marc, who is 41 years old, was already briefly introduced in the SCA1 use case, because he collaborates closely with the QA department. Marc is a trained industrial mechanic like his team leader. He has been working as a tool setter at Schaeffler for five years. He is happy when there are no problems during the day, so that he can concentrate on his work. It is important that production targets be met at zero-error tolerance. He is usually assigned to one or more machines where he is responsible for technical support. He also has to take care of the regular maintenance and retooling of the machines. During the maintenance or retooling tasks, he has to collect many paper documents to look up the relevant procedures and fill out different templates to ensure the desired quality. Unlike the team leader, he uses a handwritten shift log, which is directly attached to the machine. Sometimes it is a challenge, for example if he wants to look up solutions for problems that occurred a few months earlier. He really enjoys working on the shop floor but would like to have some tool to simplify the documentation he has to deal with during a normal working day.

Operator Josephine is 45 years old and has over 25 years of experience at Schaeffler. As a result, it is very easy for her to operate different kinds of machines. Her working day starts by checking to which machine she is assigned based on the team leader's workforce management, before she does the shift handover with the previous operator. Communication is mainly done orally and sometimes also via handwritten shift log. In case there is a problem or any other incident, she usually informs the tool setter, and they try to find a solution together. After all these years, she is still enjoying her work and likes to attain new qualifications in order to operate new machines or execute simple retooling tasks.

Jürgen
Team leader

Marc
Tool setter

Josephine
Operator

Figure 44: Relevant personas in this context-of-use

3.4.11 SCA2: Problem Scenario 1: "Paper-based maintenance work lacks important information"

At the beginning of the shift, operator Josephine has to do the regular maintenance work on the machine to which she has been assigned. Maintenance work has to be done per month, per week, per day or even per shift. The single tasks are described on paper-based maintenance instruction sheets. On the maintenance plan – a separate sheet – all employees have to sign whenever they finish their maintenance work. First, Josephine has to check which tasks have to be done today, and she executes them according to the instruction sheet. After finishing, she signs the plan. Additional information, for example whether she had to exchange a special part, is not documented. The process is static, which means all tasks are executed within a fixed interval and cannot be adjusted dynamically.

Jürgen, Josephine's team leader, is responsible for monitoring that maintenance work was done properly. The only thing he can do in this case is to check the signatures on the maintenance plans located at the machines. He cannot control whether the single tasks have been executed properly and does not have detailed information about what exactly has been done.

Figure 45 shows Josephine doing maintenance work using the maintenance instruction sheet. The maintenance plan is attached to the machine. The background illustrates team leader Jürgen's place of work.

Figure 45: SCA2 - Problem Scenario 1: Paper-based maintenance work lacks important information

3.4.12 SCA2: Activity Scenario 1: "Integrated workflow control for maintenance work"

When carrying out the shift-wise maintenance process, Josephine takes the tablet and is guided through the steps of execution. Jürgen has the opportunity to check the provided information via his tablet as well, as shown in Figure 46. Each step of the way, the system provides Josephine with precise information, enriched by images, that tell her what to do. Figure 47 shows a prototype of the digitised maintenance instruction sheet. Thus it is much easier for her to maintain all the machines, even the ones she maintains less frequently. With each step she is able to provide precise information on her actions without having to do time-consuming documentation. For example, after having checked a special part, she simply confirms the task by tapping on "Part OK" or "Part exchanged". The typical life cycle of a wear part is six months; nevertheless, Josephine has to check the attrition of that part every week, since she has no information with regard to when it was last exchanged. The new system allows dynamic adjustments of maintenance plans, which means that whenever she or one of her colleagues exchange a special wear part, the task of checking the attrition of this part will be asked for again in four months' time and not every week. By contrast, team leader Jürgen has a powerful and convenient way to not only check whether the maintenance work has been done properly but also to use the additional information provided by the system to discover and analyse special incidents. For example, the readjustment of a special measuring device usually has to be done each month, but when Jürgen takes a look at the new system he sees that the particular device has had to be readjusted three times the past week. Might this also have something to do with the high number of spoilt parts recently?

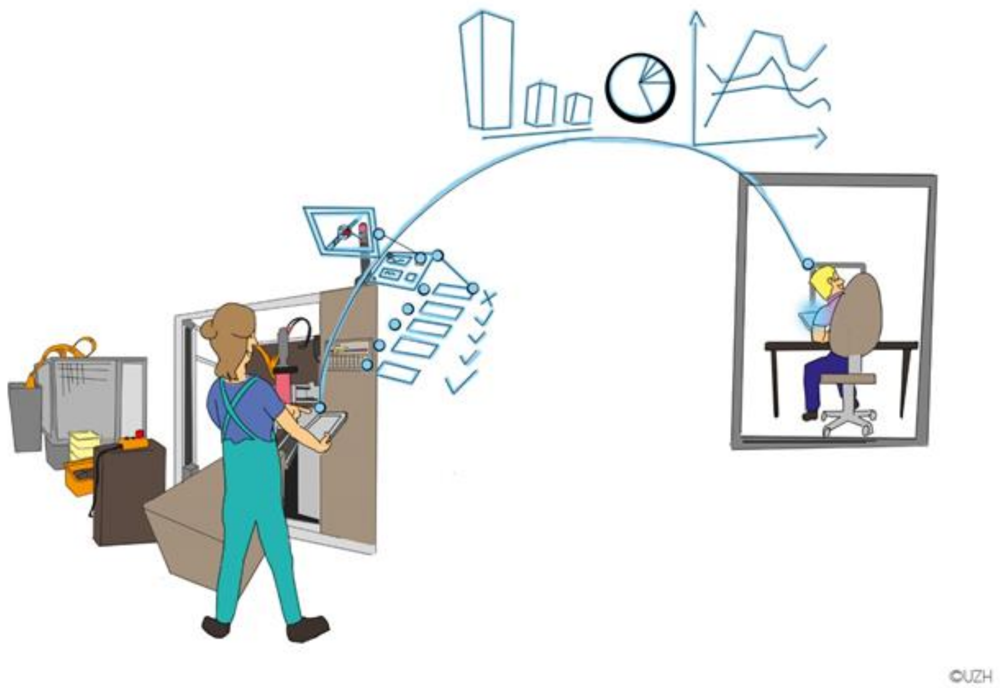

Figure 46: SCA2 - Activity Scenario 1: Integrated workflow control for maintenance work

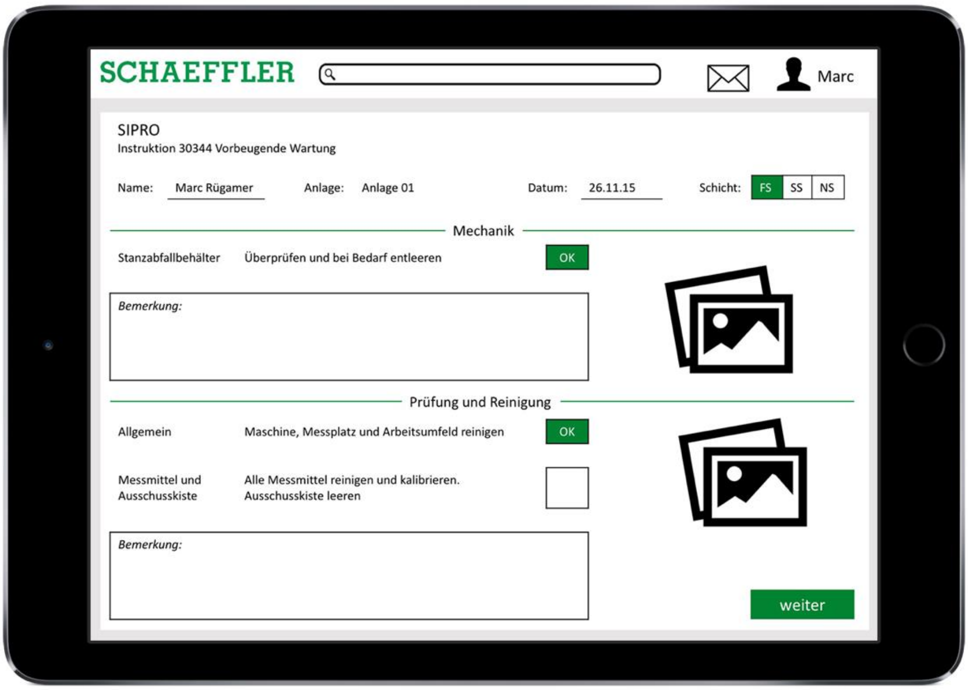

Figure 47: SCA2 - Prototype: Integrated workflow control for maintenance work

3.4.13 SCA2: Problem Scenario 2: "Issues documenting the shift in a handwritten log"

At the end of the shift, tool setter Marc documents important occurrences in the handwritten shift log. He also has to fill out a shift-handover sheet, on which he documents key issues concerning shift personnel, material, machines and further planning. Both processes are redundant, since almost the same information is being documented. For this reason, Marc sometimes only makes short records in the shift log and because of the lack of time at the end of the shift he often forgets to document incidents that occurred some hours before that might be important as well. Furthermore, the shift log is a simple paper notebook, so he cannot attach additional pieces of information such as special documents or photos, although photos could be useful to document spoilt parts. That can be a problem if he wants to look up similar incidents a few weeks later, as shown in Figure 48. The chance of finding a well-documented incident and learning from it is relatively low.

Figure 48: SCA2 - Problem Scenario 2: Handwritten shift log

3.4.14 SCA2: Activity Scenario 2: "Integrated digital shift logging"

At the end of the shift, tool setter Marc and his colleague Josephine document important occurrences in the integrated digital shift log. By contrast, Jürgen can also look up the provided information on his device (figure 49). The digital shift log contains not only Marc's manually entered information but also information automatically generated during the execution of tasks that were led by the system, e.g. tasks like maintenance work or retooling (figure 50). Moreover, the shift-handover sheet is integrated in such a way that it does not have to be filled out separately. A major advantage of the digital shift log is that all the entries, notes and status of completed tasks are being done in parallel with the processing of the tasks during the shift, and Marc does not have to take extra time at the end of a task or the shift to fill out documents. Additionally, it allows Marc to link documents and photos and thus provide a coherent view that includes all activities and incidents at a particular machine. Aggregated information is stored centrally and team leader Jürgen can access the data as well at any given time. This makes troubleshooting and problem analysis much easier and more efficient.

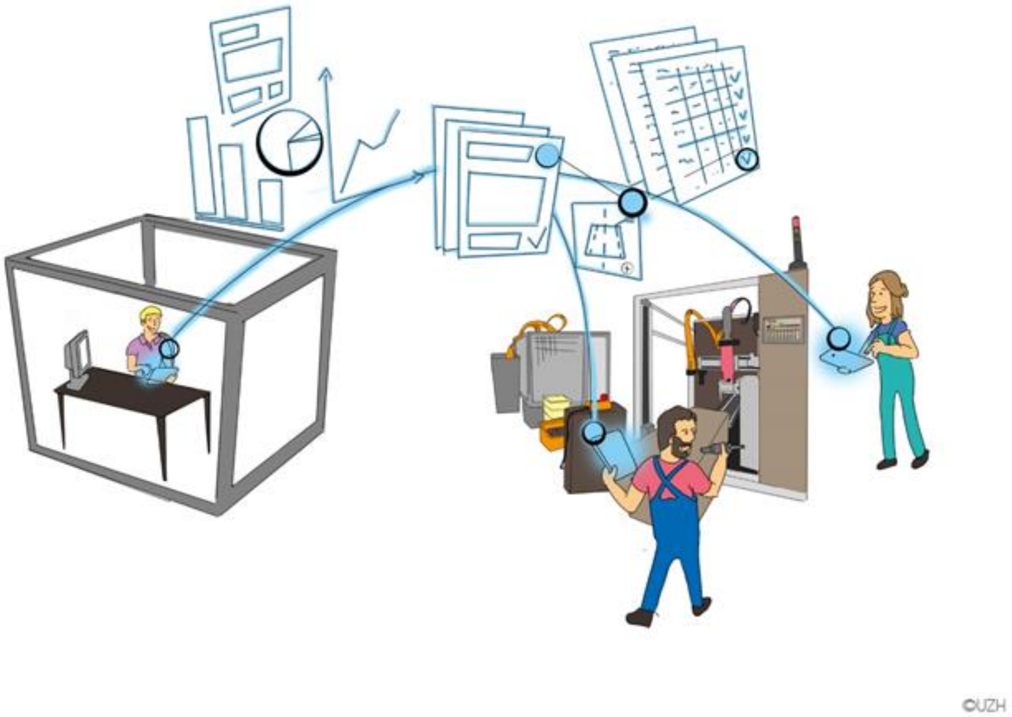

Figure 49: SCA2 - Activity Scenario 2: Integrated digital shift log

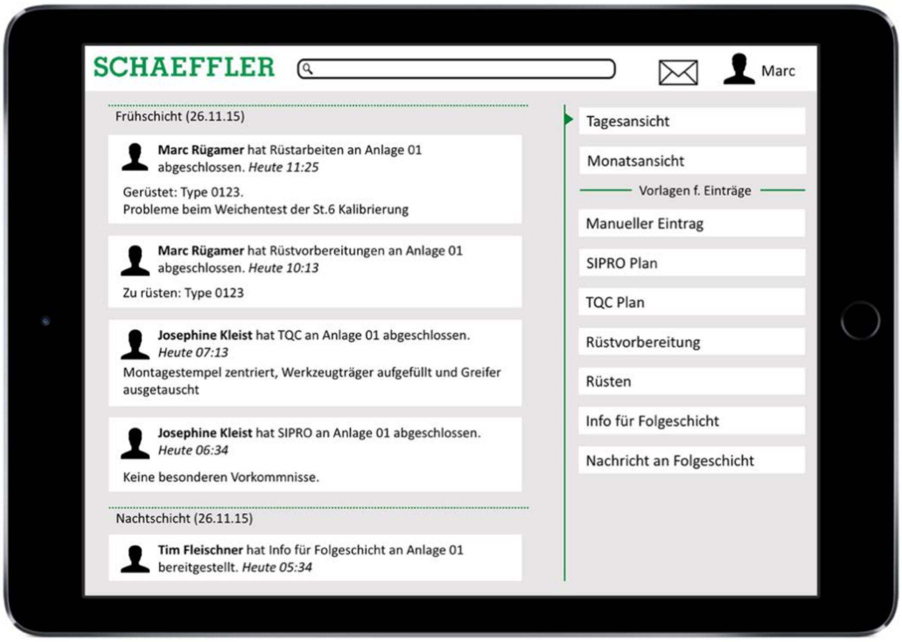

Figure 50: SCA2 - Prototype: Integrated shift log

3.4.15 SCA2: Problem Scenario 3: "Problems during the retooling of a machine"

Tool setter Marc has to retool a machine for a new type of product, so he prepares the machine for the retooling procedure. Every step must be documented in a separate "retooling preparation and follow-up processing" sheet, which has to be printed out and signed. The same counts for the "retooling script", a printed document of the steps to execute during retooling. Since Marc is an employee with considerable experience, he deals with many machines and even more types of products. From his perspective, finding and printing the right papers in this first step is a time-consuming effort.

Figure 51 shows Marc doing the retooling. He comes across a problem regarding the calibration of a specific measurement part, and he remembers that there was a similar problem during the same retooling procedure six months earlier. But what was it again, and is there any documentation about it? He cannot find anything in the standard "retooling script", so he looks for the relevant entries in the handwritten shift log, but to no avail. This leads to a loss of time and leaves Marc disappointed. He has to look for a new solution for the problem without being able to take advantage of knowledge that could be available if it was documented properly.

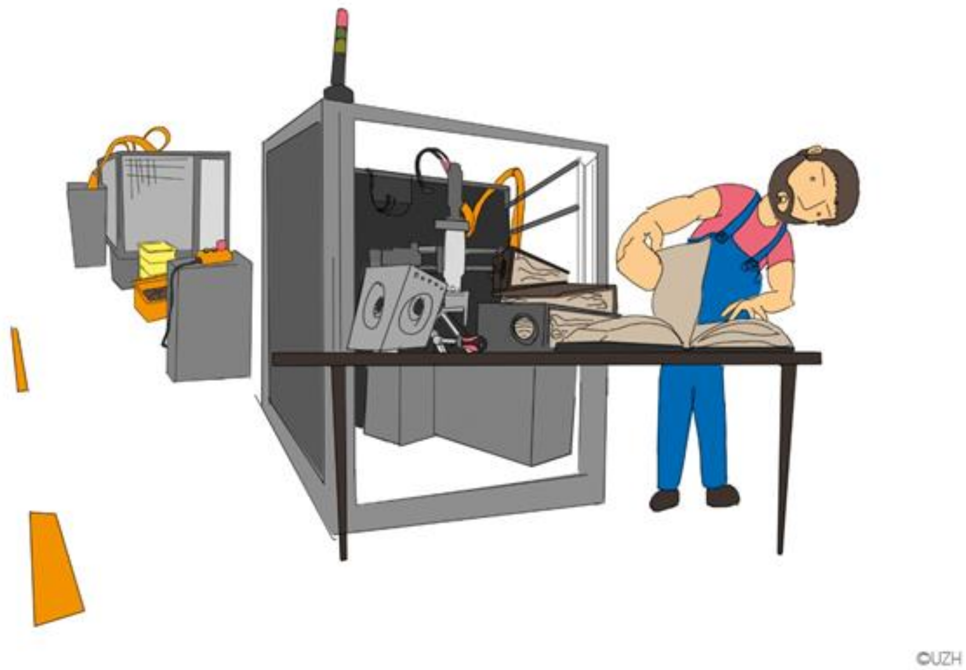

Figure 51: SCA2 - Problem Scenario 3: Problems during the retooling of a machine

3.4.16 SCA2: Activity Scenario 3: “Easy information access for retooling a machine”

Figure 52 shows Marc retooling with the help of his new mobile application. By selecting the type of product to be retooled, he makes it possible for the corresponding forms to appear automatically, without any tiresome searching and copying. He uses the digital template for “retooling preparation and follow-up processing” and sets his digital signature by simply clicking on “confirm”. The digital “retooling script”, which includes a pictorial supplement in addition to the text, guides him through the retooling procedure, and the template allows him to add notes and remarks. In other words, the execution and documentation take place at the same time and are integrated into the same form. Marc also remembers that there was a problem during retooling six months ago, and now he can use the new application’s “information archive” to look up all the information regarding the particular machine and the type of product (figure 53). Here he can choose between day and month view, and thanks to filtering options he has an optimal overview of which type has been processed, as well as when it happened and how long it look. He can also see whether any problems occurred and prevent possible new problems while retooling. Additionally, he can see all the shift log entries and pictures added concerning a certain order. The retooling procedure can be executed much more quickly and efficiently. Eventually, a new entry is automatically generated in the shift log according to the information that Marc provided during the task’s execution. This allows him to share his experience easily with other colleagues who can make use of it in the future.

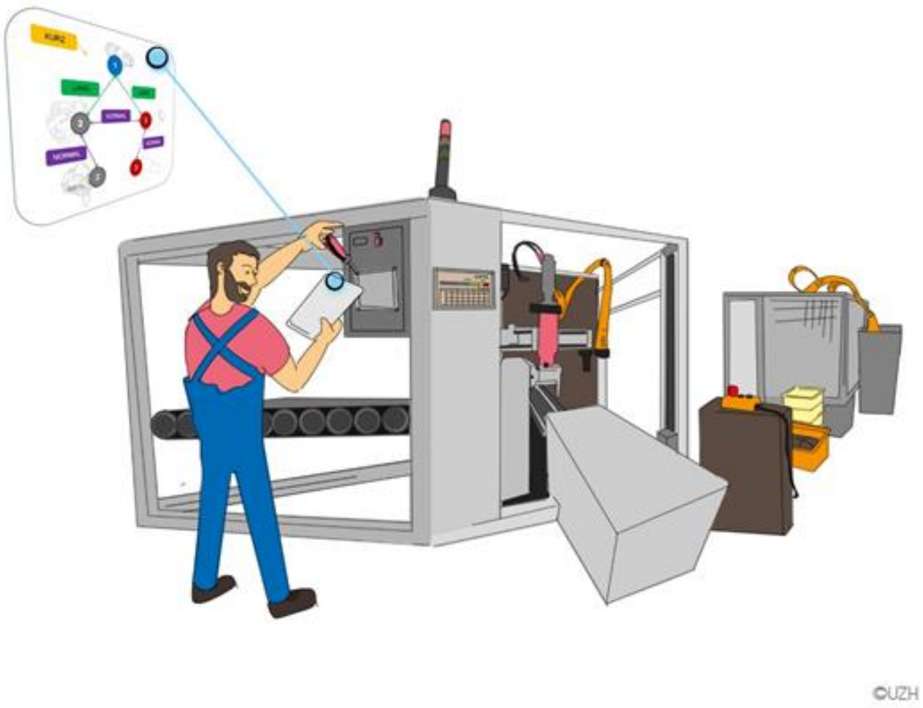

Figure 52: SCA2 - Activity Scenario 3: Easy information access to retool a machine

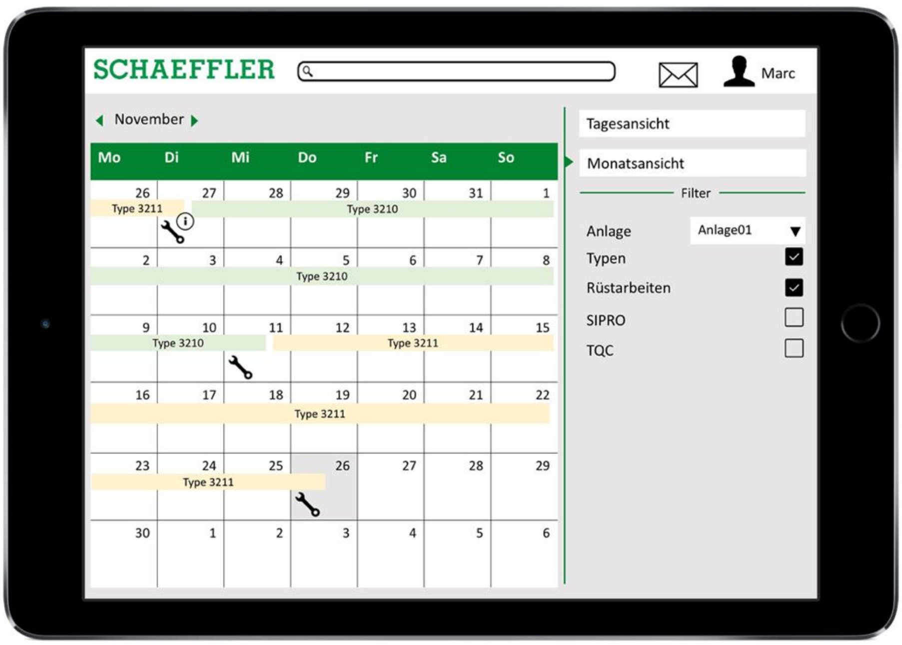

Figure 53: SCA2 - Prototype: Easy information access to retool a machine

3.4.17 SCA2: Problem Scenario 4: "Complicated workforce management"

Shortly before the start of the shift, team leader Jürgen has to draw up the shift schedule. However, he first needs to gather information about key production figures and attendance lists with all the sick certificates and "on vacation" notices before he assigns the employees to the machines they will be responsible for. He does this by putting prefabricated cards in the respective pockets on the board in his office. Jürgen has to consider special situations, for example when workers from his team are delegated to other assembly lines due to production bottlenecks or vice versa. Such situations must be coordinated with other team leaders as well as the product manager. After the schedule is finalised, operators and tool setters come to the team leader's office before starting their shift to get the information about their daily schedule, as shown in figure 54.

Figure 54: SCA2 - Problem Scenario 4: Complicated workforce management

3.4.18 SCA2: Activity Scenario 4: "Digital workforce management"

Shortly before the start of the shift, team leader Jürgen assigns the employees to the machines they will be responsible for by dragging the icon on the tablet into the corresponding field. He can choose and allocate statuses like "workplace not staffed" if some workers take sick days, are on vacation or have been delegated to other assembly lines. If additional staff is called for in the assembly line that falls under his responsibility, he can mark this workplace as "multiple staffed". The shift plan will appear on a central screen on the shop floor, so that operators and tool setters can check today's schedule directly and start working at their machines, as shown in figure 55. All possible updates during the shift also appear onscreen. Additionally the digital workforce management allows faster and more efficient ways of communicating with the HR office. Information on who was working at which machine is stored centrally in the system. This leverages transparency and makes it easier to find out whom to address if problems occur that correspond with past incidents.

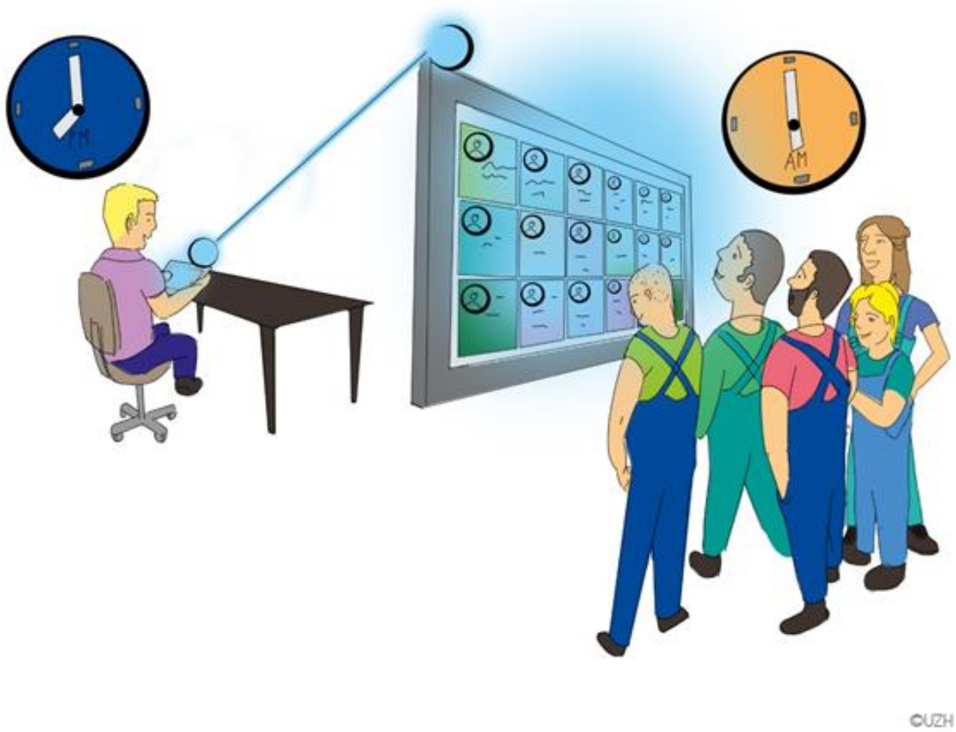

Figure 55: SCA2 - Activity Scenario 4: Digital workforce management

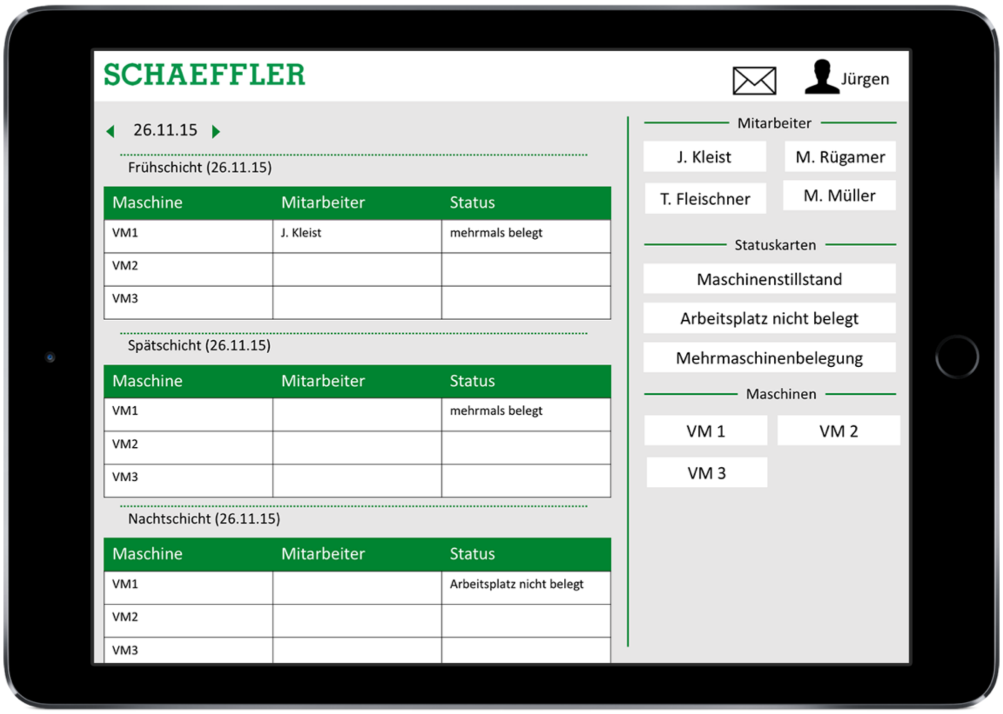

Figure 56: SCA2 - Prototype: Digital workforce management

3.5 Thermolympic

Thermolympic (THO) is a family-owned business that has been in operation since 1971. It has 60 employees and is based in Zaragoza, Spain. THO is a specialist in the field of thermoplastic injection moulding. It also designs and constructs the moulds used in this process. THO produces complete pieces or processes prefabricated work pieces as well as piece components. The components are assembled into intermediate or final products before they are shipped to the customer. THO's customer base ranges from original equipment manufacturers in the automotive industry to suppliers of end-consumer products for supermarkets. THO aims for maximum production quality and works in close cooperation with its customers from the simulation and design activities to the actual manufacturing process and, finally, to the quality control and shipping. The biggest challenge is that much information is not yet digital, and therefore most of the information quickly becomes outdated. Therefore, THO mostly wants to improve real-time data collection and analysis.

3.5.1 THO: Personas

In the following scenarios, a quality manager, a team leader and different kinds of workers are the main characters. Please meet Carla, Jose and Eduardo.

Carla	Jose	Eduardo
Worker	Quality manager	Team leader

Figure 57: Relevant personas in this context-of-use

Carla, a 42-year-old pick and place worker, has been working at THO for the past five years. On a normal workday, her team leader schedules her for a machine, and during the shift change the previous worker tells her whether anything unusual has happened. Depending on the machine, Carla works either alone or with worker. It is very important to Carla not to make any mistakes. Sometimes she gets frustrated, however, because the machine works so fast that she cannot work without making mistakes. If any problem occurs, she tries to write down all the relevant information on an information sheet. However, she does not solve major problems on her own but relies on other persons to do so. She has regular contact with her co-workers, her team leader and between 10 and 20 other workers.

Eduardo, who is 32 years old, is one of the team leaders and is mainly focused on keeping the production running. After the morning meeting and speaking to the team leader of the previous shift, he changes the moulds in the machines and maintains the machines after the change, if necessary. He also helps as soon as there is a problem with the machinery, until he hands the machinery over to the next shift's team leader. Because of his wealth of experience, Eduardo's colleagues regularly ask him for help, and consequently he often cannot fully concentrate on his tasks. However, he cannot fully rely on the data he gets either, because he knows they are sometimes inaccurate because of the circumstances. This can be frustrating. When making decisions, Eduardo often listens to his gut feeling. Working on a computer takes a moderate amount of time on a normal day but is necessary to document changes and problem solutions. It is important for high production quality, but some of his colleagues do not consider working on a computer as "work".

Jose is a 35-year-old quality manager who never has a normal working day, as he declares himself. He is very motivated and wants to be successful and to earn the respect of his colleagues. He tries to learn something new from each problem. He plans his workday based on the morning meeting, the latest emails and error reports. He is there to document, analyse and solve a variety of problems on the shop floor. If there is a problem, he grabs a work piece, takes pictures, talks to managers and tries to come up with a solution. Owing to his engineering studies and technical knowledge, he can often fix problems by himself or by talking to experts. Afterwards, the solution is meticulously documented. Information is his foundation, and he is not satisfied when there is not enough information available about a problem. As a result, he has to ask co-workers or investigate on his own in a creative manner. In various aspects, information and communication technology is already a common tool in his daily routines.

3.5.2 THO: Problem Scenario 1: "Issues with manual measurements"

After the morning round, Carla has to assess the product quality of various machines on a sample basis by checking whether specific dimensions are within the specifications. She starts by sorting the parts that have been produced, using an appropriate instrument to take different measurements of each part manually and writing down the results manually as well. Afterwards, she pins up the documentation of her work. Measuring many different parts is a tedious use of her time and can lead to errors because of a lack of concentration or when switching between different products or machines. Further errors occur when the machine works very fast and produces more parts than Carla can measure accurately. As she wants to make no mistakes, she needs a certain amount of time per piece. Beyond a certain machine speed, Carla struggles to hold up the throughput. This high amount of manual work leads to a great deal of problems. Altogether, her results are only 90% correct in terms of quality. However, this is not noticed on the whiteboard at the time, because her handwritten results are only checked once a week.

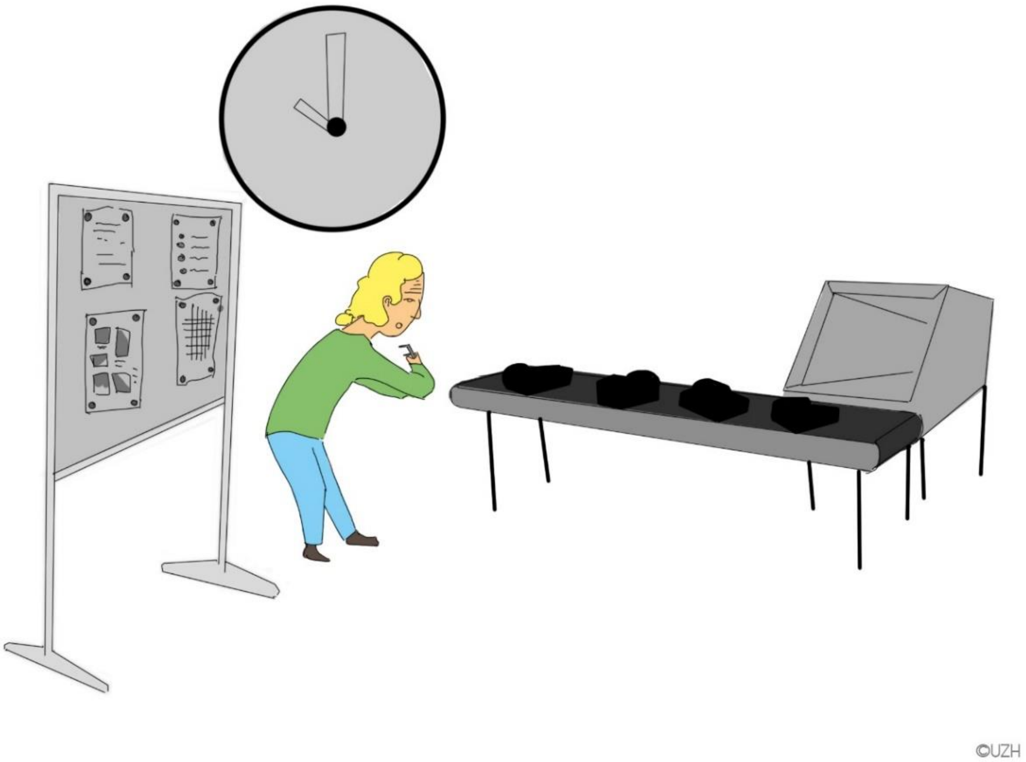

Figure 58: THO - Problem Scenario 1: Issues with manual measurements

3.5.3 THO: Activity Scenario 1: "Automatic measurement reduces job pressure"

THO has successfully introduced the novel Facts4Workers (F4W) solution, and Carla has just obtained a F4W tablet and login with her credentials. When she arrives on the shop floor, something looks different. The machine has a new automatic measurement module. This module measures all produced parts on the basis of the specifications obtained via the THO quality cloud and based on an internal web service. Carla's job is quite similar, which is good for her as she does not like changes very much. She still has to sort the parts before measuring and take the measurements of the produced parts. But now she only has to care about parts that did not pass the automatic measurement. Her tablet tells her which parts are faulty, displays all the measurements and highlights where the error occurred on the part. She manually checks the measurements again and decides whether this really is an error on the product or a mistake that the measurement module made. She documents her results and decision on the tablet. She can also contact another worker or team leader if she has to discuss certain aspects. As Carla only has to handle faulty parts, she can keep up the pace while holding up the quality level. All measurements, either taken automatically by the module or manually by Carla, are immediately stored in the THO quality cloud and are ready to use for other processes or evaluations. The F4W tablet also gives Carla the possibility to report new and as yet unknown errors.

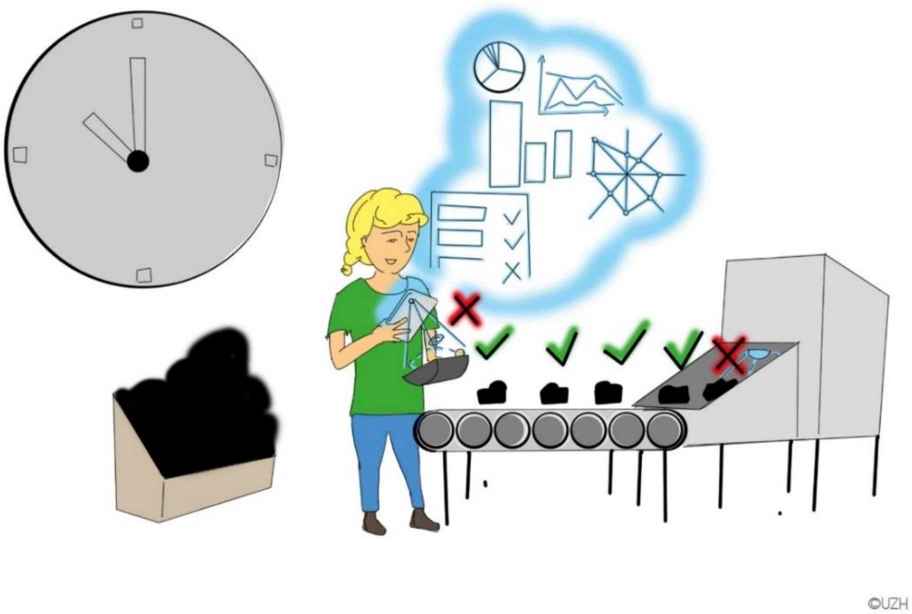

Figure 59: THO - Activity Scenario 1: Automatic measurement reduces job pressure

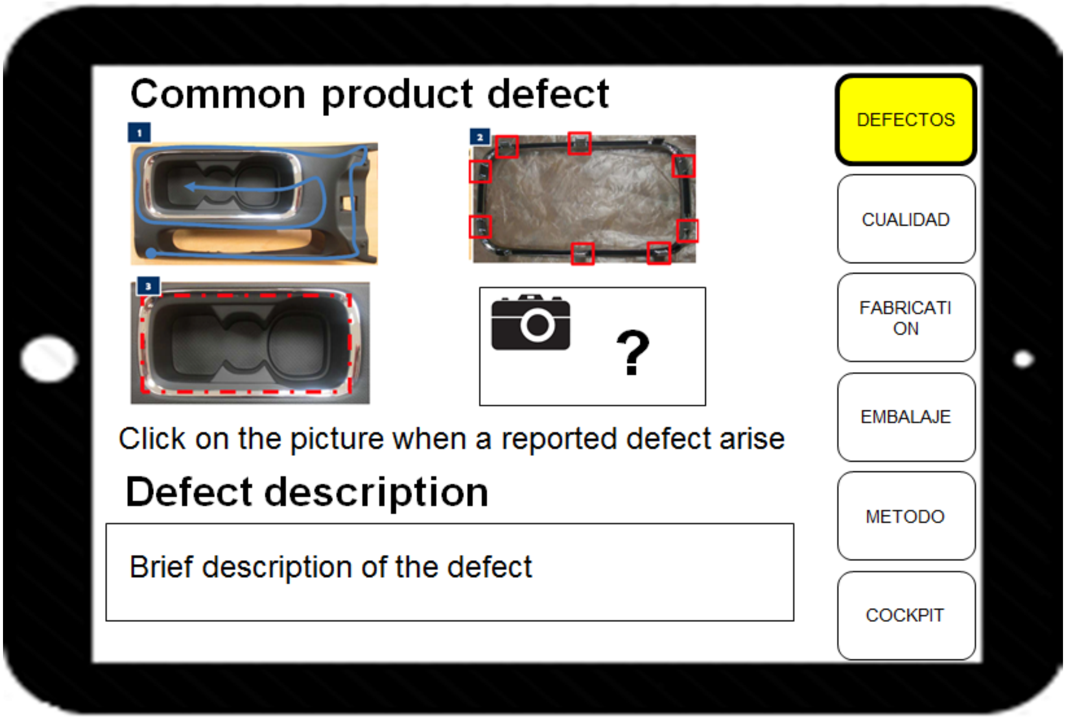

Figure 60: Mock-up of product defect report

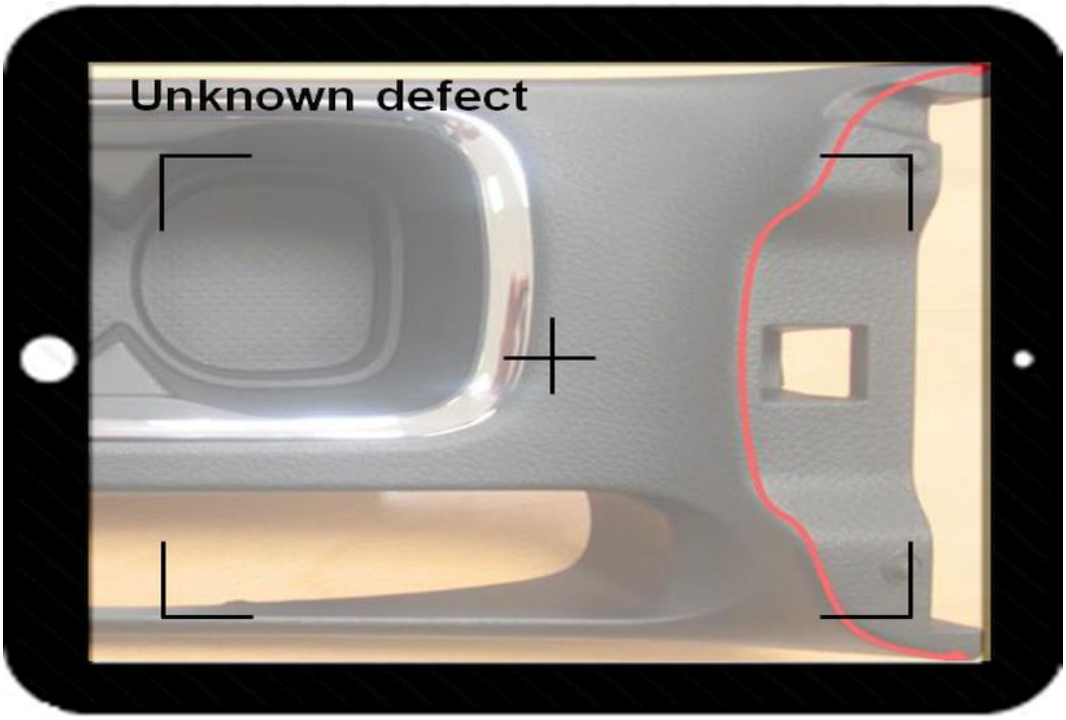

Figure 61: Mock-up of manual measurement view

3.5.4 THO: Problem Scenario 2: "Fixing the production of faulty parts"

Carla is working on a machine and is taking the measurements as per usual. Lots of parts are out of spec, and she realises that the machine is producing faulty parts. This is an emergency situation, and Carla immediately looks for Eduardo, the team leader, as she cannot fix the problem by herself. Eduardo stops the machine. Together they analyse the faulty parts and try to figure out the reason for the problem. In the meantime the machine stands still, and THO is losing precious production time. If it is a common error, Eduardo knows what to do and can adjust the machine accordingly. If the error is not so common, Eduardo has to test various settings on the machine to correct it. In both cases, Eduardo first has to inspect and analyse the documentation of the latest parts manually and then rely on his gut feeling and engineering skills to solve the problem.

Figure 62: THO - Problem Scenario 2: Fixing the production of faulty parts

3.5.5 THO: Activity Scenario 2: "Database simplifies decision making"

Carla is on the shop floor handling faulty products when she realises that the machine is producing the wrong parts in massive quantities. This is an emergency situation, and Carla now looks at her tablet, which displays the current error in an overview with a useful description. The tablet is also connected to the THO quality cloud and analyses the errors in real time. Therefore, the tablet notifies her that this has to be a mechanical error. Because the tablet also knows the machine settings and the solution to this kind of error, it tells her how to adjust the machine. Carla does not need to stop the machine but can solve the problem on the fly on her own. If the problem is more serious, she can contact the previous worker on this machine or the craft master via the tablet and ask them for more information or help. Furthermore, the error warning and all the changes made on the machine are automatically documented and sent to quality management in real time. Hence they are aware of this issue and can intervene if necessary. Because everything is documented permanently, there is an improvement in quality management, error analysis and error handling in the future.

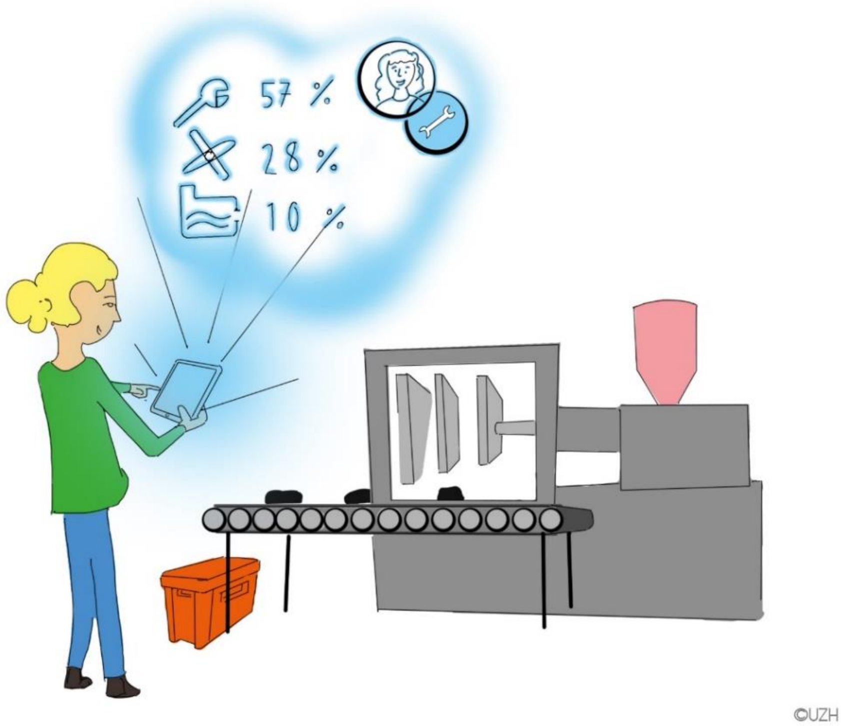

Figure 63: THO - Activity Scenario 2: Database simplifies decision making

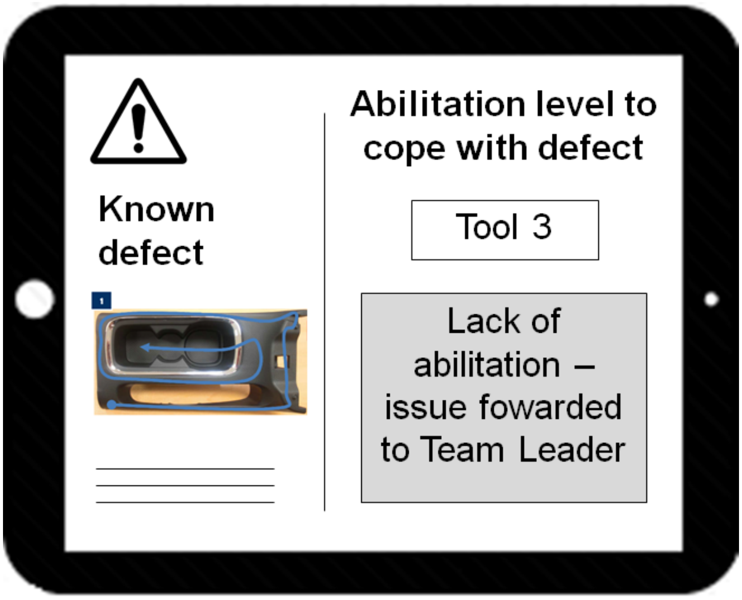

Figure 64: Mock-up of error description

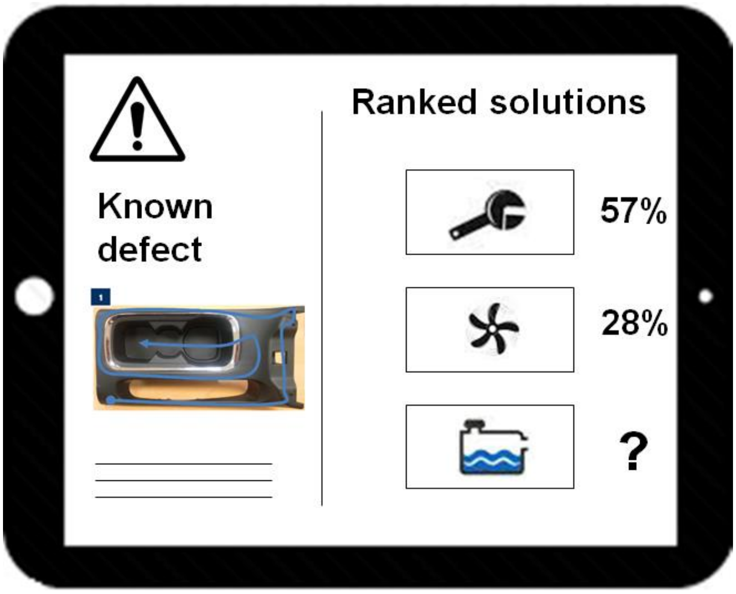

Figure 65: Mock-up of solution recommendation

3.5.6 THO: Problem Scenario 3: "High barriers for 'in-between' learning"

Carla is operating the machines as usual and checking parts for errors on a sample basis. Today, she is faster than the machine and wants to spend the "saved" time in between for some self-improvement. She wants to enhance her knowledge about the machine that she is operating. The only information available and within reach is printed on a large, inconvenient sheet of paper that is fixed to a wall nearby. The plan is outdated and does not consider the latest moulding modules or machine settings; it is also yellowed and not easy to read. Furthermore, the plan is fixed to a wall from where Carla cannot keep an eye on her current production line. Owing to these conditions, Carla's motivation to learn something new is nipped in the bud, and she turns around and walks back to the production line.

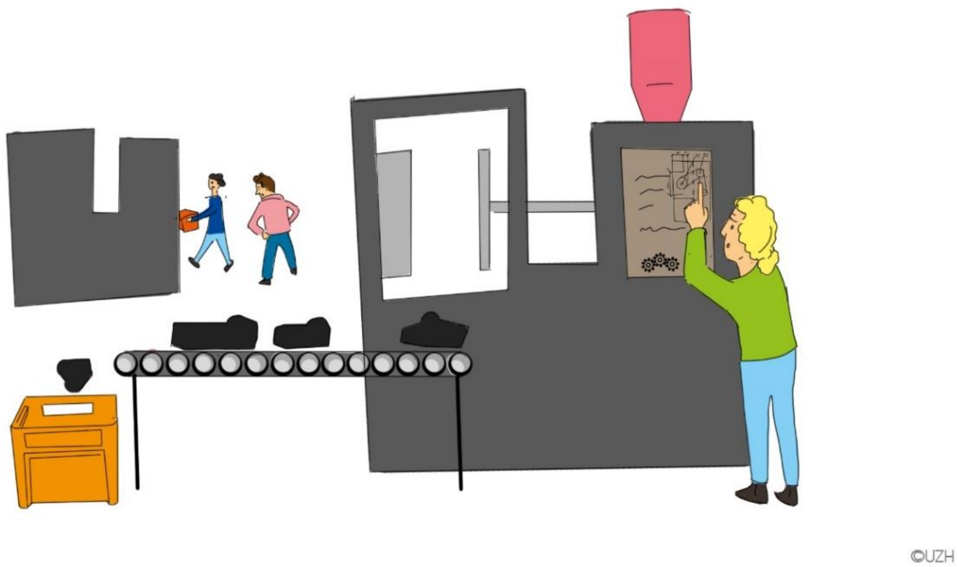

Figure 66: THO - Problem Scenario 3: High barriers for 'in-between' learning

3.5.7 THO: Activity Scenario 3: "Self-paced training on the job"

Carla is operating the machine as usual. Because she only has to handle the faulty parts, she has some "saved" time now and then. She wants to use this time to improve her knowledge about the machine she is working on. She takes her F4W tablet and opens the details about the current machine, but she can select other machines as well. In the application on the F4W tablet, she can learn about the machine and the production process on various levels of detail supported by rich media in the form of textual description, pictures and interactive videos. The application also shows the current combination of moulding module, machine configuration and error statistics, so that Carla can get a better understanding of critical combinations. She does this more often now because she can learn on her own and at her own pace. Furthermore, she can use the tablet right next to her production line while still keeping an eye on the work. The tablet also notifies her if some parts show an error, so she will not miss it.

Carla is especially interested in the final steps of the process, as this is where she gets involved. Owing to her long-term experience, she notices two tiny things that she would change, making her life easier and speeding up the process, too. She wants to make a suggestion to improve this, but she does not want to write it all down, because she has no time for this and is not used to writing on tablets. Carla just tags the last machine part as "improvable". Before the end of her shift, her line manager sees this flag and talks to Carla about her suggestion. At the end of the shift, Carla is happy because today she could learn something new and was able to contribute with an improvement that will ease her task from now on.

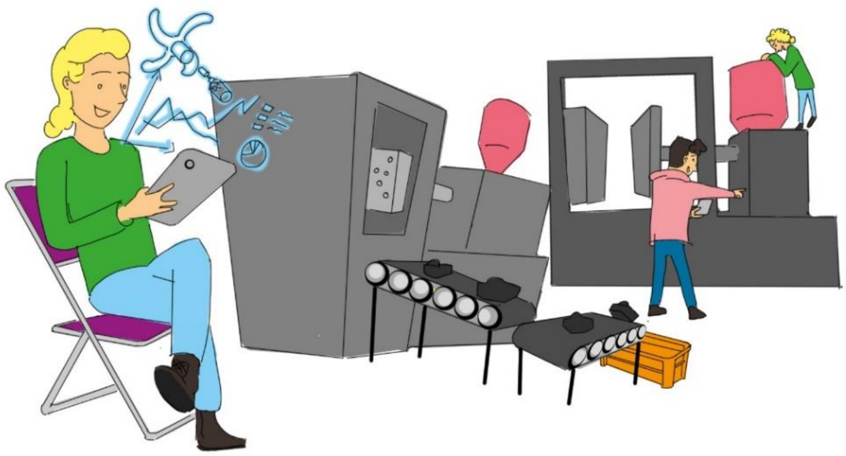

Figure 67: THO - Activity Scenario 3: Self-paced training on the job

3.5.8 THO: Problem Scenario 4: "Missing trustworthy data"

Jose, the quality manager, has a meeting with management. He presents the latest data from the shop floor. However, the data set is already a week old. All of it was manually measured, written down by hand and then transferred to several Excel sheets, and different persons were involved in this process.

These data give the management a rough idea of what was going on last week, but everybody knows that this data set is somewhat faulty and therefore not 100% reliable and already out of date, too. Therefore the management can only guess and rely on their gut feeling as to what could be the biggest issue right now. Because of this situation, they are very conservative when planning the next product line and promise to deliver only small quantities. This underperformance will have an impact on their annual revenue.

Figure 68: THO - Problem Scenario 4: Missing trustworthy data

3.5.9 THO: Activity Scenario 4: "Evaluating real-time data"

Jose, the quality manager, has a meeting with management. He is proud to present the latest data from the shop floor, because he can present accurate statistics and live data collected by different F4W solutions, like automated error reports. Owing to the high accuracy of the data, a clear representation and various ways of analysis, the management team quickly discovers that certain mechanical problems occur often during the summer time. This leads to the idea to invest in (better) air conditioning. A simple simulated production process under improved temperature conditions shows much better results.

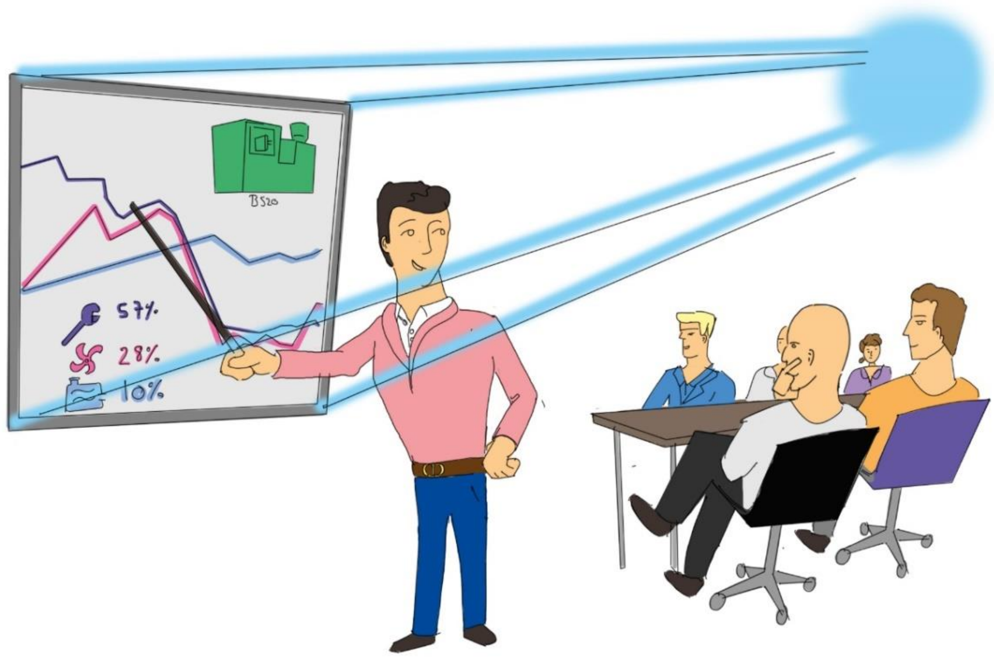

Figure 69: THO - Activity Scenario 4: Evaluating real-time data

3.5.10 THO: Problem Scenario 5: "Unhandy guidelines and incomplete technical drawings"

The production line changes, and along with it Eduardo has to reassemble the injection moulding machine. THO introduced a new product, so the injection mould module is new to him. He has to look at each part's technical drawings and specifications. However, they are quite bulky and unhandy, and the important part is always on a fold and therefore not easy to read. Furthermore, the plans do not consider the custom-made parts in the machine. He therefore requires several attempts to assemble everything correctly. He also has to make some adjustments that were not described in the technical drawings. So far he is the only person available who knows this, and there is no opportunity for him to document this change appropriately. Altogether he has to stop the machine for at least half an hour until the production line is ready again, and he cannot document the whole process at the high level of detail that he would prefer.

Figure 70: THO - Problem Scenario 5: Unhandy guidelines and incomplete technical drawings

3.5.11 THO: Activity Scenario 5: “Detailed guidelines increase reassembly speed”

The production line changes, and along with it Eduardo has to reassemble the injection moulding machine. THO has introduced a new product, so the injection mould module is new to him. Eduardo looks at his F4W tablet, which holds all the necessary information about the assembly process. Next to the technical drawings, on which he can zoom in to the level he prefers, there are also two small movie clips. They demonstrate the tricky steps during the repositioning of the new mould module in a very comprehensive way. Furthermore, the reassembly process is described in detail and annotated with comments from colleagues and other team leaders who explain how to carry out the tricky steps. If these comments are not sufficient, Eduardo can also contact the author directly via text chat or request his attendance at the machine, all by using the tablet. Eduardo can now document every step of the process with the help of a checklist and additional photos and comments if necessary. As a result, Eduardo can skip the trial-and-error process and assemble the machine in no time. He also improves the documentation, so that next time he will be even faster.

Figure 71: THO - Activity Scenario 5: Detailed guidelines increase reassembly speed

3.6 ThyssenKrupp Steel Europe: Problem-solving support for mobile maintenance workers

ThyssenKrupp Steel Europe AG (TKSE) is a leading supplier of carbon flat steel products. Approximately 19,500 employees manufacture high-quality steel products for innovative and demanding applications in various industries. Customised steel material solutions and services complement the business activities. TKSE values the knowledge of skilled workers as a crucial factor in meeting constantly increasing demands for quality and efficiency. Simultaneously, these demands also increase the work complexity. A decreasing number of employees and shorter familiarisation phases of young employees require continuous operational and extra-occupational development of the employee knowledge and competencies.

3.6.1 TKSE: Personas

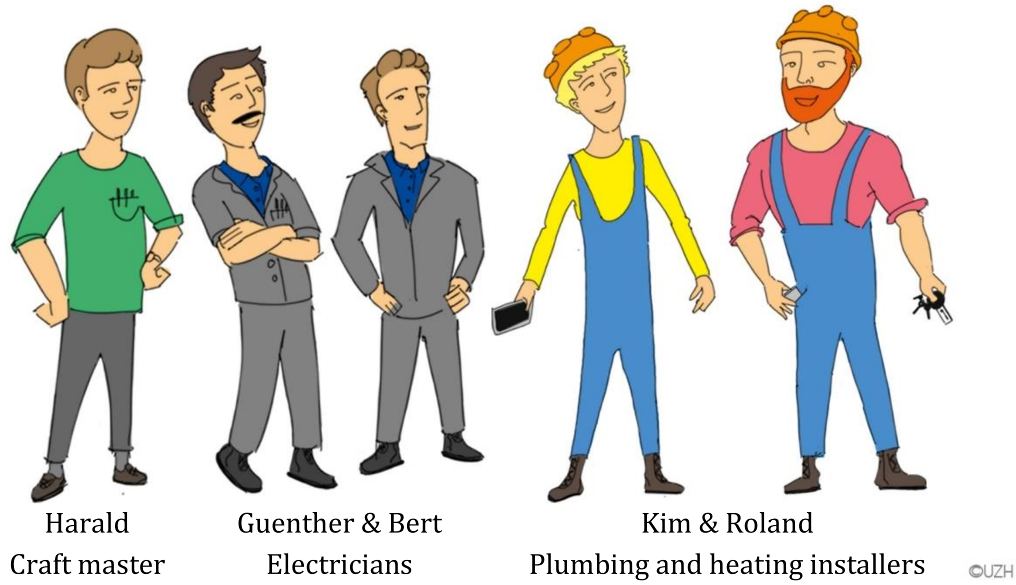

Figure 72: Relevant personas in this context-of-use

Kim is a 22-year-old plumbing and heating installer who started working at TKSE a few months ago. Kim wants to work in a modern environment, and sometimes he struggles with the given tools and the established practices. He wants to work autonomously and does not like to ask his senior colleagues about every detail. Kim is a practice-oriented worker, and in the decision-making process he trusts his gut feelings.

Roland is a 53-year-old plumbing and heating installer who has been working at the company for some 30 years. For Roland it is most important to feel like part of the company and to have the freedom to organise his daily work on his own. In terms of gathering information and in the decision-making process, Roland is nearly as practical and beliefs-based as Kim.

Harald is a 39-year-old craft master with a wife and children. He works as a plumbing and heating installer. This means that he works on measurements, regulations, control, electric and compressed air technology and sometimes does some maintenance work. His most important goals are to avoid problems and to be respected by his co-workers.

Guenther (34) and Bert (38) are both electricians, and with their deep knowledge they assist our main protagonists, Kim and Roland, if needed.

3.6.2 TKSE: Problem Scenario 1: "Start shift – missing contextual information"

Figure 73: TKSE - Problem Scenario 1: Start shift – missing contextual information

At 6 a.m., the morning shift begins. Craft master Harald is already in the tool shop from 5:30 a.m. and starts dispatching the maintenance list and defect reports to the workers at 6 a.m. Harald seldom has the time to prepare all work packing as he wished, because he does not receive all the information he requires. As a result, Kim and Roland sometimes lack crucial pieces of information about the unit of equipment:

1. Has this fault arisen before?
2. Who was the last person to maintain or patch the unit of equipment?

3. Which tool and which protective equipment is necessary?
4. Are there plants that should be handled as a priority?

The workers spend most of their time discussing how to get the needed information instead of talking about priorities and the problem itself. Often Kim and Roland have to take double ways because of missing spare parts or an unexpected situation at the plant. When Karl sees Kim getting frustrated, he says: “It was always like this; get used to it!” Craft master Harald occasionally thinks about a better solution to distribute the work and information, but daily life does not provide the time or material that is required.

3.6.3 TKSE: Activity Scenario 1: “Beginning of a shift – an informed start”

Figure 74: TKSE - Activity Scenario 1: Beginning of a shift – an informed start

6 a.m.: Morning round. Craft master Harald discusses the working packages briefings which he has already prepared and sent to his colleagues’ smart devices. He uses the F4W solution to prepare the working packages, for example by adding the needed context information to the fault messages. Among other things, the briefings include the following information:

1. Required tools and protective equipment
2. Maintenance history

When logging in to the F4W solution with one of the tool shop tablets, Kim sees his personal dashboard. His craft master just uploaded all the relevant work packages for Kim’s shift. Kim downloads the work package briefing, which is essentially a list of places where he and Roland will have to fix specific issues. When the craft master comes by to talk to Kim and Roland, they go through all the problems and think about how to solve them. By setting priorities, Kim and Roland can optimally prepare themselves for the work day. Thanks to the F4W solution, Kim and Roland can see which spare parts are needed or important during their shift and put them inside the transporter.

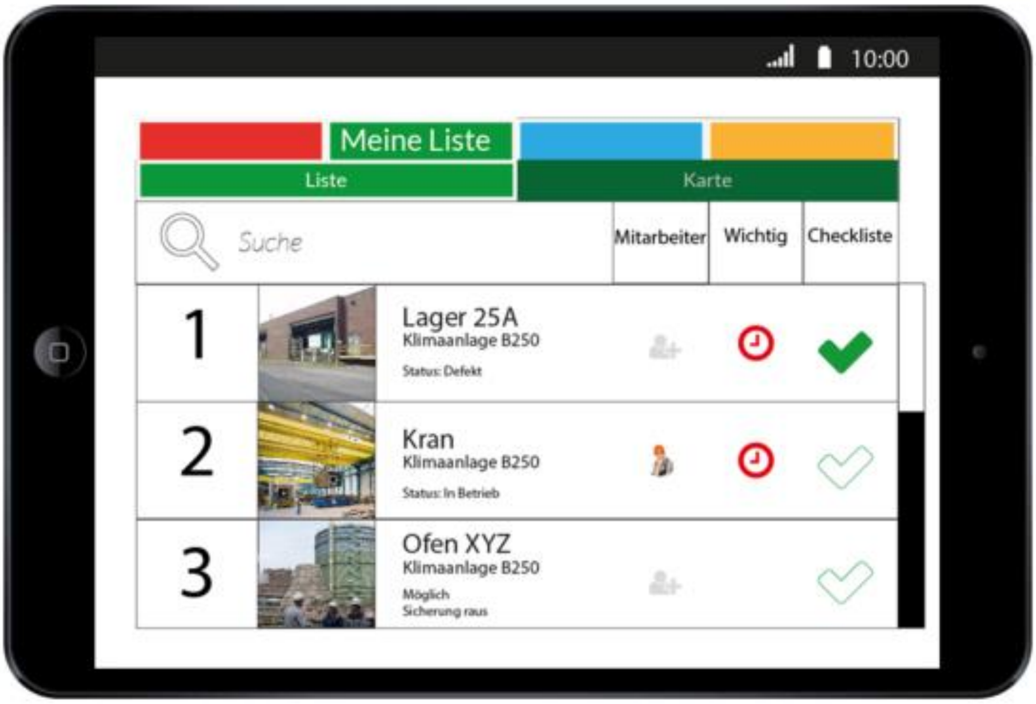

Figure 75: TKSE Mock-up: My List (Meine Liste)

Figure 75 shows how Kim can prepare his work day with the "Meine Liste" (my list) function.

In conclusion, this less paper-based process gives Kim and Roland enough time to discuss the problems themselves and not how to get the needed information. Kim says: "Now we have the required information at our fingertips." Roland knows most of the facts, but from time to time he is impressed with what the "modern telephone" knows.

3.6.4 TKSE: Problem Scenario 2: "Plans are changing – missing orientation"

Kim and Roland just finished their plans for the shift and are on their way to a planned maintenance assignment. The phone rings: Emergency! A defective air conditioner at a production plant has caused a complete standstill. Right now, between 20 and 30 workers are unable to work. Every minute is precious, and the company is losing real money. Besides this time pressure, there is one more challenge: Kim and

Roland are not very familiar with the air conditioner and its plant, even though Roland tends to know almost every corner of the TKSE work premises.

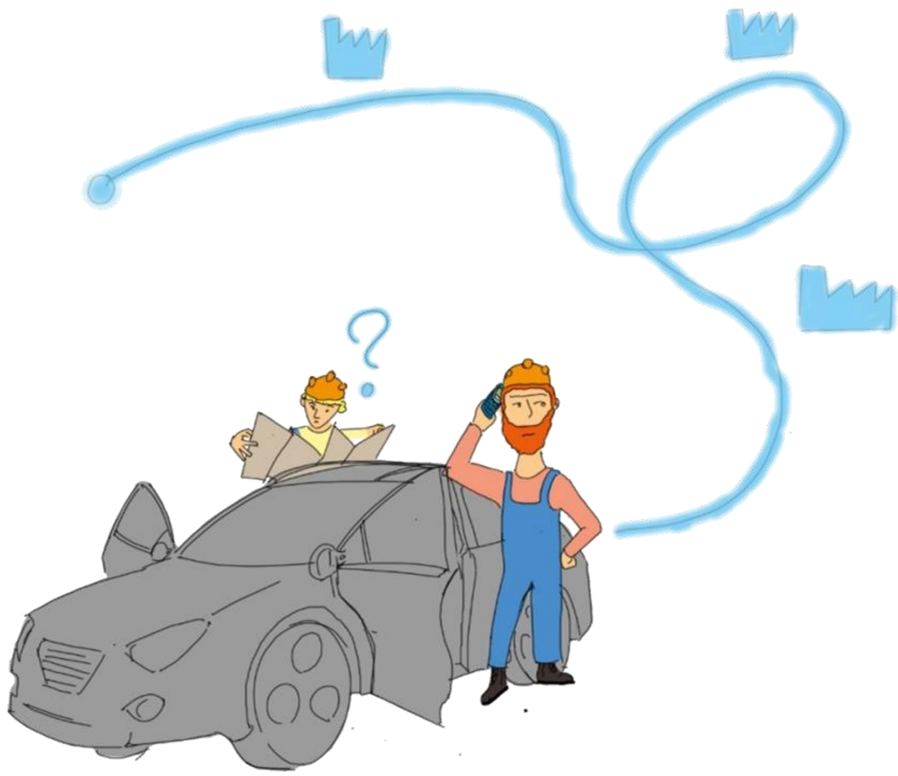

Figure 76: TKSE - Problem Scenario 2: Plans are changing – missing orientation

Now Kim and Roland have to find the way to the plant and of equal importance the right person for security check-in and detailed information. While Kim tries to find the production site with a work plan, Roland picks up the phone and calls some colleagues. The expert for that specific unit of equipment is not available, because he has the day off. Roland calls different colleagues to find out who knows the right person. Information problems like these are very annoying for Kim, who can do nothing but wait. It takes over 15 minutes before Roland gets the number of a colleague who can help – at first, however, he only reaches his voicemail. Another 15 minutes later, the colleague phones back – he was in a basement room without a connection – and explains the way to the production site and where to find the contact person. It is not so easy to get all the information via telephone, so at the production site Roland calls the colleague again to get information about the last 100 meters to the exact location.

Finally, about 45 minutes later, Kim and Roland can start to repair the air conditioner, but an important spare part is missing. So they have to drive back all the way to the tool shop.

3.6.5 TKSE: Activity Scenario 2: "Guided route"

Kim and Roland just finished their plans for the shift and are on their way in their company team car to a planned maintenance assignment. The mobile phone rings: Emergency! A defective air conditioner at the production plant! Standstill! …

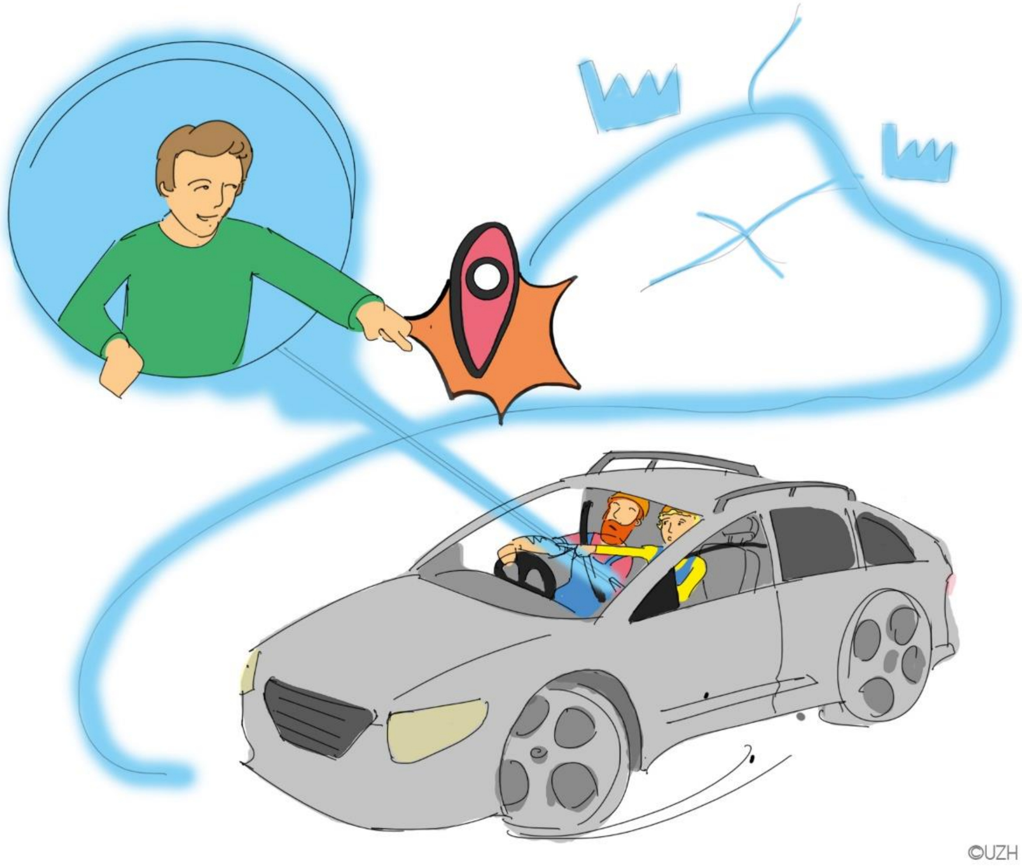

Figure 77: TKSE - Activity Scenario 2: Guided route

Thanks to the F4W solution, Kim can easily find all the important information about the air conditioner, its location and the contact person for security check-in. Kim tells Roland where to go. Meanwhile Kim takes a look in the air conditioner's log-book to see where he can find the information about the last maintenance and repair action that was carried out on the air conditioner. He gets a rough overview and advises Roland to stop at the tool shop to take some special fuses, because the last three times these fuses were the cause of the problem. Within 20 minutes, Kim and Roland arrive at the site, get a quick briefing by the contact person and can fix the issue with the fuses they brought with them. All in all, it takes 45 minutes from fault message to resolution – that is the way Kim likes to work. Roland says "the new map view solution of the plant is really good" and smiles.

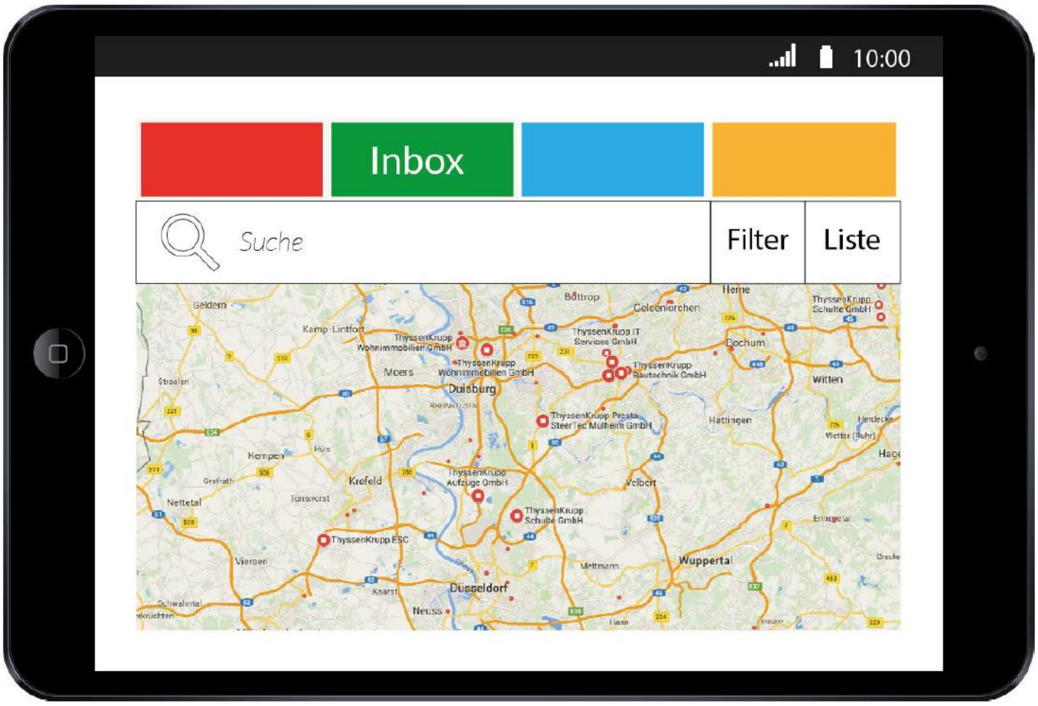

Figure 78: TKSE Mock-up: Map view

Figure 78 shows the map view of the TKSE factory site. Kim and Roland can use the map for navigation and orientation issues.

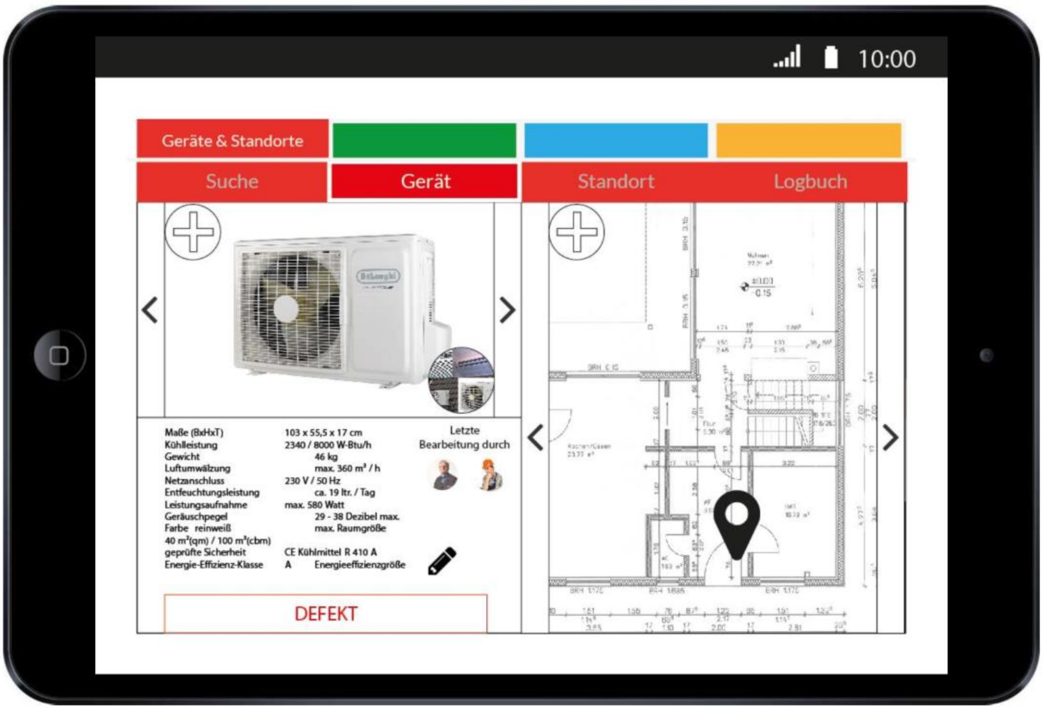

Figure 79: TKSE Mock-up: Detailed information about a device

Figure 79 shows the overview of a special device. In this case, it shows detailed information about an air conditioner. This information originates in the internal ERP system. Here Kim and Roland get a quick overview of the most important facts of the machine, contact person and location. With this information, they can prepare the maintenance work more easily.

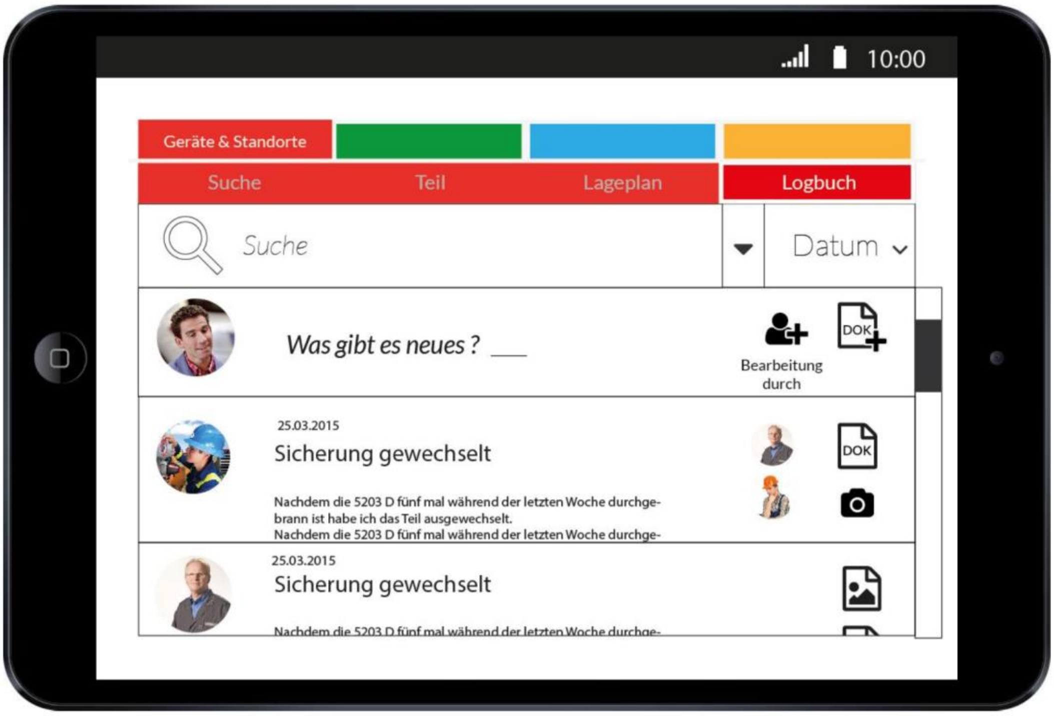

Figure 80: TKSE Mock-up: Logbook of an air conditioner

With the logbook, which is shown in figure 80, Kim and Roland get a quick but deep overview of the most recent changes made to the air conditioner. With that information in mind, they optimise their preparation for the maintenance work even more efficiently. After each work assignment, they contribute to the intended logbook with a text message and optional attached video or pictures.

In summary, it can be noted that the F4W solution is an assistant for daily work on the factory site. It helps Kim and Roland to find the right location more easily and even more important to be prepared for the maintenance work at the device on site.

3.6.6 TKSE: Problem Scenario 3: "Repair – missing support"

It is 1 p.m., and Kim's and Roland's shift is almost over, but there is one last issue on their list: An air conditioner at an important production site is not working reliably. Kim puts off the coverage and quickly sees what the situation is: "Roland, that is a case for an electrician." Roland says: "Well, I will try to get one on the phone, but their shift is also almost over…" A few minutes later, Roland talks to Bert, the electrician. He would like to help them, but he is working on an emergency issue at the company headquarters and cannot assist right now, even if the device requires only a quick look.

So Kim and Roland leave the plant without having achieved anything and go back to the tool shop.

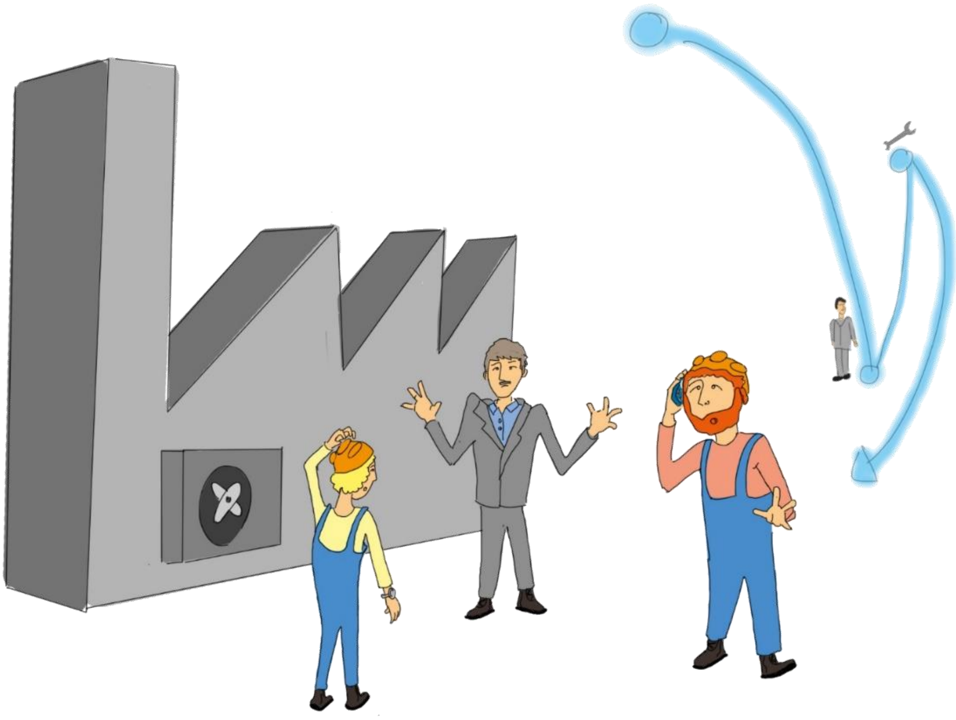

Figure 81: TKSE - Problem Scenario 3: Repair – missing support

3.6.7 TKSE: Activity Scenario 3: "Repair – virtual support"

It is 1 p.m., and Kim's and Roland's shift is almost over, but there is one last issue on their list: An air conditioner at an important production site is not working reliably. They need an electrician.

The first electrician whom Roland wants to call, Guenther, is on holiday. But thanks to the newly introduced F4W solution that made the Yellow Pages available on the mobile devices of the maintenance crew, Roland notices that one of Guenther's colleagues, Bert, who is also an expert in this field, is online. Roland talks to Bert, who tells him he would like to help them but he is working at the headquarters and cannot assist right now on site. Bert has a few minutes time, however, because he is waiting for his trainee to pick some spare parts. So Roland starts a video call, and shows Bert the problem that Kim discovered. Bert smiles and says: "That's an issue that we can solve remotely! Kim, please replace the fuse on the left-hand side, disconnect the yellow sensor and restart. That should solve the problem for today; I think the sensor is defective, but it is only an add-on – the air conditioner will run without this sensor; tomorrow I will replace the entire plug connection, so that the problem is solved for good." Kim follows Bert's instructions, and it works. They wish each other a good afternoon and stop the video chatting. Kim and Roland clean up and leave the plant with a good feeling of having gotten things done.

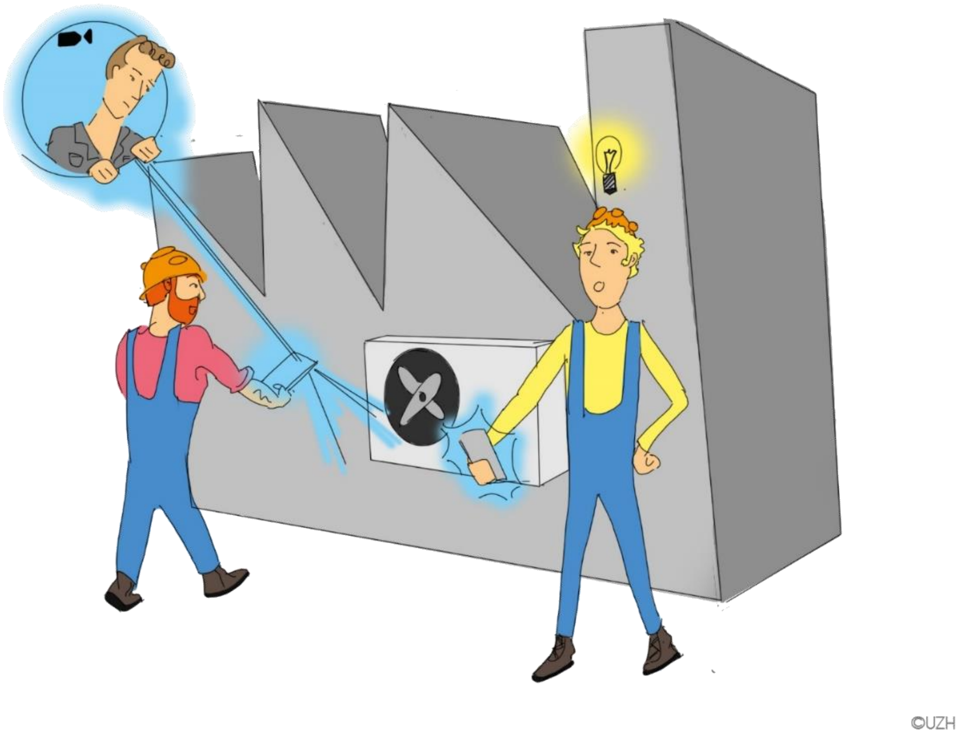

Figure 82 TKSE - Activity Scenario 3: Repair – virtual support

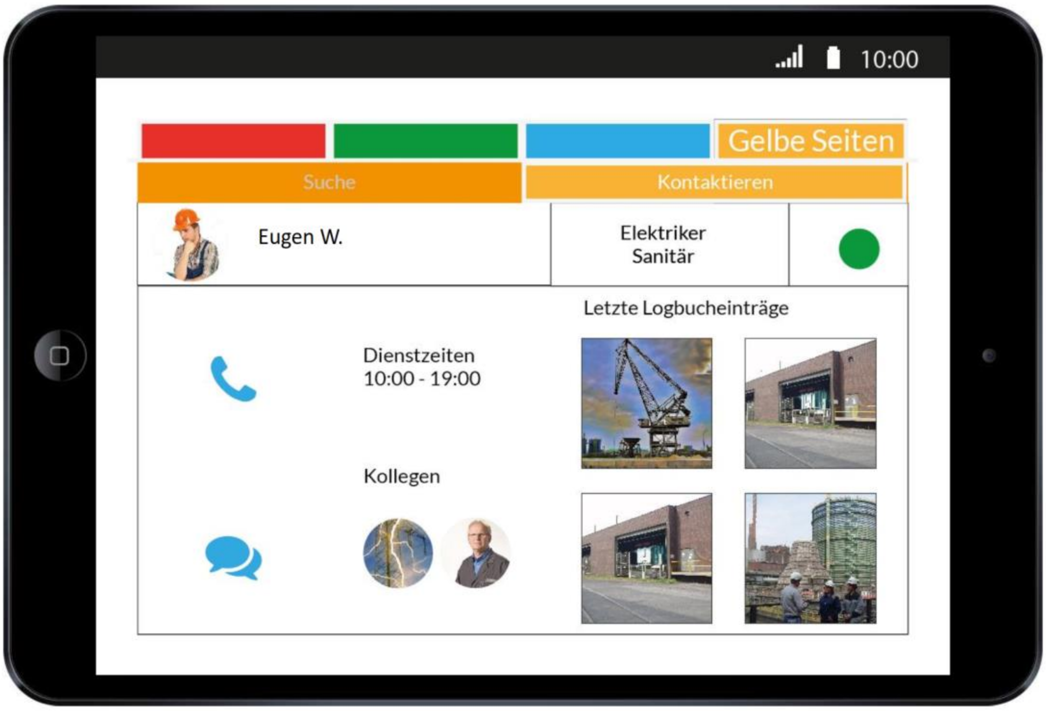

Figure 83: TKSE Mock-up: Yellow Pages (Gelbe Seiten)

To get quick access to the required colleagues, the F4W solution provides a “Yellow Pages” (Gelbe Seiten) section, shown above in figure 83. It helps to find the right person for the right topic, and even if that person is not available, the F4W solution provides the profile of a colleague who can assist.

3.6.8 TKSE: Problem Scenario 4: "60° working temperature in the crane and missing Information"

Kim and Roland are on site at a crane. The air conditioner has been broken for an hour. The working temperature is about 60 degrees. Roland tries to get an overview of the situation, but he has to take a break every 15 minutes. After 45 minutes, he has found the problem, and it concerns the compressor. What he does not know is that the same problem occurred last week already.

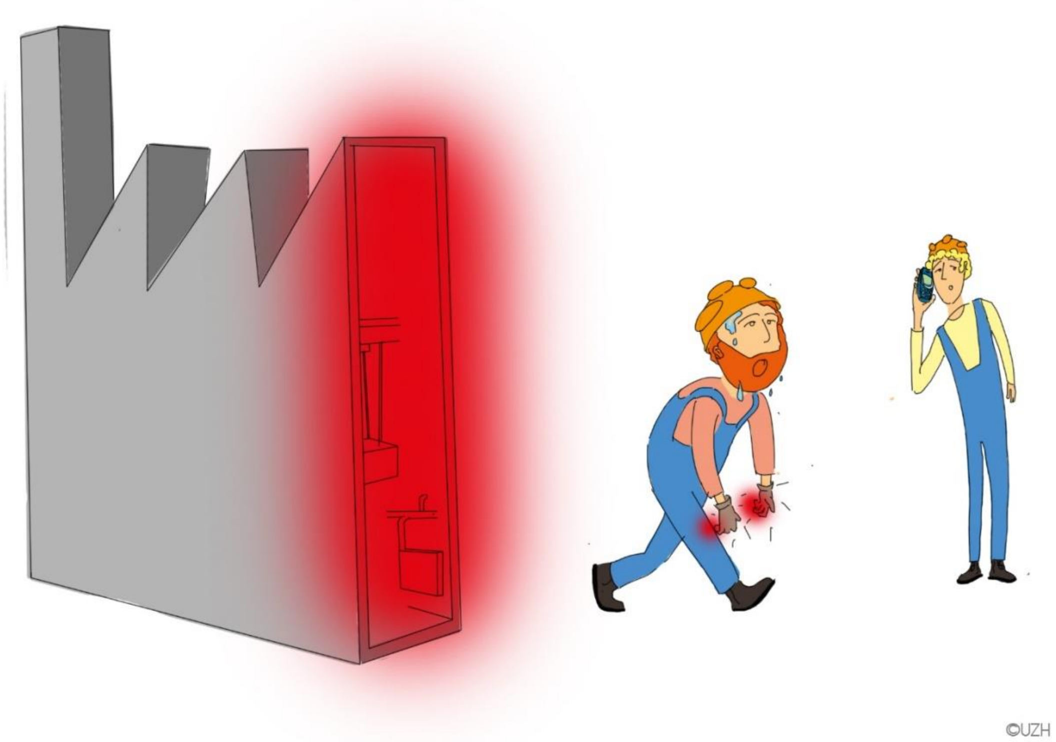

Figure 84: TKSE - Problem Scenario 4: 60 ° working temperature in the crane and missing Information

Kim tries to get an electrician on the phone. A few minutes later, he knows where he can pick up Guenther. He fetches him and drives to the tool shop to pick up the needed spare part, which takes around 30 minutes. After losing a lot of time, they are back at the plant and can start working. Roland is already a bit annoyed and says: "Things are so unnecessarily complicated. I have just called Ralf. He said he knows about the problem already, and if we had asked him in the morning he could have assisted us." Finally they solve the problem, but with the uneasy feeling of having lost two or three hours.

3.6.9 TKSE: Activity Scenario 4: "On site – progressive planning and quick fix"

In the morning round, when the shift starts, Kim has a look at one issue with a crane. He sees that Ralf was there one week before and consults him about that issue. Ralf is 100% sure that the issue is with the compressor. With that piece of information in mind, Kim asks Roland who is the best available electrician for that kind of issue. Roland is sure that Guenther can assist. He writes him a text message with the F4W solution and asks Guenther whether he would have time to help today.

With this progressive planning, Kim, Roland and Guenther go to the plant together and fix the issue very quickly by changing the compressor and doing some small adjustments. The work in the crane is still not easy with a working temperature of 60 degrees, but thanks to the F4W solution they do not need much time to research: They can just fix the problem.

Roland enters the completed work in the logbook with the F4W solution and sees that the issue is always with the same kind of compressor. He sends another text message to the shift manager with the suggestion to switch to another type of compressor.

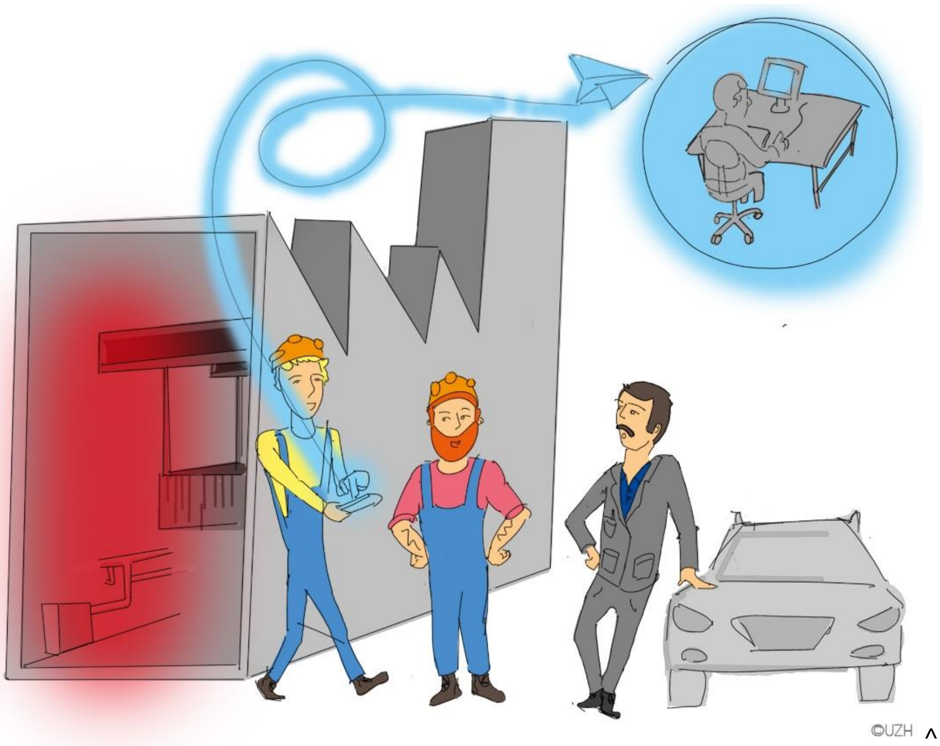

Figure 85: TKSE - Activity Scenario 4: On site – progressive planning and quick fix

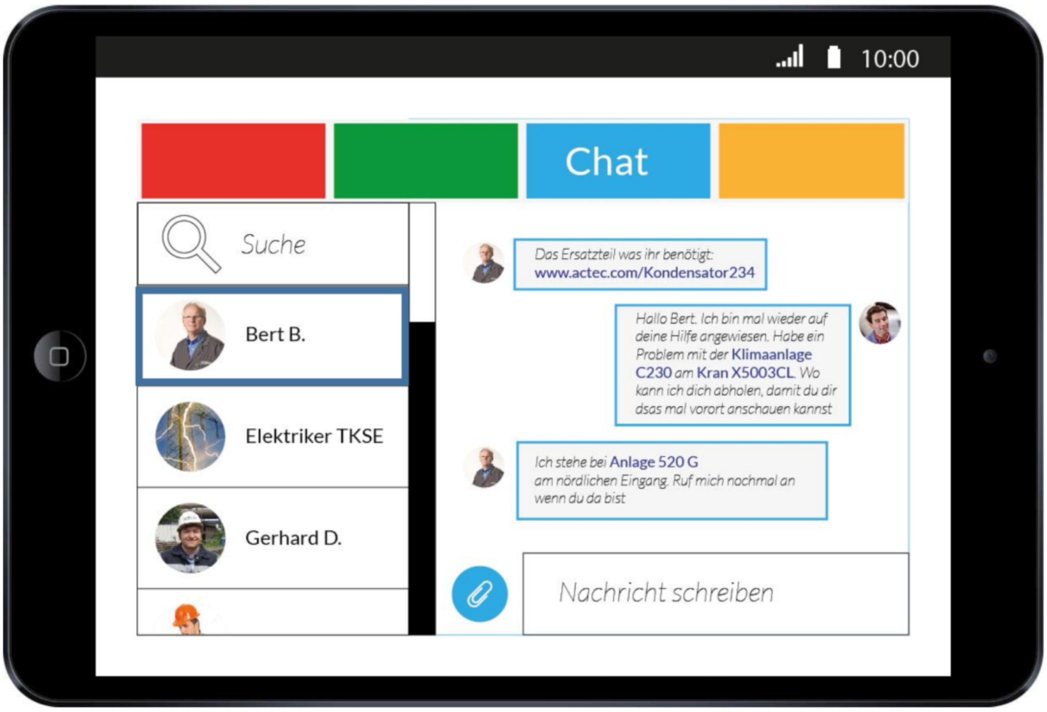

Figure 86: TKSE Mock-up: Chat

Figure 86 shows a simple text chat that offers the function of synchronous and asynchronous communication between the maintenance workers. This feature is really important, because in some areas the mobile data connection is not available. By contrast, the possibility to share pictures of the situation on site saves a lot of time that was previously used to double routes.

4 Summary and Outlook

The ultimate goal of the H2020 project "FACTS4WORKERS – Worker-Centric Work-places in Smart Factories" (FoF 2014/636778) is to develop and demonstrate soci-otechnical solutions that support smarter work, i.e. providing employees with the information they need to perform their day-to-day work at the right time and in an appropriate manner in order to improve decision making, support the search for problem solutions and strengthen employees' position on the factory floor.

Towards achieving this ultimate project goal, the main objective of this deliverable is to identify the requirements for sociotechnical solutions meant to support the day-to-day work of workers in the contexts of six IPs.

To this end, in this document we have firstly presented the current state of the art in the companies in the form of 23 problem scenarios that describe how the actors currently perform their work, and we point to critical issues in those daily activities that have potential for improvement. On this basis, we structured the identified requirements in the form of 23 activity scenarios that pick the identified issues and constitute suggestions of how the workers could be supported with a smart ICT infrastructure. Next, we presented screen illustrations of eight prototypes that incorporate many or all of the suggestions.

This document also provides a detailed illustration of our methodical approach, which primarily includes the abovementioned types of boundary objects as the best possible way to avoid inconsistencies of the requirements, in order to provide a high level of transparency to all readers. As illustrated in this deliverable and also already in D 1.1, our methodical approach has been co-designed to accommodate all of the project stakeholders' needs, which makes it especially iterative and agile. Consequently, on our ways towards achieving the ultimate project goal stated above, constant feedback from the IPs, especially the workers, has been essential, during our current progress. Over the past few months, we have developed strong bonds with the scientific and industrial partners. These bonds will form one of the core foundations of our project's future success. Apart from further developing all artefacts that have been presented here and from collecting possible processual and IT constraints that we have to consider when later piloting the sociotechnical solutions, we are currently working strongly towards the implementation of the solutions described here.

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5 Appendix

5.1 Data protection confirmation (TKSE example)

Data protection confirmation for data collection within the project Facts4Workers

Dear Mr. Richter,

We, ThyssenKrupp Steel Europe AG (TKSE), confirm that the data-collection procedures within the project Facts4Workers have been carried out according to our data protection standards. More precisely, the data collection approach in our case was as follows:

1) Our relevant organizational units have been informed about the intention of the University of Zurich (UZH) to collect data, e.g. in form of workshops, photos, videos and interviews.

2) Upon this, we have informed the concerned employees about the Facts4Workers project and the upcoming data collection.

3) Before data collection the respective method and tools like interview questionnaire, focus group agenda etc. have been suggested by UZH and confirmed by us.

4) During the data collection each participating employee was approached by UZH and again informed about the objectives of data collection. After having had time to ask questions, the respective employee signed an informed consent procedure. The participation was fully voluntary, the participants knew that consent could be refused and withdrawal was possible at any time.

5) Also during the evaluation of the prototypes, our data protection procedures were secured.

The data protection procedures of TKSE have been respected in the Facts4Workers project at every time.

About the project

PROJECT PARTNERS

The FACTS4WORKERS project is composed of 15 partners from 8 different European countries:

Virtual Vehicle Research Center	Austria
Hidria TC Tehnološki center d.o.o.	Slovenia
Universita degli Studi di Firenze, Department of industrial Engineering	Italy
Technische Universität Wien	Austria
ThyssenKrupp Steel Europe AG	Germany
Hidria Rotomatika d.o.o., Industrija Rotacijskih Sistemov	Slovenia
iMinds VZW	Belgium
Sieva d.o.o.	Slovenia
University of Zurich, Department of Informatics	Switzerland
Thermolympic S.L.	Spain
EMO-Orodjarna d.o.o.	Slovenia
Evolaris Next Level GmbH	Austria
Itainnova - Instituto Technologico de Aragon	Spain
Schaeffler Technologies AG & Co. KG	Germany
Lappeenranta University of Technology	Finland

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virtual vehicle

Captured and structured practices of workers and contexts of organisations

This document is entitled “First version of requirements of workers and organisations” and represents Deliverable 1.2 of the H2020 project “FACTS4WORKERS - Worker-Centric Workplaces in Smart Factories” (FoF 2014/636778). Building on a deep understanding of industrial workers’ individual practices, embedded in the contexts of six organisational partners (elaborated on in Deliverable 1.1), we present the first suggestions (in the form of requirements) for sociotechnical solutions that are intended to support their daily work and encourage smarter work.

We structure the identified requirements as problem scenarios (that describe how the actors currently perform their work in a described context and highlight especially critical issues in their daily activities that yield improvement potential), activity scenarios (that pick the identified issues and constitute suggestions of how the workers could be supported with sociotechnical solutions) and screen illustrations of 8 prototypes.

The artefacts mentioned above are embedded in 8 contexts-of-use at 6 industrial partners (4 industrial partners with 1 context-of-use each and 2 industrial partners with 2 contexts-of-use each).

This document also provides a detailed illustration of our methodical approach, which primarily describes the aforementioned types of boundary objects as the best possible way to avoid inconsistencies in the requirements and thus to provide a high level of transparency to all the readers.

FACTS4WORKERS