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Optimizing the workforce for an assembly line

Human-centric approach towards Industry 5.0

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ABSTRACT :

When a company aims to improve their technological solutions for their processes with the most recent ones, studies show that it will help the companies gain several benefits. The newest technological trend (Industry 5.0) has a more human-centric approach. The trend is to bring back the human workers to work alongside the machines and not automate every process. This trend shows that the focus should be more on the human workforce and optimizing the workforce by eliminating and improving bottlenecks.

This thesis study aims to find a suitable technological solution for the case company, how to optimize the workforce for their assembly line workers at their new factory. In order to optimize the workforce, the assembly line employees' tasks need to be analyzed and evaluated so that they are more fluid and efficient. Furthermore, the assembly line needs to be freed of bottlenecks (situations where production is hindered). Some possible technologies for the final solution of this thesis case subject are presented, and the final optimal solution will be presented in more detail in the results chapter. Also, which areas to focus on and improve are explained and how to optimize a workforce. A thorough research process methodology (Design Science Research (DSR)) is used to find the most optimal solution. The DSR process is explained in detail and how it is utilized for this research process about the thesis subject. The key elements to focus on when a company wants to optimize their workforce are: task management, communication, quality management, and the workers' well-being. The DSR research process showed that it is possible to utilize task management and communication to optimize the workforce with today's technology.

Utilizing wearable hardware (a smartwatch) with software (Aucobo) to optimize the workforce was an ideal solution for this case. The software and hardware will be presented in detail. A use case scenario and how to program the task with the software are also presented.

KEYWORDS: Industry 5.0, industrial management, optimizing workforce, human-centric, manufacturing industry.

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Abbreviations

AI	Artificial Intelligence
CNN	Convolutional Neural Network
CW	Continuous Wave
DK	Design Knowledge
DS	Design Science
DSR	Design Science Research
ECG	Electrocardiogram
EMG	Electromyography

FR	Functional requirements
HMI	Human-machine interaction
IoT	Internet of Things
IS	Information System
MoCap	Motion capturing
MSDs	Musculoskeletal disorders
OSME	Open Smart Manufacturing Ecosystems
OWAS	Ovako Working Posture Analysis System
PMT	Protection Motivation Theory
REBA	Rapid Entire Body Assessment
RGB	Red, Green, and Blue
RGB-D	Red, Green, and Blue - Depth
RULA	Rapid Upper Limb Assessment
3D	Three-dimensional
ToF	Time-of-Flight
2D	Two-dimensional
WFO	Workforce optimization

1 Introduction

Today's manufacturing industry faces some new changes and challenges as we move towards a new industrial revolution, Industry 5.0. With more importance on the production's resilience, shorter lead times, a better quality of products and services, climate impacts of the manufacturing process, and bringing back the importance of the human workers to work alongside the machines.

The production's resilience means the ability of the production's system to withstand disruptions without any significant degradation and the recovery time for the system to be back to average production (Kusiak, 2020). Dey et al. (2021) state that the importance of the lead times of the manufacturing process also needs to be improved and made shorter to meet the customers' demands. In Chen et al. (2020) research, they prove that companies need to think about the climate impact of their manufacturing process, as customers are getting more concerned about the negative impacts of the climate from the manufacturing process. Human-machine interaction (HMI) and human-centric operation or design are vital in the new industrial revolution. Rabaey (2019) explains that it is beneficial for a company to include human workers to work alongside the machines in the production process. Furtheron, Rabaey (2019) indicates that, instead of having the process entirely automated by the machines, as it has been in the previous industrial revolution's mindset, that the production processes will move towards a complete automation process by the machines.

A company needs to implement a holistic and optimized workforce to achieve these goals, which means that the whole manufacturing process, including the workers, needs to aim for an intelligent collaborative manufacturing process, which will, in turn, make the workforce more productive and creative (Cheng et al., 2020). This thesis aims to find a suitable solution to optimize the workforce for a company's assembly line to have a more flexible and seamless workflow for the workers. What are the possibilities with today's technology?

1.1 Background

The case company, Wärtsilä Oyj Abp, is a Finnish founded company. They are a global leader in delivering innovative marine technology and energy solutions and offer their clients sustainable technology and services to improve their clients' economic and environmental performance. They have a dedicated team of 17,000 people working for them in over 200 locations in 68 countries. In 2021, their net sales amounted to EUR 4,8 billion and were listed on the Nasdaq Helsinki (Wärtislä, 2022).

When Wärtislä moved their factory in Finland, Vaasa, from the downtown area to Vaskiluoto, Finland, they wanted to reframe their manufacturing concept. They then introduced a new concept called Open Smart Manufacturing Ecosystems (OSME) as an extended enterprise of the Smart Technology Hub. The OSME project is a collaborative initiative consisting of other leading manufacturing companies to help speed up the process of this transformation of the new manufacturing concept. Wärtsilä's OSME initiative reflects the importance of refocusing its manufacturing to better meet market demands by leveraging the skills and strengths of its partners (Wärtsilä, 2022).

In the Open Smart Manufacturing Ecosystems concept, 'Open' refers to the openness part, open sharing with their other partners to create a trust for a long-term collaboration. On the other hand, the 'Smart' part focuses on the ongoing learning process, using events and activities as the basis for the planning, where they will learn from each other how to find alternative solutions for new challenges. Furthermore, the new 'Manufacturing' concept will utilize digitalization to improve the efficiency and sustainability of manufacturing by building on this strength and becoming a worldwide known benchmark for this concept. Lastly, the 'Ecosystems' stands for all the individuals committed to a common purpose, which is key to collaboration success since OSME aims to be the leading global community for manufacturing professionals by motivating and engaging individuals (Wärtsilä, 2022).

Besides OSME, the collaboration includes a growing number of Associate Partners that will contribute to the network's success. Fliq, ABB, Sandvik, Nimetech, Valmet Automotive, and the University of Vaasa are the first Associate Partners to join this network, and this is where this thesis aims to provide insightful solutions to the new manufacturing concept or framework. In addition, Business Finland and the MEX Finland growth engine, orchestrated by Synovus, will also support OSME (Wärtsilä, 2022).

1.2 Research problem and research questions

As Yerpude and Singhai (2018) point out, our society and technology are evolving, and customers' demands are also getting more demanding. For the manufacturing industry to keep up with the end customers' requirements, or supply and demand, the manufacturing industry needs to innovate to keep up with these (Liere-Netheler et al., 2018). As the newest industrial revolution indicates, Sherwani et al. (2020) suggest that we need to make the production process more agile, intelligent, sustainable, and innovative. Furthermore, to innovate the manufacturing industry and its processes, we need to optimize its workforce by making it more human-centric (Lu et al., 2022). Lu et al. (2022) claim that this means we need to have the human workers operating alongside the machines, letting the machines do the repetitive tasks and having humans focus on the more creative solutions to optimize the workforce to its fullest.

We need to focus on the human workers' well-being and communication to gain a productive and uninterrupted flow for the manufacturing process. All of this brings us to the research question:

"What are the workers' daily tasks at the assembly line, and how can this be improved and remove all unnecessary bottlenecks?"

Leading us to the following objectives for this thesis, which are:

1. Identify the bottlenecks at the assembly line which are causing interruptions and delays to remove or improve upon these.

2. Plan the flow of information between the human workers and the information systems.

3. Investigate to develop a system setup prototype to support the workers in their daily tasks, which will optimize the workforce.

1.3 Limitations and definitions

This chapter will look at the possible limitations of the thesis and its research process. Then the most relative and essential terms relating to the topic of this thesis will be explained.

1.3.1 Limitations

Some factors limit the research, which is considered when conducting this thesis. The functional requirements need to be established first and approved by the client before beginning the research process. While researching the subjects, limitations occur, and some functional requirements can not be fully implemented.

One of the limitations is the development and availability of suitable technology. There are many technological solutions available for this case. However, many technologies are still in the development stage, meaning that the technology exists but is not yet ready to be used by a company. Not being able to implement specific technological solutions leaves out some solutions that could be potential and optimize the workforce at the assembly line to its fullest. There are also risks with implementing new prototype solutions for a case problem to be solved. The possible solution could sound good, seem like an ideal solution, and have many good customer references, but it does not always work the way the client wants. One limitation is also the budget. Implementing new innovative turnkey solutions has high costs. Also, the maintenance, license fees, and updates add to the final costs. In addition, many people have various opinions against new technologies and have their data (e.g. location tracking) collected and tracked. The fear of new technologies could lead many workers to worry about their security. The security issues lead to another limitation, collecting peoples' data. Collecting data involves some security concerns because the collected data from the workers can be stolen, sold, or distributed to unwanted parties.

Since this thesis is conducted entirely remotely, it has some limitations. Not being able to visit the factory and collect any needed information has some drawbacks. It is always better to see the process live, to fully understand and comprehend the situation. At the site, questions and discussions can be held instantly with the workers, which could be some topics that do not come to mind when reading about the case study.

That is why the thesis is conducted so that the chosen hardware and software are bought as a test trial for the author to perform trials instead of test trials at the factory.

1.3.2 Definitions

Industry 5.0 – The fifth industrial revolution will have humans and machines working together, utilizing human creativity and brainpower, increasing the efficiency of the processes by combining and focusing on the human–machine interaction, as opposed to industry 4.0 (Nahavandi, 2019).

Industrial revolution – Modern historians consider the Industrial Revolution as the transition from an agrarian economy based on handicrafts to an industrial economy with machine manufacturing (Britannica, 2022).

Optimizing workforce – The term "workforce optimization" (WFO) refers to a set of data-driven practices and strategies that are in usage to improve organizational and employee efficiency while reducing operational costs, aiming to make organizations more successful (Vulpen, 2021).

Human-centric operations (also known as people-centric operations) – Human-centric operations focus on the operational activities and how the human workers influence their performance (Roels & Staats, 2021, pp. 745-757).

Manufacturing process – The manufacturing process uses tools, human labour, machinery, and chemical processing to convert raw materials or parts to finished products (Swift & Booker, 2013).

Wearable sensor – Sensors combined with wearable objects or hardware can be directly attached to the body that provide clinically relevant data for monitoring or treating health problems (e.g. a smartwatch) (Nweke et al., 2018, pp. 233–261).

Smartwatch – Smartwatches are wearable computers or sensors in watches equipped with a touchscreen interface. An app associated with the watch allows the user to manage collected data (Isakadze & Martin, 2020, pp. 442–448).

Motion capturing – Recording objects or people's movement through motion capture (sometimes called mocap or mo-cap) (Kurihara et al., 2021).

Analyze software – A computer software or an application to analyze and manage collected data (Shykolovich, 2021).

Algorithm – In computing, an algorithm is a set of rules to follow when solving a problem (Oxford Advanced Learner's Dictionary, 2022).

Design science – A research approach concentrating on developing and validating recommendations (Peffers et al., 2007).

Information system – A formal and sociotechnical organization that collects, stores, processes, and distributes information (Peffers et al., 2007).

1.4 Structure of the study

Here we look at the thesis structure and briefly explain the chapters.

Chapter 1 goes through and explains the research topic. It will explain the case company and its background, the reason for this project and what it wants to achieve. Then, the thesis's research problems and questions are introduced. The limitations during the research process are then presented. Lastly, the most essential and used terms in the thesis are defined.

Chapter 2 focuses on the literature review part for the subject. Firstly the industrial revolutions are explained briefly, then an explanation is given of the possible technologies behind a possible solution, and finally, some examples of the hardware and software solutions are introduced.

Chapter 3 defines the research methodology, Design Science Research (DSR), which is used for the research process of this thesis. It explains the theory in detail and, at the same time, clarifies how it has been utilized for this thesis and its research progress. Then the functional requirements are explained for the wanted outcome from the solution of the research from this thesis.

Chapter 4 presents the results and findings. First, the findings briefly answer the research question and the objectives this thesis presents. Then the contributions are discussed, and the validity and reliability of this thesis. Next, some possible future research on this thesis subject is presented. Finally, this chapter discusses the results and presents the final solution setup, a use case example and how to program it with the software.

Chapter 5 is the conclusion part of this thesis. This chapter will summarize and conclude everything that has been done and established for this thesis.

1 Optimizing the workforce

The case study is not an issue. It is more of an improvement than an issue. This improvement can, and hopefully, will make the workforce more efficient and agile. The solution to the improvement is to optimize the workforce. Optimizing the workforce means that the work tasks for the assembly line employees need to be evaluated and analyzed to be more fluent and efficient. In addition, the bottlenecks (i.e. situations where the process in the manufacturing production is hindered) from the assembly line need to be removed.

In our case, the company wants to bring their assembly line workforce to the most current standards of the current, or as some argue (which is discussed in this thesis), the next coming industrial revolution, Industry 5.0. Industry 5.0 wants to bring back the ”human touch” in the production, human workers co-operating with the machines (Pathak et al., 2019). Pathak et al. (2019) try to prove their point by saying that this does not mean to have all the production processes completely automated by machines, but rather to include the human workers to co-operate with the machines and procedures efficiently. Meaning that we need to focus on the individual human worker and their well-being, cooperation between all the assembly line workers and the machines they operate.

There are some key elements to focus on when a company wants to optimize their workforce. Franssila (2019) highlights that task management is one key element to focus on. By focusing on this, measuring and analyzing the tasks management process for the individual workers can make the whole manufacturing production a lot more efficient (Franssila, 2019). Hübscher et al. (2020) point out that they found in their research that communication is also an essential aspect of making a workflow and its workforce more efficient. Many companies have seen that after implementing and focusing on quality management (i.e. a product or service that a company provides is consistent (Sallis, 2014)), the production efficiency has gone up significantly as well as the workers' well-being (Bordel et al., 2022). With these findings from their research, Bordel et al. (2022) state that the human workers' well-being will make the production a lot more efficient. When workers have positive well-being, they will automatically be more productive and efficient. The workers then want to stay at the company for a longer time since they are willing to impact their company's profits positively. From all this, they get good benefits for themselves (Bordel et al., 2022).

These are the main aspects that this thesis focuses on to find a suitable solution to optimize the workforce. The focus will be on task management. The individual worker's well-being and communication between the workers or the management. Including cooperation with the machines when possible.

1.1 The industrial revolutions

Industrial revolutions have shaped the way we work and our societies. It took us from producing items using handicrafts to the era where we utilize machines. It began in the 18th century in Britain with the steam engines and has continued to evolve until this day, with automated processes for the manufacturing industries and artificial intelligence that can run a factory by itself (Britannica, 2022). As Ellitan (2020) argues, these innovative technologies need to be considered in today’s industries since they can benefit a company if utilized correctly.

First, we will look at some background and the essential characteristics of the recent and upcoming industrial revolutions (4.0 and 5.0) as it is crucial to understand the background for these industrial revolutions, to acknowledge and understand why the shift is happening to a new and improved industrial revolution, Industry 5.0.

With the newest approach and mindset, the case company wants to improve and optimize their workforce to a more human-centric approach.

1.1.1 The fourth industrial revolution

Schwab and Davis (2018) state that the fourth revolution has not yet even begun and predict it will take some years for it still to come. Prisecaru (2016), on the contrary, claims that it already started in 2000. Popkova et al. (2018) argue that the fourth industrial revolution consists of fully automated processes and uses this as evidence that the fourth revolution has already begun since many factories are utilizing fully automated processes. We can see that researchers have various opinions about when, or if, the fourth industrial revolution has even begun. The fourth industrial revolution will bring forward new technologies and develop those we already have enlisted, such as the internet of things (IoT), fully automated processes and services, robotics, and artificial intelligence (AI) with new levels of awareness.

The infrastructure for these new technologies to be fully enabled requires rapid internet networks, new hardware for robotics, and algorithms developed for AI. Exoskeletons will improve logistics for humans that can help workers lift heavy objects more quickly without causing harmful side effects from the repetitive tasks or movement of heavy objects. These tasks will also are assisted with or entirely replaced by robotics. Transportation will see more autonomous vehicles transporting goods powered by more renewable energy resources. New materials for production and construction will be introduced, with some already being used and developed fast to keep up with these demands. 3D (three-dimensional) printing, nanomaterials, and optical fibres are new technologies and materials in demand (Popkova et al., 2018).

1.1.2 The fifth industrial revolution

The upcoming and probably the most debated industrial revolution is the fifth one. Some researchers argue that this revolution is closely underway, or if not already here. Popkova et al. (2018) claim that the fourth industrial revolution is still undergoing and has not yet reached its tipping point for the fifth one. In contrast, Schwab and Davis (2018) claim that the fourth one has not begun yet. In comparison, Pathak et al. (2019) claim that the fifth industrial revolution is here but still in its initial stage and undergoing. With evidence of companies wanting to be ahead of their competition by trying to implement the technologies and workflow characterized by the fifth revolution (e.g. utilizing nanomaterials) (Pathak et al., 2019).

Pathak et al. (2019) also mention that the fifth industrial revolution will bring back more human-machine interaction. Simpson et al. (2019) point out that companies and the manufacturing industry have realized that human workers need to be appreciated (e.g. focusing and taking care of their health), and repetitive tasks can be assigned to robotics. Then the human workers can focus on more creative tasks and create the automation processes of the repetitive tasks for robotics (Simpson et al., 1999). As a result, a process can flow better and more efficiently with the so-called human touch and have a fluent human-machine interaction benefiting everyone (Alippi, & Ozawa, 2019, pp. 245-263).

New collaborative robots (i.e. cobots) will be introduced and help out in the processes (Brown & Pierson, 2018, pp.270-277). Although these are meant to help out the human workers and co-work with the humans to maximize the output for the manufacturing processes, they will not replace the human workers. Instead, they will assist (Brown & Pierson, 2018, pp.270–277). The robotics working alongside us proves that human workers will be more focused and appreciated in this fifth industrial revolution. Pathak et al. (2019) claim that this improved human-machine interaction will benefit companies by creating more personalized products and services and showing some cost reductions from the processes by making them more efficient and removing the bottlenecks.

1.2 Technologies for analyzing and optimizing the workforce

This chapter will explain the main idea behind the technologies used for this thesis case study by utilizing a hardware and software solution together or using only one option. It will give the reader insight into the technologies, how it works, and why it matters for this thesis. The final solution implemented for this case could base on this technology. Examples of two hardware and software solutions which could be used for this case are presented briefly. The author has chosen these presented examples. The choices have been made from researching various options thoroughly on what different technologies and companies can offer. The presented examples have been researched to be the best possible solutions for this case. The research on other possible options will also be presented in this thesis. However, this does not mean that they could be implemented for this case's purposes since there are some restrictions, which will be explained. Also, some possible user scenarios and examples for this case with each subject are presented and explained. The final solution and company will be presented later in this thesis with some examples of possible use scenarios for this case.

1.2.1 Human body tracking

Zago (2020) argues that in the scientific study of measurement, i.e. metrology, human motion measurement is one of the most challenging and exciting topics. The optical motion tracking solutions are categorized into two different categories; markerless and marker-based systems (Ma'touq et al., 2018).

The marker-based system utilizes markers placed on the subject, which gives the capturing device a picture of the positions of the subject's joints and orienting body segments. The capturing device records this image via a three-dimensional passive localization of the markers. The system tracks the body by identifying common points on the object, such as reference points (i.e. points that mark out a chosen specimen). For example, these points can be a person's rotating joints on a leg, and the system interprets it as a leg, providing a skeletal image of the person's joints and limbs (Cappozzo et al., 2005). Ma'touq et al. (2018) claim that the marker-based system provides the most accurate results. However, this option is often costly and requires trained personnel to perform the recordings.

The markerless system utilizes an algorithm to determine a shape. Here the body is captured by a sensor (e.g. a camera), and the trained algorithm for the system determines the shape, location, and pose of the body or object (Colyer et al., 2018). Two types of cameras can be used for this purpose, depending on if they record a "depth image" of the subject, meaning that the pixels in an image show the subject's distance from the recording camera. The depth-sensing cameras are called RGB-D, and they record both depth and colour. Some most commercially used ones are the Intel Realsense and Microsoft Kinect. These work the best for real-time body pose estimation (Shotton et al., 2011). Colyer et al. (2018) mention that the accuracy is still lower for the markerless system compared to the marker-based system.

According to Kim et al. (2021) research paper, musculoskeletal disorders (MSDs) are the most reasons for personnel at work to be absent from work due to critical health problems.

The musculoskeletal load causes MSDs when a person repeats inappropriate postures when working on a task, usually a worker who has repetitive tasks (Viera & Kumar, 2021). The MSD can reduce this by having ergonomists observe the workers' postural assessments. These observations can be performed on-site with a real-time analysis or recorded on video by a camera setup, to be later on analyzed. These analyses help the ergonomists to improve the workers' postural assessments and reduce the MSDs. In addition, a specialized ergonomist can quickly identify the risk factors when performing analysis, and it does not require any special equipment or setup (Zago et al., 2020).

The main three assessment tools for postural ergonomics are REBA – Rapid Entire Body Assessment (Highnett & McAtamney, 2000) and OWAS – Ovako Working Posture Analysis System (Karhu et al., 1977), and RULA – Rapid Upper Limb Assessment (McAtamney & Nigel Corlett, 1993).

The motion capturing (MoCap) systems utilizing wearable sensors and markers have the highest accuracy in capturing human movement digitally. However, the setup requires trained personnel and hardware to capture and analyze the human movement and has a high cost (Trask et al., 2012). Therefore, a MoCap system would not be considered a suitable solution for all workplaces.

This technology would utilize this case by automatically having the hardware (i.e. sensor) recognize when a worker enters its field of view and start to capture it until the worker is out of the sensor's field of view. The software would make this possible when implemented with the hardware. Also, the software could analyze the scenario (e.g. how long it takes for the worker to perform a specific task) and report this back to a server computer which maintains the captured data. The company can then utilize this data as they wish, such as creating reports of the workers' task management and finding any possible bottlenecks to improve.

1.2.2 Azure Kinect DK

The Azure Kinect DK sensor is an affordable 3D camera capable of sensing depth and automatic object or human recognition. It was initially intended for gaming purposes to connect to the Xbox 360 gaming console by the company Microsoft. However, scientists, hobbyists, and programmers later started to utilize the Kinect for other research purposes, such as human recognition and interaction (Elaraby et al., 2018). Later on, Microsoft discontinued producing the Kinect sensor and is now producing a new updated AI sensor, called Azure Kinect, meant only for the developer's market as a developer kit to help build speech models and computer vision (Tölgyessy et al., 2021).

Tölgyessy et al. (2021) indicate that it is crucial to capture and detect a precise 3D joint body image for gesture-based human motion analysis and its applications. The Kinect camera is a good choice of a sensor for this purpose since it utilizes a continuous wave (CW) time-of-flight (ToF) camera system. These cameras capture the strength of the light source reflected from the source object. The difference between the produced and the reflected light is converted into a value of distance for each pixel (i.e. information of the captured picture) to create a depth image (Bamji et al., 2018). The Azure Kinect includes a regular RGB (Red, Green, and Blue) and a depth camera sensor (Microsoft, 2022). According to Microsoft (2022), the Azure Kinect can distinguish 32 possible joints of a human body and more easily recognize people and their gestures.

The camera collects data when it automatically identifies humans and their movement—a machine learning algorithm and artificial intelligence process the data.

When connected to software, all of this would be implemented to capture the data of the human workers. This data is then stored and utilized when needed by the management to optimize the workforce.

1.2.3 RealSense D400

The RealSense D400 series is a vision depth stereo camera sensor system manufactured by Intel. It includes a stereo depth module, vision processor, RGB sensor (for signal processing of the colour image), and an inertial measurement unit to measure the sensor's angle and orientation. It can be utilized for autonomous machinery (e.g. drones and robots) and 3D scanning, for example (Intel, 2022).

The RealSense sensor is an alternative to the Azure Kinect DK sensor. The two of them have more or less the same capabilities and would be used in a similar setup solution. It is always good to have a choice since one can be discontinued.

1.2.4 OpenPose

OpenPose is a deep-learning computer software library specialized in human body pose estimation. It can detect multiple persons using key points (joints) of a human body from a captured 2D (two-dimensional) image or video using any ordinary RGB camera (Lee & Ahn, 2020). A research group created it at Carnegie Mellon University (Cao et al., 2016).

OpenPose produces its output for the map of the critical points for a human body by taking colour images or recordings as an input and uses a convolutional neural network (CNN) to produce the digital human skeletal map. A human skeletal map also allows the software library to recognize several human bodies (Zago et al., 2020).

This software could automatically track a human worker when connected to a sensor (e.g. the Kinect). It could, for example, track and identify a human worker, follow the workers' every move; how long it takes for a worker to finish their task or identify some possible hazards. Connecting this software with an RGB camera could potentially lead to a solution to optimize the workflow and help out the human-machine collaboration. Unfortunately, it is too early to find suitable and available solutions with this software for this case. Furthermore, programming an algorithm for the software requires exceptional programming skills.

1.2.5 OTRS10 Time and Motion Study Software

OTRS stands for Operation Time Research Software, and the 10 stands for its 10th software version number. It is a motion and time analysis software intended to improve a company's operations, mainly targeted in the manufacturing industry (Shinka Management, 2022).

The OTRS software utilizes time and motion analysis performed directly on-site to increase the workforce's efficiency through continuous improvement programs (Shinka Management, 2022). Continuous improvement programs mean the creation, analysis, and improvement of standardized work tasks and line balancing (Shinka Management, 2022) (i.e. maintaining a balance between machine and operator time to improve the production rate (Tulip, 2022)). The software needs an operator to manually analyze the captured video data (e.g. a task performance), recorded manually by a video sensor (e.g. RGB camera). For instance, a task performed by an employee is recorded and fed into the software. Then an operator of the software (e.g. a line manager) looks through the footage and splits it into more minor elements (e.g. a screw has been inserted for a machine) and categorizes them (e.g. time-consuming element). When the task is split into more minor elements and categorized, the software will show what elements to improve (e.g. in a graph form), such as some unnecessary elements in a task that take up too much time. Comments, text inputs, and voice recordings can also be added to the analyzed footage.

The software gives a manager or the management a clear picture of what to improve on. The analyzed footage can also be used for training purposes, to educate the employees on how to perform a task correctly. Since everything is done manually, it does not automate any workforce analysis, meaning that it would not be an ideal solution for this case. Moreover, it does not support smartwatches. However, it will give the management a clear picture of the bottlenecks to improve in their workforce once the tasks have been recorded and analyzed, optimizing the workforce, hence suiting our case.

1.3 Wearable sensors

Since the environment is a manufacturing industry in a factory, the conditions are somewhat rough. These conditions mean that the wearable needs to be able to handle these conditions. Also, the range for the device's operations (i.e. the limits for its wireless connectivity, e.g. Bluetooth), accuracy for measuring the needed data (e.g. heart rate, via electrocardiogram (ECG)), or the toughness of the device needs to fulfil the environmental requirements. For example, the device can take some damage from hitting on objects when an employee is performing an assembly task or some scratching of the device's interface (e.g. the screen of a smartwatch), and it needs to withstand these conditions. These conditions also mean that the user interface of the wearable device needs to be easily operated, e.g. big enough buttons to efficiently operate in these conditions and that the content is easily readable. An easily operatable interface accounts, especially for the elderly employees.

One point to focus on for implementing this project would be to think about how the company and its employees would benefit from wearing and utilizing the data from such a device.

According to Khakurel et al. (2018), Wearable smart devices can significantly or entirely remove mental and physical workplace accidents. On the other hand, Hassard et al. (2014) found that workers with work-related anxiety, stress, and depression reported health problems were the most severe. In Europe, this causes yearly costs of up to €240 billion. The features (i.e. applications' configurations) for a wearable smart device can be configured according to the workplace conditions and the employees' statistics (e.g. age and working conditions). Also, ideally, the work tasks would be improved by measuring and optimizing the data from the workers, either followed manually by the manager or having software to optimize this data.

Since there are many wearable smart devices for the commercial market (Yang, 2015), finding a more specific kind of wearable smart device was needed to work in somewhat rough working conditions. Finding a smartwatch to work in these conditions means that the chosen wearable smart device for this project would ideally be configured for the industrial manufacturing working conditions since these are the conditions for this case. Simple wearable smart devices (e.g. pedometers (Glance et al., 2016)) and less technologically advanced smartwatches do not track and provide that much data to be utilized for optimizing the processes (Yang & Shen, 2015). Meaning that more advanced wearable smart devices (e.g. smartwatches with built-in electromyography (EMG) sensors (Nadeem et al., 2015)) need to be utilized for this project. Kritzler et al. (2015) state that wearable smart devices (e.g. smartwatches) with a screen meant for the consumer market do not necessarily hold up to the working conditions of an industrial environment (e.g. assembly line in a factory). This factor also indicates that a wearable device meant for the industrial environment needs to be researched.

One issue that can come up with wearable smart devices for the employees is the security or social issues. Studies show that a violation of privacy raises concerns for its users, such as location-based tracking and health consisting data (Lavallière et al., 2016; Zenonos et al., 2016). Also one other main issue for the users of wearable smart devices is how the data will be collected and how it will be stored and used without the users' knowledge

(Kritzler et al., 2015). Since the workforce can also have elderly employees working on the assembly lines, there can be issues. Lavallière et al. (2016) state that these individuals, who are more unfamiliar with this kind of technology and privacy concerns, need to be educated in this subject and taught how this data would be utilized. Lavallière et al. (2016) indicate that this kind of education needs to have a high priority for the rest of the employees since it will not only concern the elderly. Nikayin et al. (2014) disclose in their research that there are also concerns for the users of the wearable smart devices and their collected data. It could affect the management choices in a company when possible layoffs in a company occur. The harmful data causes concerns that this data could affect the management to lay off an employee. These concerns also need to be discussed in the company with their employees wearing the smart devices on how they will utilize the data and not affect any possible layoffs. Guidelines on who will interpret the data and give the analyzed feedback to the employees must also be discussed. The chosen software will handle the data from the employees, and its privacy conditions, need to be complied with by the employees. The discussions for these guidelines can be handled by utilizing the protection motivation theory (PMT) framework (Norman et al., 2015). Chenoweth et al. (2009) claim that this framework could ease the adaptation of new technologies and utilize them accordingly. The management should clarify to the employees that it will solely try to optimize the work tasks, benefit the company and its employees, and not use the collected data for any other purposes.

1.3.1 Smartwatch

The smartwatch is a wearable device that lets the user control the same information as a smartphone, such as receiving and making phone calls, text messages, and emails. In addition, most smartwatches today can connect to the internet and have sensors that let the user log, transmit, and receive data, such as monitoring their health (e.g. your heart rate and steps). (Chuah et al., 2016). Massaro (2021) claims that since the technology for the smartwatches has improved and gained more sensors, companies are now starting to look at possibilities to track their employees by following their well-being and health and improving their work efficiency. These two also go together because when an employee's well-being is kept positive, they are more likely to want to contribute their best performance for the company's good and stay there longer (Massaro, 2021).

Chuah et al. (2016) state that the markets and the interest for the wearable devices and smartwatches have been growing steadily since 2010, with having more than 111 million units sold in 2016, compared to a 44% increase from 2015. Eighty per cent of these sold units are wrist-worn smartwatches (Chuah et al., 2016). Furthermore, in 2021 the shipments of wearable devices reached over 533 million units, and out of that number, 280 million units were smartwatches (Laricchia, 2022).

Still, there remains a question on how people, or human workers, will accept this technology for tracking their daily habits or work tasks at their workplaces (Chuah et al., 2016).

1.3.2 Utilizing a smartwatch in the manufacturing industry

Wearable sensors, such as smartwatches, can collect and provide much data and information about those who carry such a sensor throughout their workday (Aehnelt & Urban, 2014). Aehnelt and Urban (2014) mention that some data could be information about the worker's health, inventory tracking, or immediate warnings and alerts about a malfunctioning machine. This data could be analyzed by software or a human (e.g. line assembly manager) to identify, e.g. bottlenecks in the production line (Aehnelt &

Urban, 2014). Bucko et al. (2020) explain that for a manufacturing process to be streamlined in the production, the information process also needs to be streamlined. Streamlining the process will also adjust the manufacturing process to the customers' requests (Bucko et al., 2020). Therefore, a sensor, such as a smartwatch, is a good and easy way to keep a real-time connection throughout the manufacturing process and to keep it streamlined.

A smartwatch can alert a worker at the assembly line to grab more parts from the inventory before it runs out since it has collected the data from other workers who have been using the same parts from the inventory. Thus, streamlining the manufacturing process since the needed parts will not run out of stock at the assembly line, manufacturing can go on seamlessly. Another good example would be sending or receiving reminders about the maintenance of machines. Preventive maintenance helps the production line to be operative (Bucko et al., 2020) since the machines will not break down during the processes because they have been maintained. The smartwatch can even provide information on how to do the maintenance step-by-step, including pictures. Furthermore, using a smartwatch frees up both of the workers' hands since the smartwatch is worn on the wrist of the workers. It could help new workers to remind them how to do specific procedures without having the supervisor explain them, thus, making the new workers more confident about their new position (Kokkalis et al., 2013) and freeing up time for the supervisors to concentrate on their tasks.

It can be clear to see how much some data can benefit a company to streamline their processes from the previously mentioned examples. This data would be automatically collected through their workers by the smartwatch they wear throughout their workday. Then, the data needs to be utilized by software or a competitive manager in charge of the manufacturing process.

2 Methodology

This chapter explains the research method used for this case. It will describe the methodology's basics and detail how and why it applies to this thesis case.

2.1 Design science research (DSR)

The methodology approach to finding a solution for this case utilizes design science research (DSR), a research method for problem-solving. It aims to enhance human performance and efficiency by creating innovative artefacts (Brocke et al., 2020) (i.e. an object made by a human (Oxford Advanced Learner's Dictionary, 2022)), which means that it solves real-world problems by utilizing the innovative artefacts. In this case, the problem is how to optimize the workforce for the assembly line workers (i.e. enhance the human performance and efficiency (Brocke et al., 2020)), and the innovative artefact(s) is the solution to be utilized.

Brocke et al. (2020) state that, by developing the innovative artefacts used to solve the problems and enhance the environmental elements created, the DSR approach aims to advance the knowledge base of the used technology and science (i.e. the environmental elements) in the company. Meaning that we need to enhance the existing environmental elements (i.e. the recent technology (industry 4.0) in usage for the company). As a result of DSR, newly designed innovative artifacts and design knowledge (DK) (Brocke et al., 2020). The design knowledge explains how to utilize the design theories and why the newly designed artefacts enhance or distort the environment to which they are applied (Hevner et al., 2004). It is a widely used research paradigm because, as Watson et al. (2010) claim, organizations' will foster innovation through its potential and contributes to the transformation of a society moving towards sustainability, which are core elements of the Industry 5.0 framework. Hevner et al. (2004) explain that it was designed to extend human and organizational capability, and DSR aims to develop these artefacts utilizing models, constructs, manifestations, and methods. Brocke et al. (2020) further describe that the goal of the DSR's framework is to create the knowledge of how things should and could be designed when having specific goals for a company's environment (e.g. successful decision making from data analyzes). Therefore, the goals for the DSR refer to the design knowledge.

Throughout this chapter, a few concepts and frameworks are introduced that are essential for how to perform DSR following scholarly standards. It will also present how this research methodology applies to this thesis subject.

2.1.1 The design science research framework

The conceptual framework intends to serve as a guide to analyzing, understanding, evaluating, and implementing design science research (Hevner et al., 2004). Figure 1 will present this framework concept and explain it below further on.

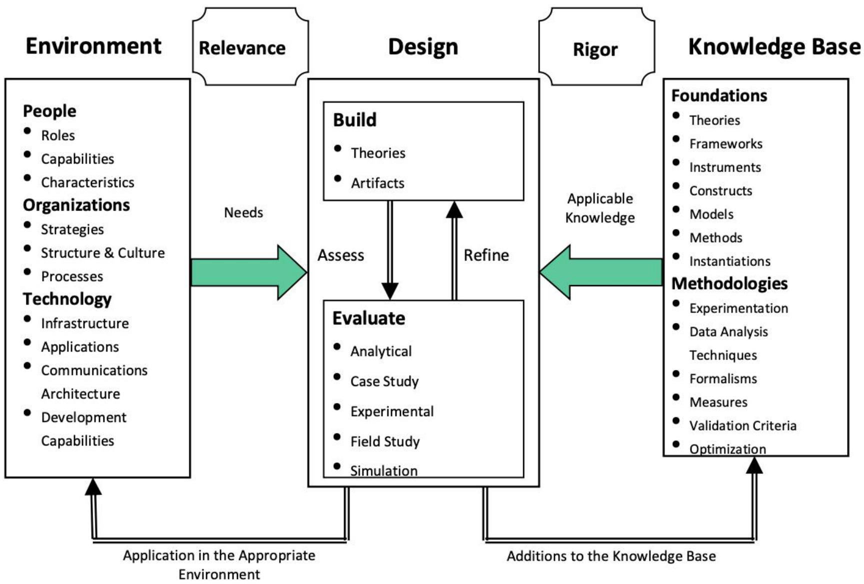

Figure 1. The DSR framework (Hevner et al., 2004).

The environment explains the place for the issues where the phenomena of interest exist, including already existing and planned technologies, organizations, and the people inside it (Hevner et al., 2004). For this case, the environment is the company's factory and its assembly line, the organization being the client company, the people being the assembly line workers, and the existing planned technologies are the existing Industry 4.0 technologies with the planned Industry 5.0 technologies. The environment also includes the needs of stakeholders in the organization according to their issues, tasks, goals, and opportunities (Hevner et al., 2004). This case means optimizing the workforce to gain economic and efficiency benefits. Since Industry 5.0 is a human-centric approach, the workers' well-being is also considered.

Hevner et al. (2004) describe that the needs are the estimated and evaluated organizational needs. The required knowledge about the organization's structure, strategies, culture, and existing work processes, are positioned concerning the existing technological applications, infrastructure, communication architectures (i.e. the information flow between the employees working in the company), and capability to develop (Figure 1) (Hevner et al., 2004). Hevner et al. (2004) summarize these as the so-called research problem since the relevance in research is ensured by framing the research activities according to the stakeholders' needs. Once again, these factors relate to the development of the Industry 5.0 framework in this case.

DSR is accomplished using the knowledge base, consisting of methodologies and foundations (Hevner et al., 2004). Hevner et al. (2004) define that, for a research study to be successful, previous research and results from related disciplines which provide the theoretical and methodological foundations, instruments, frameworks, models, constructs, methods, and representations are utilized during the building phase. Previous work related to the subject needs to be assessed and compatible with available technologies to achieve the goals for this case needs to be researched thoroughly (Hevner et al., 2004). For the evaluation phase, the methodologies will provide the guidelines for evaluating the case and applying the existing methods and foundations appropriately, and the rigour will be achieved (Hevner et al., 2004). From this, the available technologies and what is capable of implementing for the case are found.

DSR studies real-world problems in diverse application domains (Hevner et al., 2004). Hevner et al. (2004) further explain that research suggests that organizations using specific technology have a "need" to conduct empirical investigations about the possible solutions before final implementations. Before implementing the solution, the possible final solution needs a proper prototype testing phase for the possible solution on a minor test subject group within the workers to implement. The company will receive valuable feedback, and improvements can be made before the final implementation. The DSR analyzes what knowledge base is applied to the case subject and if there is already any available knowledge base on this subject (Hevner et al., 2004). Before researching the subject case (i.e. what is possible for the subject case), preliminary thorough research work needs to be done. Since the technologies available for the newest industry framework (Industry 5.0) are relatively new, there are not many types of research or technological advantages as ready solutions, which means that many fields of technology need to be researched to find a solution combining these.

DSR aims to create innovative solutions for an issue, which can also build upon already existing technologies in the usage of the company. It should be taken into account that no such technologies (i.e. innovative artefacts) exist within the company, meaning that new creative and innovative solutions are needed. Diverse research methods employ in DSR studies, including surveys, interviews, focus groups, and literature reviews (Brocke et al., 2020). For this thesis research, literature reviews are extensively utilized to find out about the subject, such as what technologies could be possible to implement. Before implementing the final solution, it is greatly advised to test out the final solution on test groups.

2.1.2 The design science research process

The design science research methodology (DSRM) applied for this thesis subject research is the one developed by Ken Peffers, Tuure Tuunanen, Marcus A. Chatterjee, and Samir Rothenberger (2007). It assesses a methodology to conduct design science (DS) within the information systems (IS) research (Peffers et al., 2007). This chapter explains the theory behind DSRM, how to apply it, and how it applies to this thesis subject.

DS is essential in a discipline that focuses on successful artefact creation (Peffers et al., 2007). Peffers et al. (2007) conclude that this model has three objectives:

– Following previous literature

– Providing a theoretical process model on which to perform DS research

– Serving as a mental model to present and evaluate DS research for IS

The process for the DS is divided into six steps: identify and motivate the problem, define its objectives, design, develop, demonstrate, evaluate, and communicate the solution (Peffers et al., 2007).

The design science research methodology (DSRM) is presented in the figure below (Figure 2) and is explained briefly for each step.

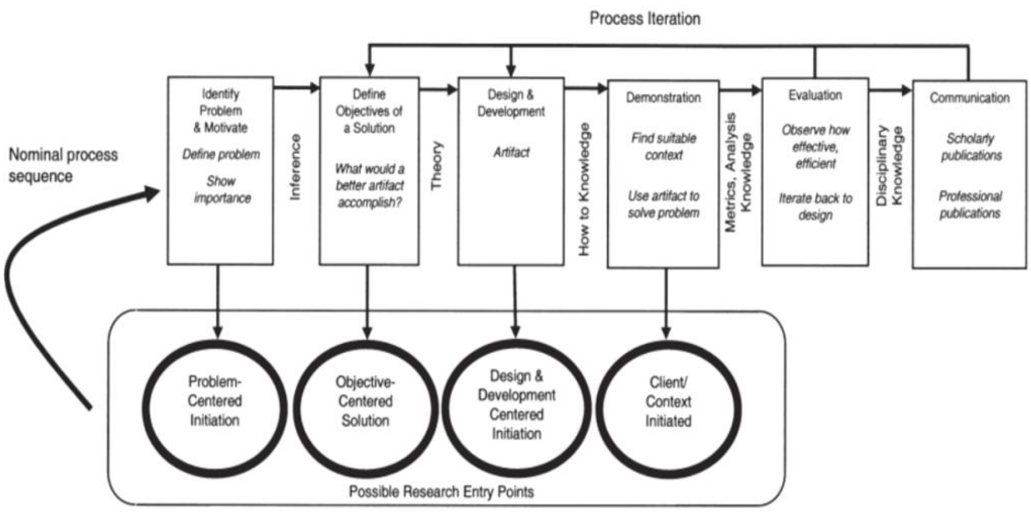

Figure 2. The design science research methodology (DSRM) process model (Peffers et al., 2007).

Identify and motivate the problem – The first step is to explain and justify the research problem and the value of the proposed solution. Two things are accomplished when a solution is justified: the researcher and the audience are motivated to pursue the possible solution, and the audience benefits by understanding the researcher's problem (Peffers et al., 2007). Peffers et al. (2007) mention that understanding the problem and the importance of the outcome (i.e. solution) is required for this activity.

The problem or issue in this subject case was the desire to bring the assembly line to a more modern era (i.e. Industry 5.0) with a human-centric approach (Wärtsilä, 2022) (i.e. justification for a solution). Concluding that, this means optimizing the workforce for the assembly line workers. Therefore, the value of the outcome, or the proposed final solution, is more than economical. The aim is to move towards an innovative, collaborative manufacturing process (i.e. optimize the workforce), which means, in turn, that production, efficiency, information flow, sustainability, and the workers' well-being are benefiting at the same time (Cheng et al., 2020) (i.e. the value of the outcome).

Define the objectives – It is possible to determine a solution's objectives by defining the problem and knowing what is possible and feasible. Peffers et al. (2007) describe the quantitative objectives, such as how an innovative solution would benefit more than the current one(s), or qualitative objectives, such as describing how the new artefact will support the new solutions to problems not previously addressed. The objectives need logical descriptions from the problem's specifications (Peffers et al., 2007) (i.e. functional requirements).

As mentioned in the first phase of the activity, the objective is to optimize the workforce and what can benefit the company. The solution's needs and requirements (i.e. functional requirements) are described in depth in Chapter 3.2.

Design and develop – In this stage, the artefact is created. A DSR artefact, in theory, can be any created product that incorporates a research contribution. The activity involves identifying the required functionality and architecture of the artefact and building the actual item (Peffers et al., 2007).

Through the research process, a suitable solution is found. Going through previous literature reviews about the subjects, it was clear that the wearable sensor combined with software would be the ideal solution to optimize the workforce.

Demonstrate – This activity explains how the artefact may be used to address one or more problems. For example, the demonstration might include using it in experiments, simulations, case studies, proofs, or other relevant activities (Peffers et al., 2007).

Since the thesis is done completely remote, there can not be any live demonstrations of the new innovative artefact or solution. However, the thesis author tests the prototype, and the results will be shown in Chapter (results). Later on, it would be preferable that the company itself performs prototype testings for smaller test groups upon the conclusions from this thesis.

Evaluate – The evaluation assesses how much the artefact contributes to a problem-solving solution (Peffers et al., 2007). Peffers et al. (2007) explain that this activity entails comparing a solution's aims to actual observable results from the artefact's use in context. Peffers et al. (2007) mention that the evaluation can take different shapes depending on the nature of the problem and the artefact. Peffers et al. (2007) conclude that after this activity, the researchers can choose whether to return to the design and develop phase, increase the artefact's efficacy, or continue to communicate and leave further improvement to future initiatives.

After the company performs the test group trials on the new solution, they will receive valuable feedback from the test group and have concrete feedback data collected (data from the hardware). From this, they can choose whether to continue implementing the final solution to a larger group of the assembly line workers, a more extensive section in their factory or if they wish to continue further researching the subjects on how to optimize their workforce. If the final results from the solution do not meet the standards, they are aiming for.

Communication – The relevant stakeholders are informed about all parts of the challenge and the intended artefact. Depending on the study aims and the audience (e.g. practising professionals), appropriate modes of communication are used (Peffers et al., 2007).

Results from this thesis and the feedback from the test trials will be handed over to the upper management in the company (i.e. the ones in charge of the vital decision-making for the division). They can then either reject or buy the suggested and tested solution.

2.2 Functional requirements

This chapter will explain the functional requirements for this case. The meaning of functional requirements explains why they play an essential role in implementing a successful solution. All the individual functional requirements for this case are thoroughly explained. They are the agreement between the client and the contractor on how the solution should work when implemented. It is worth noting that in some cases, not all functional requirements are possible to implement due to various complications or hinders (e.g. not enough advanced available technology). These are noted during the research process and negotiated with the customer to find an optional solution or wholly removed from the functional requirements. There were some hinders with the functional requirements in this case, which will be discussed later in this thesis.

Shaofan et al. (2019) emphasize in their published research paper that first, the functional requirements need to be defined to find a suitable solution for an assignment. The functional requirements are the functions that the solution needs to be fully compatible with and meet the customer's standards and requirements (Shaofan et al., 2019).

Our case is to optimize the workforce, which means that task management, workers' well-being, and communication need to be emphasized, as previously described. Therefore, a solution is needed which could focus on all of these sections. It would be ideal to find only one solution or system capable of focusing on all, instead of having three separate systems, each focusing on its section (e.g. task management). Only one solution would be better because there would be only one ecosystem handling all three sections instead of three separate ones. Hence, making the communication protocols for three systems obsolete. Having multiple systems working together can cause problems, such as communication issues (Dizdarevic), 2019). There are usually also economic benefits from paying for only one system instead of multiple ones, which was observed during the research about various solutions for this case. The functional requirements (FR) are as follows:

– FR1: Track the time for each task on the assembly line.

– FR2: Improve and make the tasks more efficient.

– FR3: Wearable hardware to collect data.

– FR4: Create reports from data.

– FR5: Capture human movement.

– FR6: Prevent a hazardous work environment.

– FR7: Focus on the workers' well-being.

– FR8: Task management between the workers and the management.

– FR9: Communication between workers and the management.

– FR10: Analyze the captured data.

FR1 – Track the time for each task on the assembly line: The first functional requirement states that each task a worker performs needs to be captured, measured, and analyzed. How long does it take for the workers to perform a particular task on the assembly line? When each task is captured, measured, and analyzed for each worker, the management can find the bottlenecks to improve.

FR2 – Improve and make the tasks more efficient: When the tasks have been captured, measured, and analyzed, the results show the statistics for each task performed by a worker. It is easy to find and see which possible improvements could be implemented to improve and optimize the workforce. Wu et al. (2019) proved that by doing this, a company would gain improvements for their workforce on the assembly lines' efficiency since the bottlenecks will be obliterated or improved. For example, to educate a specific worker on how to improve their performance on a specific work task.

FR3 – Wearable hardware to collect data: To collect the data from each employee (e.g. time spent on each task), we need to find a suitable sensor (i.e. a device that can collect inputs or data from a physical environment (Kandris et al., 2020)). A wearable sensor is the most suitable option for this environment (this is explained and discussed in this thesis).

FR4 – Create reports from data: To get the most out of the collected data, it needs to be analyzed and reports created. Then the person in charge (i.e. the manager) of the team for the assembly line workers can analyze it to find the bottlenecks and improve the workforce performance. Data analysis will improve workforce performance, as Maione and Barbosa (2019) proved in their research about workforce improvement utilizing collected data.

Ideally, the data would be collected from each worker so that the manager can see each worker's performance. These reports can also be presented to the upper management, who can then make decisions if needed.

FR5 – Capture human movement: A system that could automatically identify and record the human worker when they perform a task would be ideal for collecting data. Automation would require videography (i.e. recording moving images with a video camera (Straw, 2021)) and capturing sensor (i.e. video- or RGB camera) system setup. The sensor is connected to software, which is run by computer hardware, that would perform the software's algorithms (i.e. a process of calculations and rules to run the software (Wang et al., 2020)). The setup would automatically identify a person and then record when the person begins to perform a task and stops recording when the task is being performed. Ideally, the software would also include an analysis function to analyze and create reports from the captured data.

FR6 – Prevent a hazardous work environment: A videography recording system should also be able to identify objects. Doing this could prevent

hazardous workplace incidents. The software would identify if a dangerous element or situation occurs in real-time and then sound an
alarm to the workers to prevent danger from occurring. It could also record near-miss incidents at the workplace, which would then be forwarded to the management, and reports would be created from this to be utilized to improve safety at the workplace. This setup would then require a speaker that would sound the alarm when a dangerous situation occurs. In addition, a sensor (e.g. smartwatch) could send an alarm in the form of vibration (if the sensor is equipped with this functionality) and a notification on the screen or user interface to warn a worker.

FR7 – Focus on the workers' well-being: The wearable sensors (e.g. a smartwatch) that would collect the data from the individual workers could simultaneously collect data (e.g. heart rate) that would benefit the workers' well-being. By collecting and analyzing this data, the workers could improve their health and well-being. As earlier discussed in this thesis, when improving and focusing on the workers' well-being, the more they will contribute to their company's performance, optimizing the workforce. Therefore, it would benefit the company and individual workers' health and improve well-being.

FR8 – Task management between the workers and the management: Having a digital ecosystem (i.e. connecting systems and interacting through them digitally (Anwar & Gill, 2019)) would improve the task management and communication for the whole workforce, including the management. The workers would utilize their wearable sensors (e.g. smart watch). Since they would all be connected to the same digital ecosystem, anyone connected to it could interact consistently with each other. Furthermore, it would improve the communication between the workers and the management, optimizing the workforce. Since then, the workers and managers would not need to look and find each other at the factory, which takes up much time if the worker is in another part of the factory, and immediate response or action would be required.

The administrator, usually the team manager, could create the tasks for each team member or team from their office on the software and send them forward to everyone or whichever worker or team they wish to respond to the assigned task. The worker(s) who will receive this will see it immediately on their wrist if the sensor is a smartwatch, and then they could react to it as soon as possible, saving up time and optimizing the workforce. Depending on the task, the receiver of the task can choose if they then accept it or forward it to another employee or team by interacting with the sensor since smartwatches are equipped with a touchscreen or physical buttons. The other team members and the manager would see that the task has been responded to and action is performed, and then no one has to worry about whether the task is being taken care of. Creating a dynamic flow in the workplace leads to a more optimized workforce (Ophir et al., 2018). This system could also provide other useful interactions. Such as step-by-step guidelines for a task to a new team member, thus eliminating the need for a senior team member to stand by their side guiding them, saving time to focus on more creative tasks.

FR9 – Communication between workers and the management: This same method and setup would be utilized as in the previous functional requirement (FR8) for communication between the team members or the manager. If the sensor has a screen, as with a smartwatch, the message receiver could reply to it, forward it to a team member, or acknowledge it, depending on the message. Sensors equipped with a microphone and speaker could utilize these by making phone calls and sending or receiving recorded voice messages. This communication enhances the workflow by creating a hands-free communication workplace. The team members or managers do not have to search and find each other at the factory to communicate, which would save up much time. The team members could also instantly react to a machine malfunctioning since they receive a warning from this immediately if it is connected to the digital ecosystem. These instant reactions make the production flow run seamlessly without interruptions and even benefit the company economically (Ophir et al., 2018).

FR10 – Analyze captured data: By analyzing the captured data, the company could utilize this in many ways, as also discussed in earlier functional requirements. Having reports created from the captured data, whether the time spent on tasks or who has performed the most tasks, the management can utilize this and improve their workforce. They could, for example, eliminate unnecessary bottlenecks or give different tasks to employees who underperform in some areas.

Rosa et al. (2022) prove in their research about optimizing the workforce that to evaluate and optimize the workforce, the issue needs to be evaluated first to find the needed functional requirements, which are the basics and guidelines for creating the solution.

3 Results and discussion

This chapter presents the chosen final solution for this thesis case subject. First, the findings are presented and discussed, deriving from the analysis in the methodology chapter (Chapter 3), connecting to the literature review chapter (Chapter 2). Furthermore, the contributions will be discussed and presented for this thesis case subject. Then the validity and reliability will be addressed. The final part of this chapter will propose any possible future areas of research for this case subject.

3.1 Findings

The case subject for this thesis was analyzed in Chapter 3, how the design research process could be used to find a suitable solution on how to answer the research question presented in Chapter 1.2:

"What are the workers' daily tasks at the assembly line, and how can this be improved and remove all unnecessary bottlenecks?"

The following three objectives presented in Chapter 1.2 will be utilized to answer this research question.

Objective 1: Identify the bottlenecks at the assembly line which are causing interruptions and delays to remove or improve upon these.

After the final solution is implemented, this objective will be analyzed and solved by the company. Once the final solution is set up at the factory for the company, they will gather all the needed data utilizing the implemented solution to optimize their workforce. It is difficult to say which tasks will be the bottlenecks since the final solution has not yet been implemented at the company. However, the main focus will be on task management and how much time each employee spends on each task. Therefore, task management is a possible bottleneck to improve upon.

Objective 2. Plan the flow of information between the human workers and the information systems.

Implementing the solution to optimize the workforce will improve the flow of information between the employees and the information system software (Aucobo, 2022). The hardware (smartwatch) is connected to the information system software (Aucobo), enabling information flow. By being connected in real-time, each task, workflow, or reminder can be forwarded to the responsible employee or team (e.g. machine maintenance). This real-time connection enables the workforce to be optimized by reducing the delays in communication between the employees.

Objective 3. Investigate to develop a system setup prototype to support the workers in their daily tasks, which will optimize the workforce.

The final solution to be implemented for workforce optimization was found through research utilizing the DSR framework. The final solution from the company Aucobo will offer a complete system setup (including software and hardware) for the case company to implement as their solution to optimize their workforce. The final solution presented in this thesis is only a suggestion from the author of the thesis. The presented final solution is a valid recommendation since the author has thoroughly researched the subjects. It is also possible for the case company (Wärtsilä) to purchase the software or hardware solely from Aucobo since it is possible to utilize other manufacturers' hardware or software together with Aucobo's solution.

3.2 Contributions

A comprehensive literature review of the available and possible technological solutions to optimize a workforce is included in the thesis to contribute to the theory. However, since this subject has not been researched on the company's behalf before, there is no differentiating compliance with the case company's requirements.

This thesis narrows down which areas a company should focus on when optimizing a workforce to the newest standards of today's technological requirements. In addition, the thesis presents what technologies are available to utilize for optimizing the workforce.

This thesis explains why it is essential to focus on communication, quality management, the workers' well-being, and task management. However, with the available technologies for this case subject, quality management and the workers' well-being should be utilized separately. The workers' well-being is available to be optimized and followed with the presented technological final solution, but previous research indicates that this is not optimal.

The final solution is presented, which contributes to the theory of keeping up with the newest standards of Industry 5.0 and having the workforce optimized whit a human-centric approach.

3.3 Validity and Reliability

The validity is achieved in this thesis by the thorough design science research process on the available technological solutions possible to optimize a workforce and bring them to the Industry 5.0 standards and having a more human-centric approach at the assembly line. When a suitable solution was found, some preliminary interviews were performed via email with the point of contact for the company providing the possible solution. From these preliminary conversations, it was possible to identify which solutions could be the most optimal ones to utilize for this thesis case subject. This thesis does not present these preliminary conversations since they are not official interviews. Nevertheless, these are essential in the DSR process to find the optimal solution for the case company. The possible solutions are considered if, for example, the functional requirements for this thesis comply with the offered solution.

Reliability was realized by performing a thorough literature review research process about the subject. Since there were no preliminary interviews conducted, the reliability had to be based on previous research performed on the subject. By following the DSR's framework, the theory for the case subject could be connected, and an optimal solution to be found. When the final presented solution is implemented, the case company will get preliminary data to analyze and improve their workforce to optimize it ideally.

Since the thesis was conducted entirely remotely, there were some clear disadvantages. The workforce could not be preliminary followed, analyzed, or interviewed. With this, it could have been possible to point out the possible bottlenecks and improvements to be made. However, the final solution will pinpoint the bottlenecks to improve on and optimize the workforce. Ideally, the final solution would have been implemented for a test trial, and the results would have been included in this thesis. These findings would have made it possible to get feedback and determine what works based on the analyzed data. This test trial is to be done by the case company.

3.4 Future research

Future research in this area has several possibilities.

Firstly, the suggested final solution from this thesis should be implemented and given a test trial for the targeted workforce at the assembly line. From the test trial results, the company or the manager in charge can decide if the solution provides them with the desired results. The results from the test trials will also give the company a better picture of which areas to focus on and improve since the results can show that some areas need to be focused on with other technologies or solutions. Also, if the results are to the companies' standards and liking, they can implement the solution in other workforce groups and possibly at their other factories.

This presented solution could also be researched if it could be implemented in other divisions at the company since the solution is flexible to be programmed for other functions.

3.5 Aucobo

Aucobo is a software solution company that aims to optimize processes for companies working in the industrial field. Additionally, the software allows workers and machines to communicate over a network, which improves both data management and decentralized communication. The company's mission is to revolutionize industrial management utilizing smart wearable solutions with a human-centric approach (Aucobo, 2022), which is the aim for this thesis subject case. Their offered solutions utilize wearable smart devices in the manufacturing environment, increasing productivity and optimizing workflows. Hence, optimizing the workforce.

Aucobo will provide the setup for the final solution to be implemented: hardware (smartwatch), license access to the system software (Aucobo workflows) with which the user programs and manages the tasks and data. As well the license access to the graphical user interface for the smartphone and smartwatch. The final solution consist of these objects:

The hardware: Smartwatch (Aucobos's Model M)

The hardware for the solution is an industrial standard smartwatch. Aucobo offers a third-party smartwatch called the Model M. They offer four different smartwatches. The Model M is the most suitable for this case subject and has the following technical specifications:

- Operating system: Android 9.0
- Screen size: 2,8”
- Camera: 13 Megapixels with an autofocus function
- Network connectivity: Wi-Fi, Bluetooth, and LTE
- Measurements: 54,7 x 80 x 17 mm (without wristband)
- Weight: 62 grams
- Ingress Protection Code: IP67 (i.e. dust and water resistant, can be submerged up to 1 meter of water for 30 minutes)
- Battery capacity: 3300 milliampere/hour
- Other features: Vibration function for alerts and reminders, a proximity sensor that may be utilized to detect a target, support to light up the screen when the user raises their hand, and GPS

Figure 3. Model M Smartwatch (Aucobo, 2022).

The software: The workflow editor (Aucobo Workflows)

Supervisors, warehouse managers, and other employees can create workflow tasks and applications through the workflow editor. It does not require any programming language knowledge. The workflow editor uses a graphical interface with built-in function boxes connected with nodes when creating the tasks and workflows. It contains essential functions for the production process, such as various blocking options, escalation mechanisms, and ready-to-use workflows that meet the demands of the production process. The editor works on any internet browser.

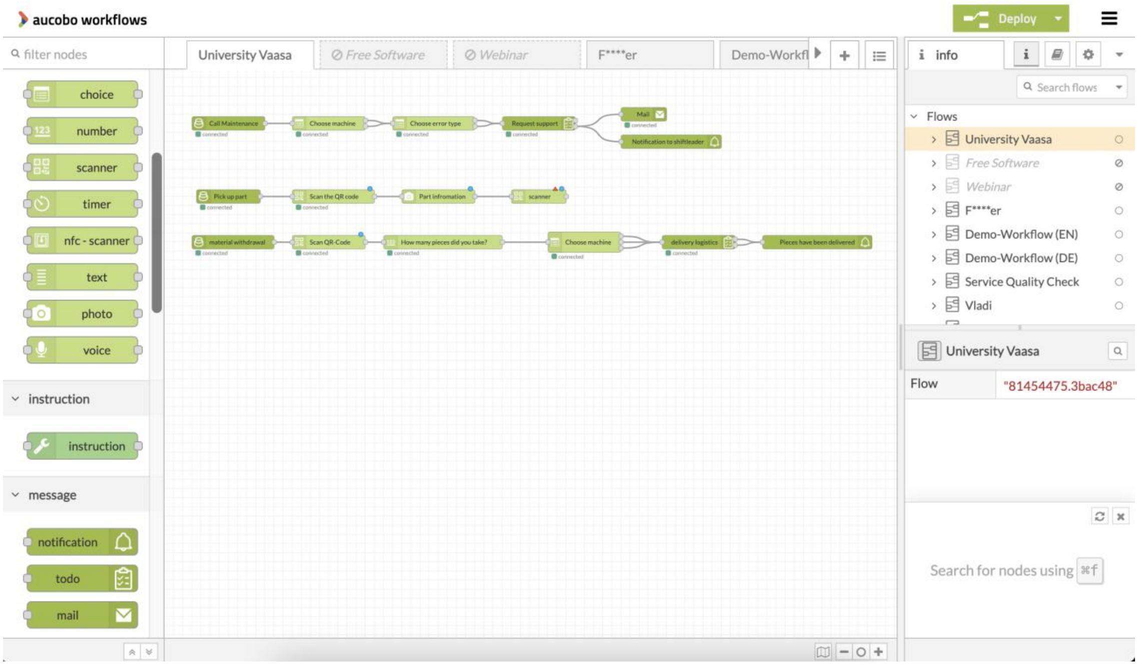

Figure 4. View of the workflow editor when creating tasks (Aucobo, 2022).

The software: Aucobo connector and core

The Aucobo connector allows the Aucobo infrastructure to be connected to the various systems and hardware. All the data is managed by the Aucobo core, which is the control centre for all connected devices and users. The system collects and evaluates this data, and the data can be anonymous or grouped accordingly. The graphical user interface dashboard shows all the information on data, applications, tasks, connected users, and hardware. To visualize all the data information the dashboard uses customizable widgets to present the data visually, utilizing figures and tables. The dashboard is also accessed via any internet browser.

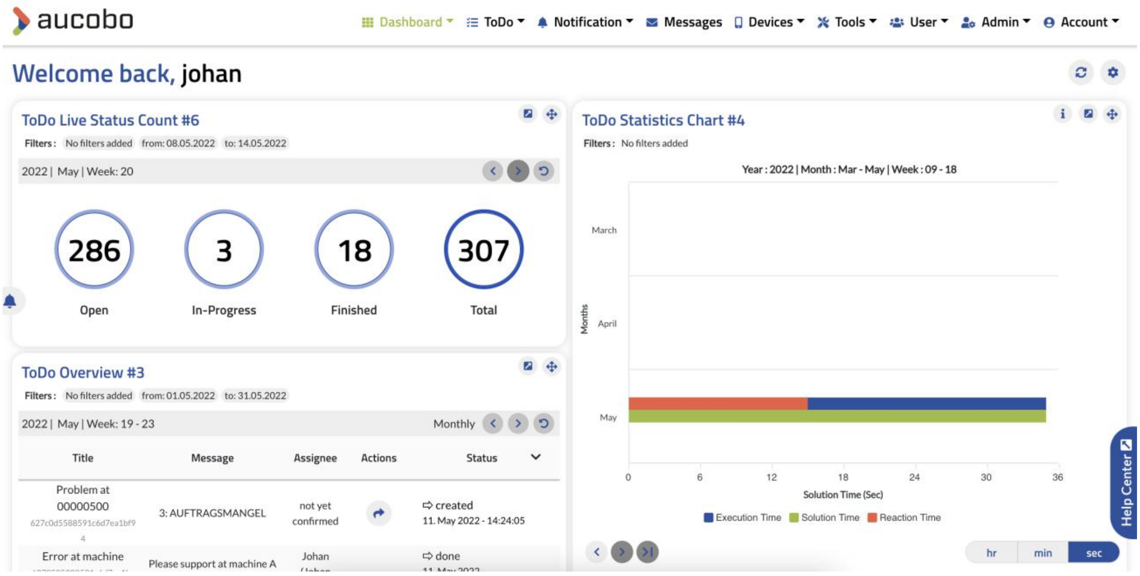

Figure 5. View of the main dashboard (Aucobo, 2022).

3.6 Use case example scenario

This chapter presents a plausible use case scenarios, which could be considered as a bottleneck in the industrial manufacturing industry. The use case example scenario is introduced shortly, then explained how the scenario would be optimized utilizing the final solution setup, how it looks like on the software's user interface (Aucobo messaging system), and a brief explanation of how it would be programmed in the software. This test setup was performed by the author using a smartphone (Oneplus) and the Aucobo workflows system software to program the task.

Scenario: Machine maintenance

Suppose a machine for the assembly line process breaks down. In that case, it causes much downtime for the assembly process because the machines that come after the broken machine will not be able to operate. Therefore, preventive maintenance or immediate action is required to prevent these scenarios (bottlenecks). Preventing this scenario requires frequent reminders for the employees about preventive maintenance for the machines and the possibility for any employee to get immediate help.

In the scenario that a machine has broken down, requesting the task would look like and programmed as follows: Require assistance (Call Maintenance) (Figure 6) → Which machine needs maintenance (Machine A or B) (Figure 7) → What type of error does the machine have (Electrical or Mechanical error) (Figure 8) → Request is sent. This request is then automatically sent to the responsible team member who has been assigned to handle the requested issues. For example, an electrical issue is always sent to the electrical supervisor working that same shift. To illustrate, if there is an electrical malfunction for Machine A, this request is sent to the warehouse's electrical supervisor. The supervisor will then see this request on their hardware’s (smartphone, smartwatch, or tablet) user interface, and then they can choose to either accept it (check mark), reject it (X), or postpone it with a reminder (clock symbol) of 1 – 20min (Figure 9). It is also possible for the supervisor to forward this task to another employee. When the employee accepts the task, it will go into the to-do list in the application of the user (Figure 10). After the task is performed successfully, the employee needs to finish the task from the to-do list by choosing the “double-check mark”. During these steps, the employee always has the option to accept it, reject it, or postpone it with a reminder. The request sender will always get an update about the task, on who and what action is being performed.

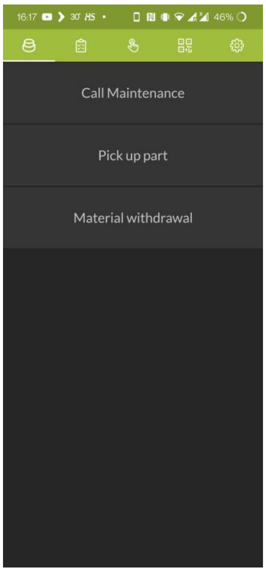

Figure 6. View for the progress of requesting maintenance assistance on a smartphone for a malfunctioning machine, step 1: Choosing the task (Aucobo, 2022).

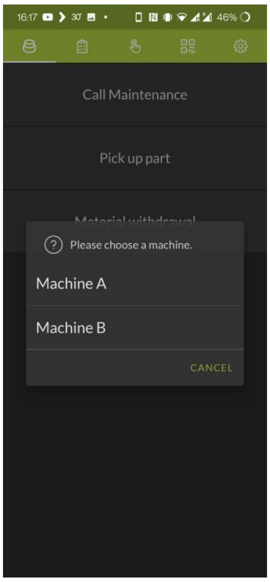

Figure 7. View for the progress of requesting maintenance assistance on a smartphone for a malfunctioning machine, step 2: Choosing the machine (Aucobo, 2022).

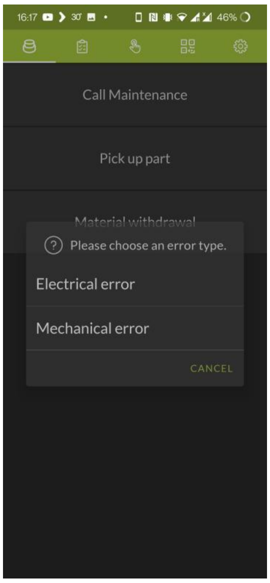

Figure 8. View for the progress of requesting maintenance assistance on a smartphone for a malfunctioning machine, step 2: Choosing the type of error (Aucobo, 2022).

Figure 9. View for the progress on a smartphone of when an employee receives a task (Aucobo, 2022).

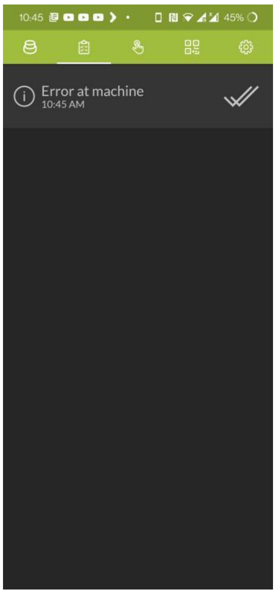

Figure 10. View for the progress on a smartphone of when an employee accepts a task (Aucobo, 2022).

The smartwatch was not bought for this thesis. Instead, the programmed application was performed and tested by the point of contact at the Aucobo company. As a result, it works seamlessly, the same as on the smartphone. See below for step-by-step pictures of the application performed on the smartwatch.

Figure 11. View for the progress of requesting maintenance assistance on smartwatch (Model M+) for a malfunctioning machine, step 1: Choosing the task (Aucobo, 2022).

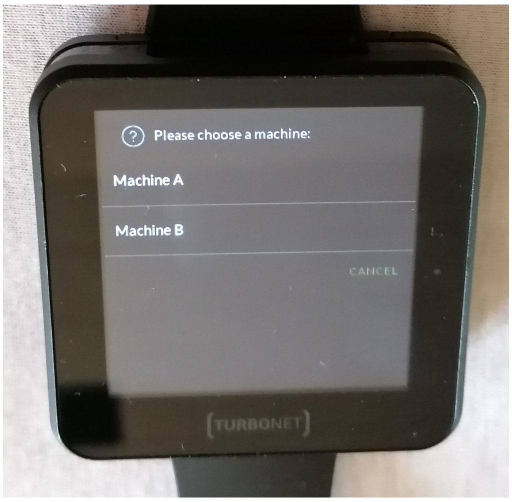

Figure 12. View for the progress of requesting maintenance assistance on smartwatch (Model M+) for a malfunctioning machine, step 2: Choosing the machine (Aucobo, 2022).

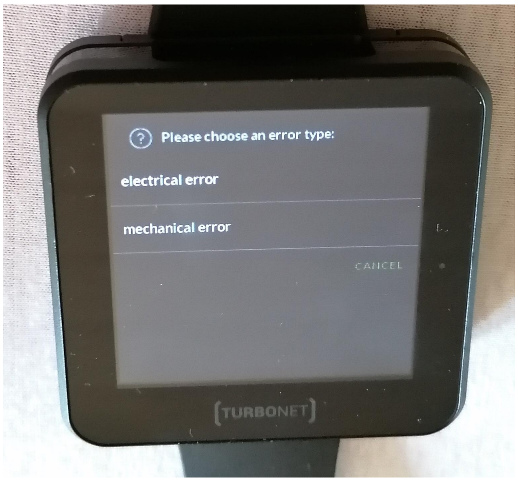

Figure 13. View for the progress of requesting maintenance assistance on smartwatch (Model M+) for a malfunctioning machine, step 3: Choosing the type of error (Aucobo, 2022).

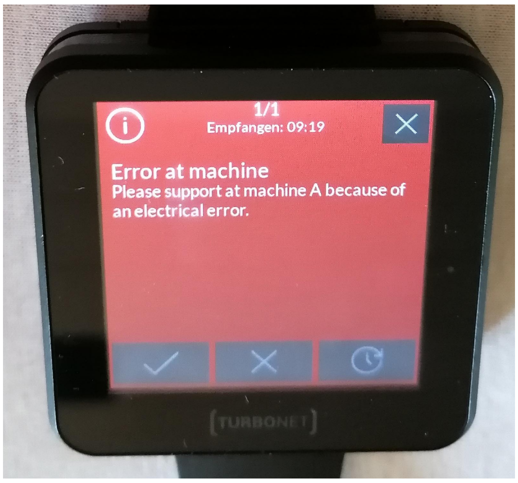

Figure 14. View for the progress on smartwatch (Model M+) of when an employee receives a task (Aucobo, 2022).

For an employee to send a maintenance request as mentioned earlier, it needs to be created or programmed in the Aucobo workflows software. It would be programmed as follows (Figure 15).

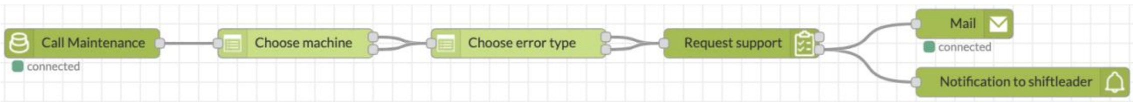

Figure 15. View of the programmed task in the Aucobo workflows interface (Aucobo, 2022).

1. Call maintenance (button trigger function box) (Figure 16) – This provides a notification (to the responsible employee) when a specific button ('Call

Maintenance') is pressed on the device (smartphone, smartwatch, or tablet). The data about that is fed into the Aucobo messaging system.

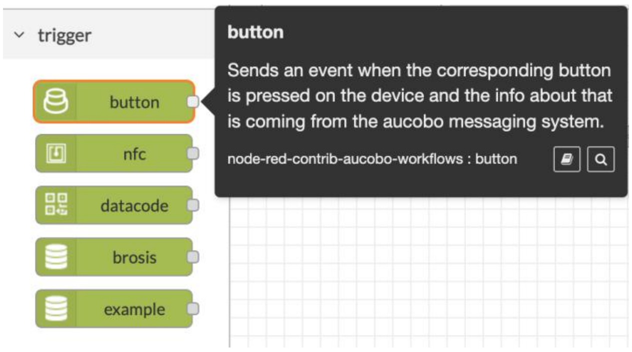

Figure 16. The possible trigger function boxes to choose from in the Aucobo workflows interface. This use case step uses the button function box (Aucobo, 2022).

2. Choose machine (choice trigger function box) (Figure 17) – This action sends the Aucobo messaging system a choice interaction (Machine A or B). The user then selects one of the options given by the device when the interaction is received.

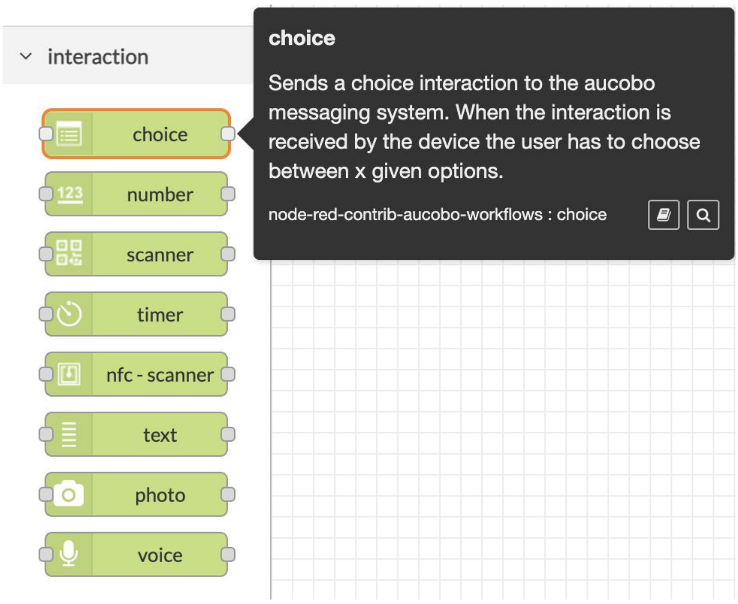

Figure 17. The possible interaction function boxes to choose from in the Aucobo workflows interface. This use case step uses the choice function box (Aucobo, 2022).

3. Choose error type (choice trigger function box) – This function utilizes the same choice trigger function box (Figure 17). Only the choices vary (Electrical or Mechanical error).

4. Request support (todo trigger function box) (Figure 18) – This action sends the task to the Aucobo messaging system's to-do list for the responsible employee.

Figure 18. The possible message function boxes to choose from in the Aucobo workflows interface. This use case step uses the todo function box (Aucobo, 2022).

5. Mail (mail trigger function box) (Figure 19) – This action sends an email to the responsible employee about the task.

Figure 19. The possible message function boxes to choose from in the Aucobo workflows interface. This use case step uses the mail function box (Aucobo, 2022).

6. Notification to the shift leader (notification trigger function box) (Figure 20) – This action sends a notification to the shift leader about the task.

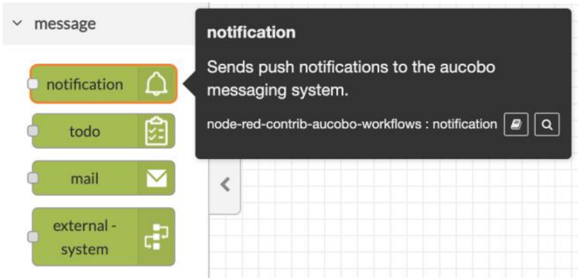

Figure 20. The possible message function boxes to choose from in the Aucobo workflows interface. This use case step uses the notification function box (Aucobo, 2022).

After all the function boxes are put in place and configured with all the necessary information, they must be connected. These connections are made by connecting the input and output nodes for the function boxes together. The trigger function boxes only have output nodes since they trigger an action. Interaction function boxes have both input and output nodes. Since these are executed actions, they need a trigger function (input) from the trigger function boxes and result as an output for the following action in the sequence. The message function boxes only have input since these end the action sequence, such as notifying about the task or sending an email. These function boxes can be connected as needed, following the above mentioned rules about connecting nodes.

4 Conclusions

The research for this thesis aims to find a solution to optimize the workforce for a team of assembly line workers. Therefore, a thorough investigation of possible solutions was conducted to optimize the workforce and find a suitable solution set up for the case company. The primary methodology utilized for the research was Design Science Research (DSR).

The research analysis concluded that hardware (smartwatch) combined with software (Aucobo) is the most optimum solution to optimize a workforce for assembly line workers. In addition, the research concluded that communication is a crucial factor in improving the workforce. The workforce will be connected and have real-time communications with the smartwatch connected to the software's ecosystem. Other crucial elements in optimizing a workforce are task management and receiving real-time data from the workforce's task management, with the possibility to send real-time data and tasks to the workforce.

An extensive literature review on possible technologies to utilize for workforce optimization is presented in this thesis. The design research methodology utilized for the literature review found that a smartwatch combined with analyzing software is optimal as a solution to optimize the workforce. Because the thesis work was performed remotely, it was impossible to have questionnaires or test trials for the final solution setup. However, it is possible for the case company of the thesis to have a test trial of the final solution, which is confirmed by the company that will provide the final solution setup.

The chosen company to provide the final solution will give the instructions for the final solution and how to set up the system for the company. Guidelines and a programmed use case scenario of a task example are performed with the solution, on the author's smartphone application provided by Aucobo and on Aucobo's smartwatch, which was tested remotely by the point of contact for Aucobo. These results are documented and shared in this thesis. The company or a future researcher on the subject can then pick up from where the thesis ended and build or test the chosen setup. If the case company for this thesis chooses the final presented solution, they will purchase it. The chosen final solution could be bought either as hard- and software or only purchase one of them separately. It is firmly advised for the company to purchase the final solution as a hardware and software solution.

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