Martin Hoislbauer, BSc

IT-based Visualization of Work Instructions for an Assembly Line of Construction Machines according to the Framework of Industry 4.0

MASTER´S THESIS

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Dipl.-Ing. Christian Höller

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Univ.-Prof. Dipl.-Ing. Dr.techn. Franz Haas

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Abstract

About 90 percent of the work instructions on the assembly lines of Wacker Neuson Linz GmbH are paper based and at some work places, they are even missing. This deficit was the impulse to start this thesis, because bad and outdated work instructions can have a direct negative influence on the quality of the produced products and on the productivity of the production department.

The aim of the thesis is to create a concept for a better generation and maintenance of the required work instructions. A digital visualisation of the instructions and a linkage between the work places and the production planning department, according to Industry 4.0 related techniques and possibilities, should be realized. Paper based work instructions should be replaced by tablets or PCs on the work places of the assembly lines, which are connected with the network of the company. This measures should provide easier updating, a faster creation and a comprehensive standard of work instructions for Wacker Neuson to reach a better quality of their produced construction machines.

To get an overview of these topics, a detailed literature research regarding Industry 4.0 and work instructions in general was conducted. Afterwards, the current state of work instructions at Wacker Neuson was investigated. The subsequent creation of a maturity model of work instructions, customized for Wacker Neuson, rests on the before gained knowledge. All further steps, from the status quo up to the final concept, are based on this model.

The outcome of the thesis is, in addition to the comprehensive maturity model, a concept to realize an automatic generation and updating of digital work instructions on the assembly lines of the plant. Based on a benefit analysis, the most suitable software in terms of the existing data and the required hardware was determined. To ensure an economically positive solution, a calculation regarding the required investment was conducted. Clear cost advantages because of lower rework time and a lower amount of work in the production planning department are the most important monetary benefits of the concept. Furthermore, the results show also possible benefits with no direct financial impact, like a better quality of the produced machines, a better image of the company and a higher satisfaction of the employees.

Kurzfassung

Etwa 90 Prozent der Arbeitsanweisungen an den Montagelinien der Wacker Neuson Linz GmbH basieren auf Papier und an manchen Arbeitsplätzen fehlen diese gänzlich. Dieser Nachteil gab schlussendlich den Impuls, diese Masterarbeit zu starten, da schlechte und veraltete Arbeitsanweisungen einen direkten negativen Einfluss auf die Qualität der Erzeugnisse und die Produktivität der Produktion haben.

Das Ziel dieser Masterarbeit ist es ein Konzept für eine bessere Erstellung und Wartung der erforderlichen Arbeitsanweisungen auszuarbeiten. Eine digitale Visualisierung dieser und eine Verlinkung zwischen den Arbeitsplätzen an den Montagelinien und der Arbeitsvorbereitung, nach dem Vorbild und den Möglichkeiten von Industrie 4.0 soll realisiert werden. Auf Papier basierende Arbeitsanweisungen sollen durch eine Lösung mit Tablets oder PCs, welche mit dem Netzwerk der Firma verbunden sind, an den Arbeitsplätzen der Montagelinien ersetzt werden. Diese Maßnahme soll eine bessere Aktualisierung, eine schnellere Erstellung und einen einheitlichen Standard der Arbeitsanweisungen für Wacker Neuson bieten, um schlussendlich eine höhere Qualität der produzierten Baumaschinen zu erlangen.

Um einen guten Überblick über die genannten Themen zu erhalten, wurde eine detaillierte Literaturrecherche bezüglich Industrie 4.0 und Arbeitsanweisungen im Allgemeinen durchgeführt. Anschließend wurde der aktuelle Stand bezüglich Arbeitsanweisungen bei Wacker Neuson aufgenommen. Die darauf folgende Erstellung eines für Wacker Neuson maßgeschneiderten Reifegradmodells, in Bezug auf Arbeitsanweisungen, baut auf das im Vorhinein erarbeitete Wissen auf. Alle weiteren Schritte, beginnend beim Status Quo bis zum finalen Konzept, basieren auf diesem Modell.

Das Ergebnis der Masterarbeit, zusätzlich zum Reifegradmodell, ist ein Konzept zur Implementierung einer automatisch Erstellung und Wartung beziehungsweise Aktualisierung von digitalen Arbeitsanweisungen an den Montagelinien des Standortes in Hörsching. Hierfür wurde die geeignetste Software im Hinblick auf die bereits existierenden Daten und die benötigte Hardware, basierend auf einer Nutzwertanalyse, ermittelt. Um eine aus wirtschaftlicher Sicht positive Lösung zu garantieren, wurde eine Berechnung über das erforderliche Investment erstellt. Durch das Konzept sind klare monetäre Vorteile durch eine geringere Nacharbeit an den erzeugten Maschinen und durch Einsparungen in Bezug auf eine Verringerung der Arbeit in der Arbeitsvorbereitung zu erwarten. Im weiteren Sinne können auch Vorteile, die keinen direkten finanziellen Vorteil mit sich bringen, wie eine bessere Qualität der produzierten Maschinen, ein besseres Image der Firma und eine höhere Zufriedenheit der Mitarbeiter, erwartet werden.

Table of Contents

1 Introduction

In this master thesis, the work instructions of the assembly lines at the production department of the company Wacker Neuson Linz GmbH should be analysed and improved. This will be executed regarding to the context of Industry 4.0. The following chapter gives an overview of the Company Wacker Neuson and the main objectives of this thesis.

1.1 Wacker Neuson

“All it takes!” is the perfect mission statement for the manufacturer of high quality construction machines and equipment. Wacker Neuson offers nearly everything which is needed for a construction site. The range of services aims at professional end users in the construction, gardening and landscaping architecture and agricultural industries, as well as at local authorities and companies in industry, such as the recycling industry.[1]

Core Data of the Wacker Neuson Group:[2]

- Group headquarters: Munich, Germany
- Production and development locations: Germany, Austria, USA, the Philippines, Serbia
- Affiliates: worldwide more than 50
- Sales and service locations: worldwide more than 140
- Product groups: more than 300
- Utility models/patents: over 400
- Employees: over 4,600
- Listing: since May 2007, SDAX

Wacker Neuson Linz GmbH is a subsidiary company of the Wacker Neuson Group, located in Hörsching (see Figure 1). This production and development site was built in 2012 and has about 1000 employees, producing and evolving about 14,000 compact excavators and dumpers per year.

[1] Wacker Neuson (2016), online source [10.04.2016].
[2] Wacker Neuson (2016), online source [10.04.2016].

Figure 1 : Wacker Neuson Linz GmbH in Hörsching (Austria), source: Wacker Neuson (2016), online source [10.04.2016].

1.2 Problem Statement

At fast growing production sites, deficits according to work planning and other organizational tasks can occur. Because of their fast growing sales over the last few years, Wacker Neuson is also affected by this problem. Therefore, it is on the dice that a good approach will be to rework the theme of work instructions on the assembly lines.

Generally, each assembly line needs work instructions to give the worker the required knowledge to fulfil the given tasks. The complexity of the instruction depends very strong on the produced parts and on the observed station of the line.

Work instructions regarding a construction machine are relatively complex, due to the big number of parts a finished excavator or dumper consists of. The efficiency of the whole assembly process and the quality of the built products largely depends on the quality of the work instructions. This fact can be observed at some work places at Wacker Neuson, which have no or only old instructions, because at these work places failures more often occur. Furthermore, it is also of vital importance how the workers use work instructions.

The way Wacker Neuson Linz now generates and maintains the work instructions and uses them on the assembly line is not satisfying at some main aspects:

- Bringing modifications of a work instruction, if a part of an assembly gets changed, to the assembly line is now a lot of work for the production planning department. This workload could be less by using an automatic generation of work instructions.
- Having standardized and comprehensive work instructions and creating them with a special for this purpose designed program is no guideline at Wacker Neuson at the moment.

There are many good approaches to reach better quality and to achieve well made work instructions, but as mentioned in the lines before, there are some deficits.

Due to that issues, it is necessary to improve and enhance the work instructions at labour intensive assembly lines, like the ones of Wacker Neuson. This makes sense because of the potential of cost reduction, due to the lower rework after the assembly line. Also the possibility of decreasing quality issues and underperforming of workers is high.

1.3 Research Aims

The main goal of the management of a production site is to produce high quality products with the lowest possible costs. There is a large number of factors influencing this complex issue: Good or rather perfect work instructions can help to improve the quality of the produced products, because of a clearly given work procedure. Therefore, the focus of this thesis is to optimize the work instructions at the assembly line. This should be realized with the help of approaches that the topic Industry 4.0 provides. The aim of this thesis is to create a concept for automatic creation of digital work instructions, based on SAP and CAD data. The advantage of such an IT-driven system is to have a faster and more trouble-free process to generate work instructions and to keep them always up-to-date, on the workplace and at the assembly line.

1.4 Methodology

At first the present situation will be analyzed. The main focus is a very detailed investigation of the process how a work instruction is created, used, and how it is integrated in the assembly process at the moment.

To get the actual state, it is also necessary to talk to the employees, who are in contact with work instructions at Wacker Neuson every day. The procedure of this examination will reach from collecting data for the instructions from different departments, up to the employees who are creating it, and to the workers who are using it at the assembly lines.

The next step is to find solutions regarding the automatic generation and the visualization of the instructions on the workplace. To gain all the required knowledge about this topic a comprehensive literature research regarding Industry 4.0 and work instruction generally gets performed. Therefore, the research is focused on existing systems at other plants or companies and also how a vision for the longer future should look like.

The gained knowledge will be transferred into a maturity model which shows the whole range beginning with having no work instructions up to the top level with using data glasses and a mass production with the lot size of one. A good overview of creating and displaying work instructions nowadays and in the future should be demonstrated with this model.

After finding companies who offer an overall solution which fits to the existing system and data, the different providers will be assessed. In the end, the best solution in terms of price-performance ratio will be selected and a concept for implementing will be considered.

2 Literature Research

The literature research of this thesis focuses on future technologies that Industry 4.0 provides to solve existing problems in the production. First, the term Industry 4.0 will be examined in detail, because a lot of varying opinions and written papers exist concerning this topic. With this research, all main elements according to Industry 4.0 should be examined and shown up clearly. The second part focuses on work instructions and points out how important they are for the producing industry.

2.1 Industry 4.0

This part of the literature research should provide an adequate overview of this big topic Industry 4.0, including the main elements of it.

2.1.1 Definition

“Industry 4.0” is a term which describes the newest technology of advanced digitalization and the overall use of internet technology in context with the production industry. Industry 4.0 has been introduced in Germany for the first time, in 2011. Furthermore, the Federal Ministry of Education and Research of Germany described Industry 4.0 as a future project regarding the high tech strategy 2020.[3]

The real big technological innovations of the past led to so called industrial revolutions, which tagged a breakthrough in the field of producing factories. Mechanization and the steam engine constitute the first industrial revolution at the end of the 18th century. Production lines and the comprehensive use of electrical energy was the second revolution at the beginning of the 20th century (see Figure 2).

Digitalization, computers, and the first programmable logic controller signed the third industrial revolution in the 1970s.

It can be noticed that a lot of experts and politicians talk about Industry 4.0 in the context of the 4th industrial revolution. The world of industry is on the threshold to the next real revolution. However, there are also different voices of experts who talk about it in the context of an evolution. These people see it, considering the already existing digitalization and computers used in the industry, only as a further step.

[3] Cf. Lasi, H., et al. (2014), p. 239.

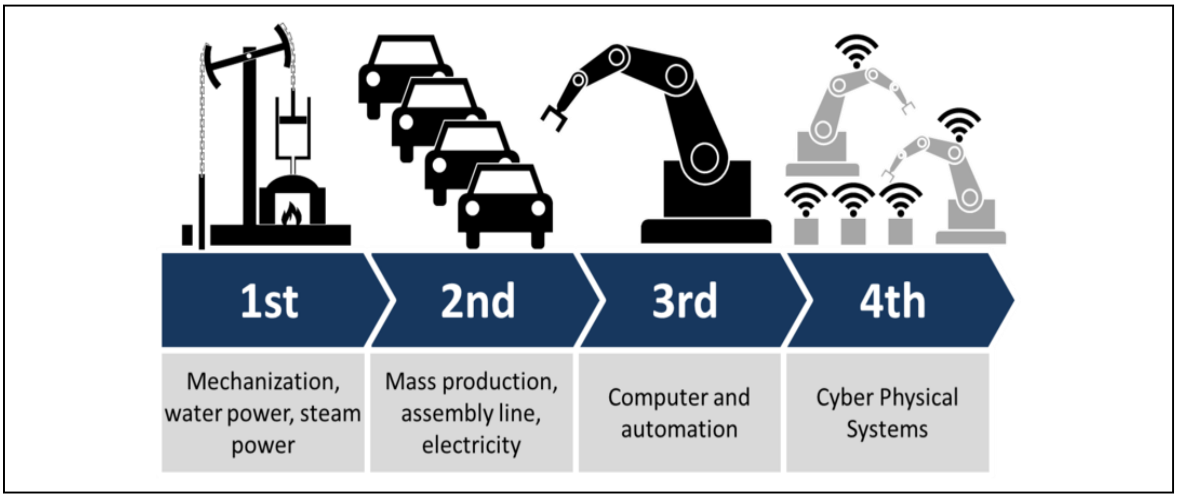

Figure 2 : Industrial revolutions, source: Marr, B. (2016), online source [10.05.2016].

It does not really matter how different people see the topic Industry 4.0, in the end it could be a combination of big data and the internet of things which result in cyber physical systems. If this occurs, these systems are able to change the state of production nowadays in a very fascinating way.

Industry 4.0, is also the idea of smart factories in which machines are augmented with web connectivity and connected to a system that can visualize the entire production chain and make decisions on its own.[4]

The following points show the main applications, the technology push, and some fundamental concepts Industry 4.0 is going to bring to the world of production and economy.

2.1.2 Main Components of Industry 4.0

In this chapter the main components that define the theme of Industry 4.0 are introduced. This is important for a better understanding of the whole working procedure the vision of Industry 4.0 provides for the economy. After an overview, the most important terms are explained in detail.

The main focus of Industry 4.0 is on intelligent machines, plants, and equipment which are called cyber-physical system. This intelligent components are made intelligent with very small sensors, memories, computer chips, or RFID tags. The last step of this evolution regarding intelligent objects is the so called ubiquitous computing. In this case every object has its own tiny computer chip implemented and is able to make its own decisions according to several environmental or programmed situations.

Embedded systems is the overall term for the mentioned components on or inside the products.

[4] Cf. Marr, B. (2016), online source [10.05.2016].

Through the Internet of Things, embedded systems will play a big roll, because more and more functions are implemented in the products and machines, which need a high computing power.[5]

Cyber physical systems are simplified systems, which have an interface between the digital (cyber) and the real world (physical).[6]

All these components are installed on the machines and other equipment, where they produce a huge amount of data in a short period of time. The data is sent mostly via the internet to a central server or computer to see the actual state or other parameters of the connected object. Due to the linkage of the different operators via the internet, the whole uprising system is named the internet of things.

The internet of things are for example parts that knew where they will be mounted and integrated or tools that knew their own expiration date.[7]

For connecting these parts in the best way, cloud computing will be necessary in the future. Therefore, it is possible to get access form nearly everywhere in the world to the provided data. By reason of this large quantity of information and facts from different connected participants, the collected data is called big data.

Big data is the usage of sensor generated and linked but unstructured data from many different sources.[8]

To gain profit out of it, the use of several special algorithms is necessary. These algorithms create error patterns, forecasts, and other very valuable information for the industry. This processed data is called smart data because of its usability and benefits.[9]

For instance, an auto configuration example of an extra equipment leads to the interaction of different data ports (engineering data, production data, price data, tool data, distribution data). Out of this, it comes to a decision, whether the manufacturer can offer the customer the extra equipment to an acceptable price or not.[10]

A main fact of Industry 4.0 is the connection of many different systems, which are often not really new if you look at them separately.[11] But if they are connected they can show their real talents and benefits for the industry.

In a vision of Industry 4.0, orders pilot themselves through the whole supply chain, book their processing machines and their material. At the end, they organize the distribution to the customer.[12]

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[5] Cf. Kaufmann, T. (2015), p. 3.
[6] Cf. Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016].
[7] Cf. Schnitzler, L., Hohensee, M. (2013), online source [28.04.2016].
[8] Cf. Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016].
[9] Cf. Acatech (2014), p.19
[10] Cf. Kaufmann, T. (2015), p. 6.
[11] Cf. Kaufmann, T. (2015), p. 7.
[12] Cf. Spath, D. (Ed.), et al. (2013), p. 24.

Subsequent the important terms and components are shown, which are indispensable when Industry 4.0 is discussed. Consequently, understanding these terms is very important in order to understand Industry 4.0.

Ubiquitous Computing

Ubiquitous computing describes the omnipresence of smallest, among each other cross-linked, intelligent computer and objects, which get equipped over the embedded computing with the necessary computing power.[13] In Figure 3, the development of computer technology up to Ubiquitous computing is shown.

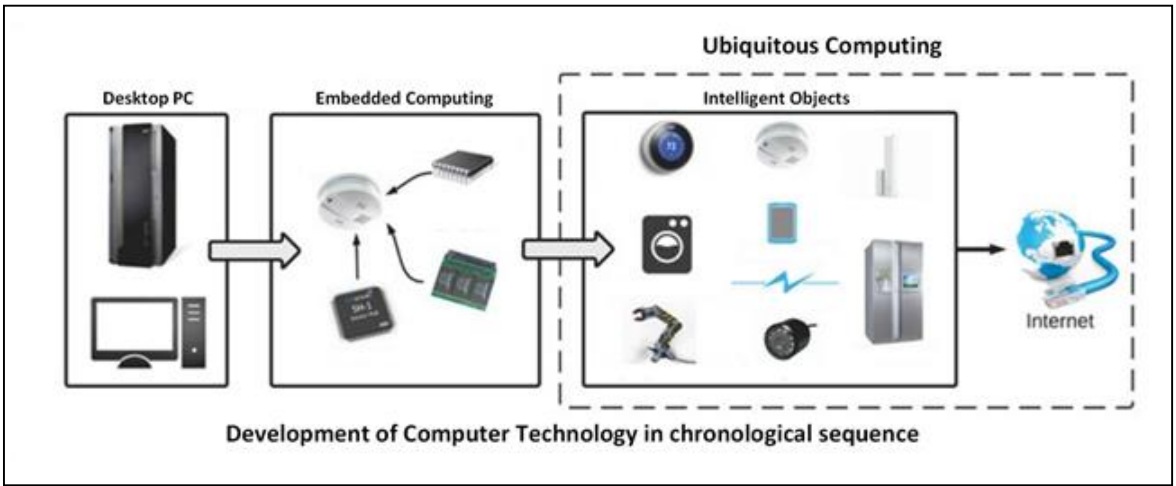


Figure 3 : Ubiquitous computing scheme and the development of computer technology, source: Siepmann, D., Graef, N. (2016), p. 25., modified

Big Data

In facilities, machines, cross-linked vehicles, etc. are many hundred sensors installed, which are able to transfer data. Depending on the number of attached sensors, a lot of data can be generated in a short time. This data is called big data (see Figure 4).[14]

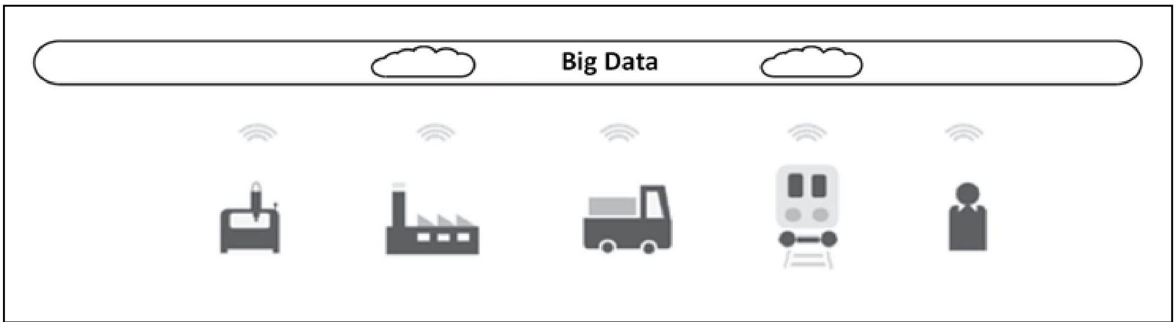


Figure 4 : Big data scheme with inked devices, source: Kaufmann, T. (2015), p. 8., modified

[13] Cf. Siepmann, D., Graef, N. (2016), p. 31f.
[14] Cf. Kaufmann, T. (2015), p. 6.

Smart Data

The base for smart data is big data. In order to get useful data out of this huge amount of data, it is necessary to work with data processing and special algorithms. This processed and useful data is now called smart data (see Figure 5) and provides an added value for the industry.[15]

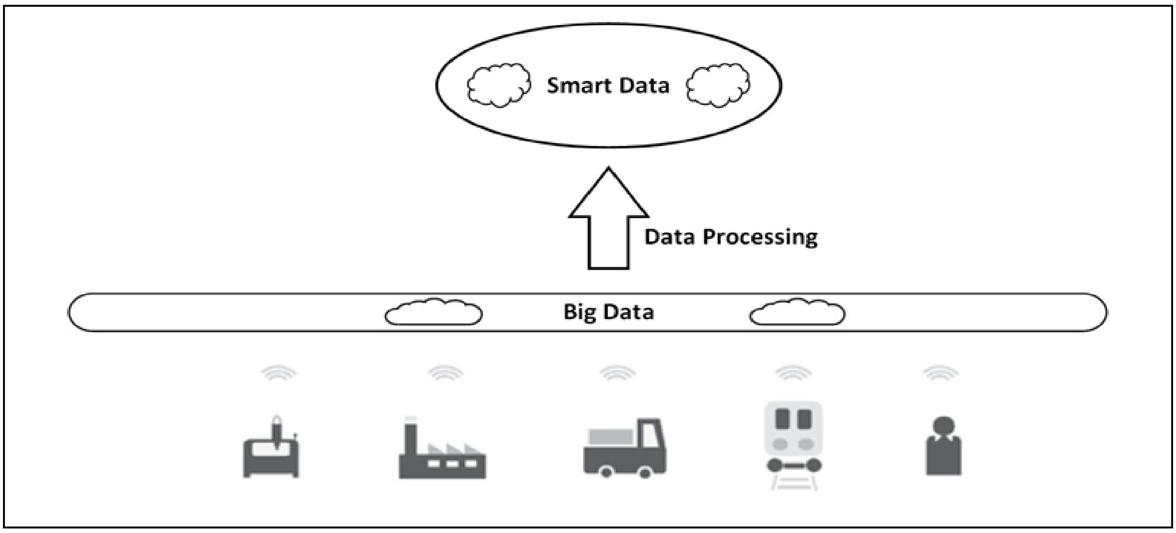


Figure 5 : From big data to smart data, source: Kaufmann, T. (2015), p. 8., modified

Cyber Physical System (CPS)

Cyber physical systems are connecting the manifold processes of production, logistic, engineering, management, and the internet services. Furthermore, they are collecting data with several sensors on their own, exchanging them via digital services, are able to release actions based on the collected and processed informations, and control themselves on their own. In cooperation with creative operators on this path, the possibility is given to improve varied industrial processes fundamentally.[16]

CPS-based ad hoc networking enables dynamic configuration of different aspects of business processes, such as quality, time, risk, robustness, price, and eco friendliness. This facilitates a continuous improvement and trimming of the material management and supply chains.[17]

Cyber Physical Production System

A cyber physical production system is for example a machine tool that provides data from the overall system and from each of its components (maybe even from the actual work piece) and permits easy access for data acquisition and commands execution.[18]

[15] Cf. Acatech (2014), p. 19
[16] Cf. Botthof, A., Hartmann, E. A. (2015), p. 24.
[17] Cf.Thiel, C., Thiel, C. (2015), p. 114.
[18] Cf. Schlechtendahl, J., et al. (2015), p. 143.

Embedded Systems

These systems are not only micro-processors but also other computer elements which are mounted for control tasks in machines and other devices. Simple processors, which do not have to gain highest performance for multimedia PCs, can be produced very cheap. Over 98% of the several billions micro-processors produced each year, are not used in PCs, but are used in other devices like cars, sewing machines, game consoles, home trainers, electric toothbrushes, washing machines, vending machines, and in lots of other daily used equipment.[19]

Cloud Computing

Cloud computing is an establishment for data processing resources over the internet. From the perspective of a company, some parts of its IT-infrastructure are not located in the company any more. Actually, the company rents the IT infrastructure form a provider. Components of these infrastructure are for example a specific software, data storage, server, platforms, or other services, which can be used from every place where a fast internet is available (see Figure 6).[20]

The main advantage of the cloud computing is that the IT infrastructure and all the data and services a company needs are available everywhere in the world, which is very important regarding the wide spread acting of big concerns.

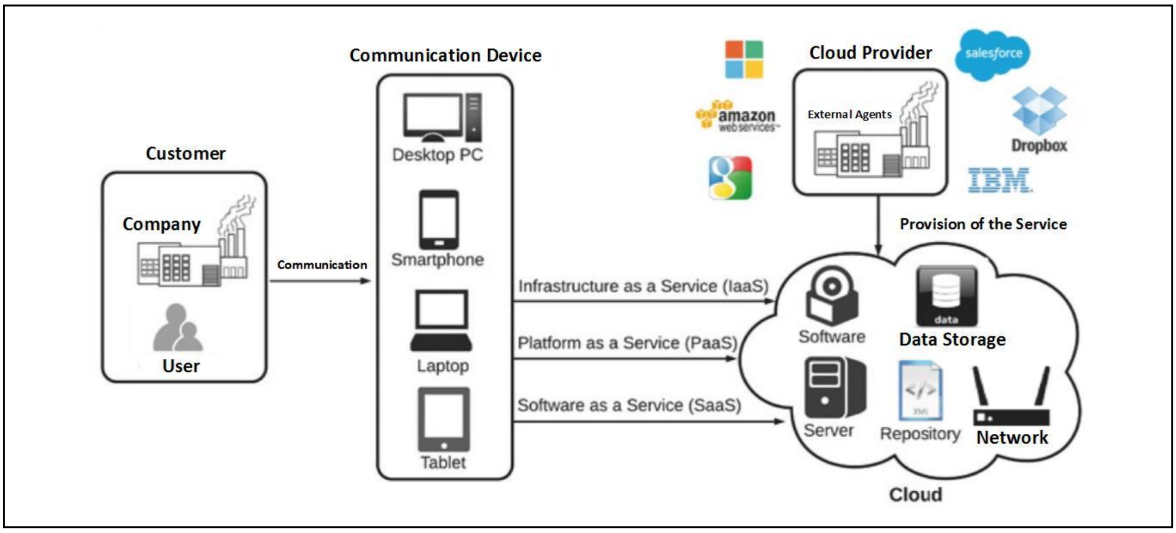


Figure 6 : Cloud computing as a service, source: Siepmann, D., Graef, N. (2016), p. 54., modified

Radio Frequency Identification (RFID)

Radio Frequency Identification is an automatic identification technology. Information, typically a serial number, is stored on an RFID-transponder. This transponder contains a micro-chip and is used as electronic data storage. The specific serial number can be

[19] Cf. Fleisch, E., Mattern, F. (Ed.) (2005), p. 61.
[20] Cf. Siepmann, D., Graef, N. (2016), p. 54.

detected with wireless communication over several meters via a suitable reading device. Compared to barcode scanning, RFID has its advantage in the full automatic, simultaneous identification of several RFID-transponders, whereby no visual contact between the transponder and the reading device is needed. This fact enables to embed the transponder in objects under their surface, which means a usage under extreme conditions like heat or dirt is possible. Furthermore, it is possible to change the information of the transponder during the whole term of validity, another application a barcode is not able to manage.[21]

A typical RFID-System consists of three main components: The reading device, attached to it a coupling device, and a transponder (see Figure 7).[22]

The transponder, which is mounted on the object, can have a size of about less than one square millimeter and does not need electricity to work. This is perfect for the use in production and other fields of industry where the transponder should not be seen.

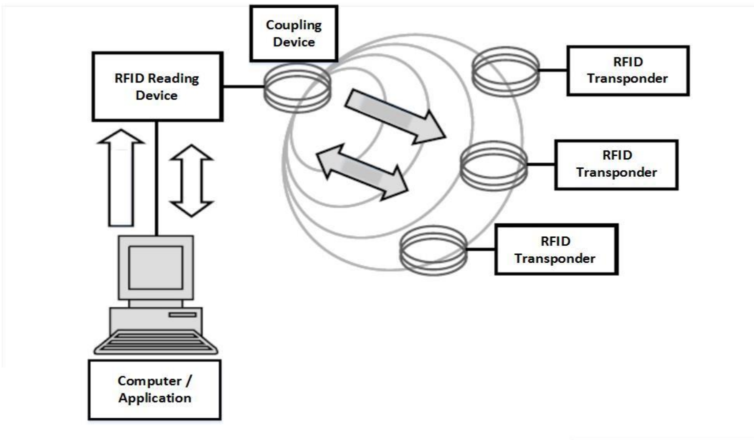


Figure 7 : RFID-System components, source: Fleisch, E., Mattern, F. (Ed.) (2005), p. 75., modified

Smart Products

These are products that are capable to do computations, store data, communicate, and interact with their environment. Starting from early approaches, enabling products to identify themselves via RFID[23] the capabilities of products to provide information on them evolved. Today, smart products not only provide their identity but also describe their properties, status, and history. Smart products are able to communicate information on their lifecycle. They know not only about the process steps already passed through, but are also able to define future steps.[24] Smart products constitute one of the main modules for realizing a cyber physical system.

[21] Cf. Fleisch, E., Mattern, F. (Ed.) (2005), p. 70.
[22] Cf. Fleisch, E., Mattern, F. (Ed.) (2005), p. 70.
[23] Messe, H. (2013), online source [29.10.2016].
[24] Abramowicz, W. (Ed.) (2015), p. 18.

Smart Factory

At the heart of Industry 4.0 is the smart factory, comprising self-configuring production resources and the associated planning and control systems. It uses a network to connect virtual and physical production elements by introducing the “Internet of things and services” to manufacturing operations.[25]

An example how such a smart factory may looks in the future is shown succeeding: In these factories, a part navigates itself through the production with no human assistance. In many cases of a smart factory most tools and production machines have at least a reader implemented to communicate with the environment in a production hall. The manufactured parts are often equipped with an electronical device to communicate with the machines, which execute the required work steps of the product.

Smart factories are factories in which machines are augmented with web connectivity and connected to a system that can visualize the entire production chain and make decisions on its own.[26]

This digitalization at such a factory does not stop at the walls of the production hall, there are many other influencing factors like smart buildings, smart mobility, smart grids, and the smart product, which contribute to a smart factory (see Figure 8).

The internet of things and the internet of services is the basis for this complex interaction of various components in a smart factory. With this kind of factory, all kinds of batch sizes can be produced and therefore it could be very useful to produce first prototypes or small series of a product in such factories. Also mass customization, which is one of the most difficult production types, can be realized in a smart factory.

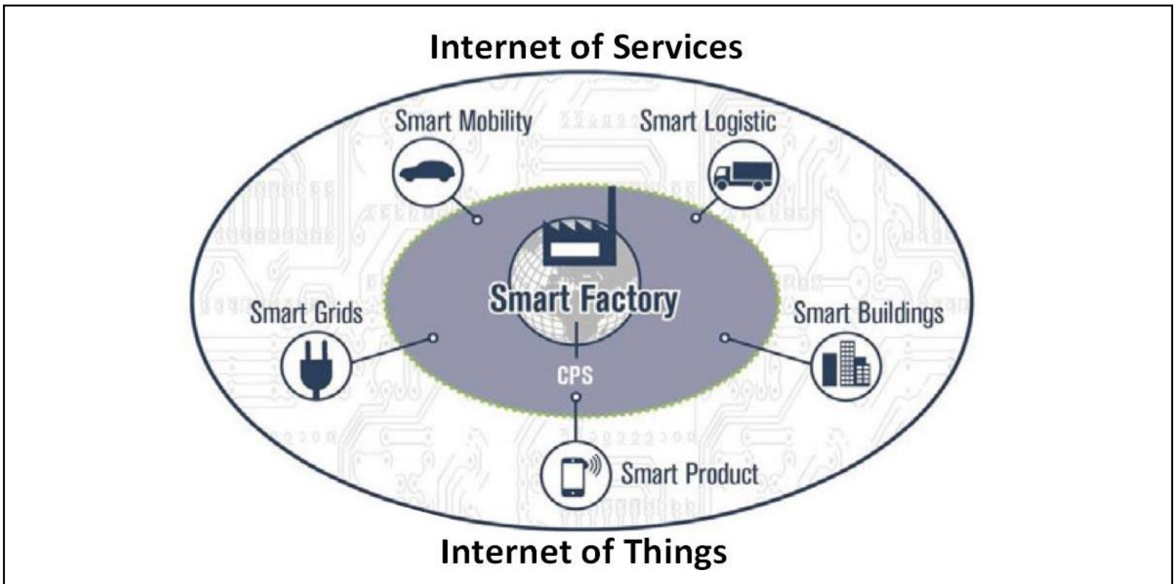


Figure 8 : Smart factory and influencing factors, source: Siepmann, D., Graef, N. (2016), p. 77., modified

[25] TRUMPF GmbH + Co. KG (2016), online source [30.11.2016].
[26] Cf. Marr, B. (2016), online source [10.05.2016].

Smart factories can constitute with all their required components and the complex interactions of them one of the highest stage of development regarding Industry 4.0. Nowadays, smart factories are in most cases research projects or only a part of a big factory, but they should show how the future of the industry could look like.

Corporate Social Responsibility (CSR)

CSR is a very important and widespread topic in economy. The main focus is on gaining a better work atmosphere, a better resource efficiency, a higher loyality according to customers and employees, and also to gain financial benefits. It is for example the responsibility towards the environment, the employees and the customers of a company or concern. In context to Industry 4.0, this topic will be more important, because of the available data and information of the whole supply chain of a product and its customers. According to this important information, a company can save resources, be better in after sales affairs, and improve in employee related topics.

2.1.3 Technology Push and Chances

In this chapter the often promoted and predicted new products and new lines of business will be discussed. Some of the shown models are transcribed partially yet, others are only visions which have good chances to be realized in the context of Industry 4.0.

Flexibility

A higher flexibility in product and production development is possible and necessary in the near future, because there will be more individual customer requirements and wishes. Therefore, a fast time to market is essential, also in terms of shorter product life cycles. The reaction time on new products of competitors is also a very essential factor for being competitive in the future. Due to these facts, high flexibility, also on the production line, should be a main focus and goal for the future at leading companies. This is of vital importance for companies acting in high technological branches all over the world. The highest step of flexibility in interaction with mass production is called mass customization.

Decentralization

Decentralisation is necessary for faster decision making procedures and a reduction of the strict organizational hierarchies becomes mandatory.[27] To ensure that a reaction to regional situations or problems of a company or market can be made as fast as possible, local departments are given more decisiveness.

[27] Cf. Lasi, H., et al. (2014), p. 239.

Another main section is the decentralisation of production, logistics, and also engineering. The focus is on outsourcing to reach big local markets like China, India, and the USA more easily. For realizing decentralization in a positive way, it is necessary to have a good communication base and perfect cross-linking between all the different subsidiaries of the company and inside the whole supply chain.

Resource Efficiency

Increasing shortage and the related increase of prices for resource plus the changed thinking in the context of ecological requirements leads to more sustainability also in the correlation of the producing industry.[28] The goal for the companies is to save costs by using less resources and to have a smaller ecological footprint. The recycling of goods after their lifecycle is a very significant issue. As a consequence, the usage of environmental friendly materials becomes an important topic.

Mass Customization

New technological approaches should make it possible to communicate and exchange information with the production, the whole company, and the supplier in real time to be able to react on different new situations very fast. Due to this approach, the reaction time according to changes decreases dramatically and standard products change to individual custom-made products. These products can be produced according to the individual customer requests, which means a lot size of one.[29]

The main aim of mass customization is to produce individual goods like in a normal, common mass production with the same high amount of pieces per time unit at the same price.

Furthermore, consumers who buy products in online shops often return it (especially in the European Union), because they do not fit to their individual preferences. Therefore, mass customization via Industry 4.0 can reduce product returns by producing more consumer individual products.[30]

A main part of the lot size one production is also the invention and the continuous improvement of the 3D-printing systems, where an individualization of products is easy to realize.

[28] Cf. Lasi, H., et al. (2014), p. 239.
[29] Cf. Siepmann, D., Graef, N. (2016), p. 223.
[30] Cf. Abramowicz, W. (Ed.) (2015), p. 23.

Miniaturization

Compared with computer technology some years ago, devices nowadays, with the same performance, are much smaller and can be installed on a few cubic centimetre of space. This allows a lot of new applications, especially in the field of production or logistics.[31]

According to the growing use of small computers, they are getting cheaper and therefore interesting for more applications in the industry.

2.1.4 New Markets (Market Models)

New technical applications and devices provide the chance of new business models. This involves also new competitors on the market for long-established companies. According to this, these established companies have to rethink their business model to be able to compete against the new business on the global market.

Many of the existing companies change form pure product to solution providers. Due to the embedded systems and the knowledge about the work pieces resulting out of it, the service part gets very important.

Some more important business models that may change the models of today are mentioned in the next lines.

Sensors and Microcomputers: Both are a main part of the cross linked and embedded systems of Industry 4.0. Because of the increasing amount of "intelligent products", the demand for these products will grow very fast.

Personalized Products like 3D-printed parts or the very individual configuration possibilities of many car producers.[32] High quantities of such products can be realized with efficient lot size of one production.

Intelligent Products and Services, which can communicate via internet and send many useful data directly to the user, like service requests or hazard informations. Also the use of all the received data for creating forecasts or showing trends in daily life situations is very helpful for different applications.[33]

Open Source-Concept is a model, where a community is acting and designing new products.[34] This concept has its roots in the software industry, where many users program

[31] Cf. Lasi, H., et al. (2014), p. 240.
[32] Cf. Kaufmann, T. (2015), p. 17ff.
[33] Cf. Kaufmann, T. (2015), p. 13ff.
[34] Gassmann, O., et al. (2014), p. 184

different software solutions for free and offer them at the end also for free. With tiny changes, this interesting concept will also be interesting for the production industry.[35]

Availability on Demand: A lot of customers only need the service of a machine every now and then. That is why it may be beneficial for them to buy the service from a provider, just like a farmer who does not own a harvester himself, but buys the service of harvesting his fields for some days of the year. This business model saves costs for the customer (farmer) and the provider realizes a better utilization of the equipment. To have the machines always in a perfect condition, the approach of embedded systems is very important for having a forecast of upcoming maintenance or breakdowns. Otherwise an unpredictable failure can occur.[36]

New Systems in Distribution and Procurement: Distribution and procurement will be increasingly individualized. Connected processes will be handled by using various different channels.[37] For example, cars of an American manufacturer are distributed only via internet in countries where fix dealerships are too expensive. Generally, online shops are by now part of everyday business and an important distribution channel for most companies.

2.1.5 Industry 4.0 and the German Industry

Germany is the country of origin of Industry 4.0, because Industry 4.0 was mentioned there first in 2011. Due to that, German companies and their progress in Industry 4.0 topics are considered in this chapter.

To reach the internet of things in the modern production, the fusion of the virtual and the physical world is necessary. The product of this fusion should cause cyber physical systems. According to this, the possible merging of technical processes and business processes should lead the production location Germany into new ages.[38]

According to an article of “Horvath & Partners”, German companies and their conduct regarding Industry 4.0 was explored: 116 offered applications according to Industry 4.0, were considered.

The benefit potential of the majority of these applications has a focus on cost reduction first and on flexibility second (see Figure 9).[39]

[35] Cf. Kaufmann, T. (2015), p. 16.
[36] Cf. Kaufmann, T. (2015), p. 21.
[37] Lasi, H., et al. (2014), p. 240.
[38] Cf. Botthof, A., Hartmann, E. A. (2015), p. 3.
[39] Cf. Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016].

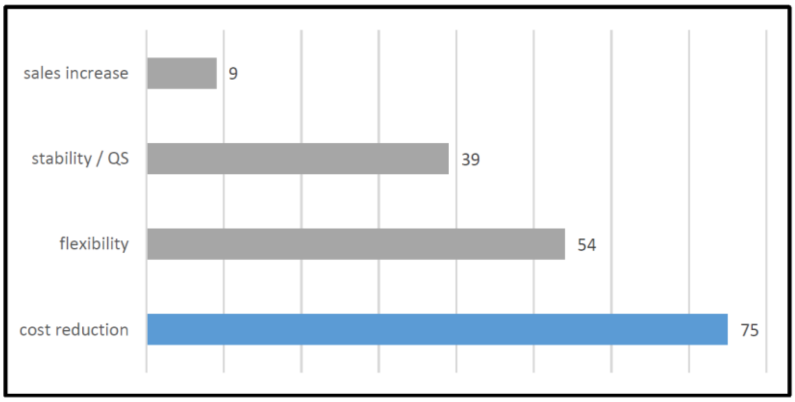


Figure 9 : Benefit potential of Industry 4.0-applications (n=112, multiple answers possible), source: Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016]., modified

The enabler for implementing Industry 4.0 are considered as well and the outcome is a clear focus on needed software and moreover on the needed hardware components to be able to realize Industry 4.0. Not that important seems to be the creation of new business models.[40] (see Figure 10)

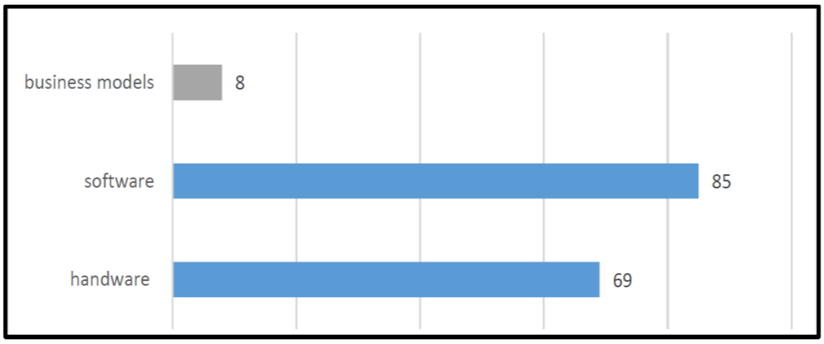


Figure 10 : Enabler of Industry 4.0-applications (n=112, multiple answers possible), source: Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016]., modified

About 90 percent of the applications according to Industry 4.0 affect the production or the work preparation directly or indirectly (see Figure 11). The reason for this is that the applications are in most cases focused on improving the concern value.[41]

[40] Cf. Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016].
[41] Cf. Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016].

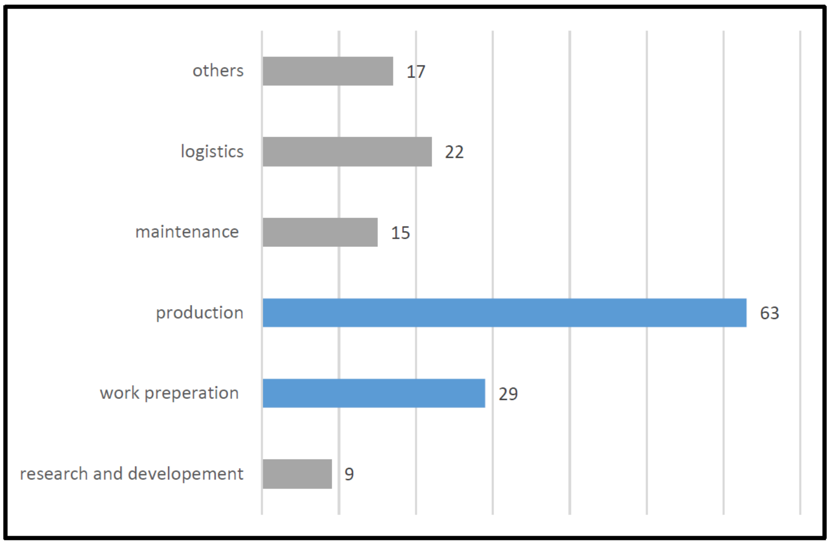


Figure 11 : Affected functional areas of Industry 4.0-applications (n=112, multiple answers possible), source: Sauter, R., Bode, M., Kittelberger, D. (2015), online source [06.04.2016]., modified

Another survey of the Forsa institution was performed with 200 German companies of the manufacturing business and more than 300 employees. The topic of the survey was Industry 4.0 and especially the question, how far the participating companies analyze their machine data.[42] More than 84 percent of the companies belief in a growing importance of new production processes like connected or communicating production sites. Most of the companies (81 percent) think that the analyse of machine data will be more and more important in the next two years. A big part of them (75 percent) indicate that they are already analyzing machine, sensor or service data.[43] To fix their faults in quality or errors in the production process is very important for 86 percent of the asked companies.[44]

A lot of German companies spend time on Industry 4.0 topics and are already using some applications in context to Industry 4.0. Therefore, Germany is a leading country in the fields of modern production and by using production data for quality control applications, according to this study.

2.1.6 Visions for the Future

In this chapter, various visions for the future of the production industry are discussed.

Today it is still common to distribute work instructions for a milling machine paper based, but in the future or at some modern productions the worker gets the instruction on a tablet or smartphone.[45]

[42] Cf. WirtschaftsWoche (2013), online source [21.04.2016].
[43] Cf. WirtschaftsWoche (2013), online source [21.04.2016].
[44] Cf. WirtschaftsWoche (2013), online source [21.04.2016].
[45] Cf. Spath, D. (Ed.), et al. (2013), p. 115.

Google Glass for example, can fade in hints on the display of the glasses. This could also be an instruction for a specific work step or a reference, including what to do next in an assembly process.[46]

In the future, a production order could be triggered by the customer and navigate autonomously through the value chain. Thereby, the order reserves processing steps, facilities, materials, and controls the processing on its own. Furthermore, the order recognizes threatening delays of the delivery, organizes as far as it is possible additional needed capacities and reports unavoidable delays to the affected customer. The used production facilities exchange drawings and other useful information among themselves to organize the order sequence and maintenance requirements.[47]

The National Academy of Science and Engineering in Germany assets the value of productivity growth in the production department in Germany up to 50 percent, if the whole potential of Industry 4.0 is exhausted.[48]

These visions are in the distant future, but there is a clear direction where the world of production goes in the next few years. A lot of infrastructure is installed yet but its different parts are not fully connected by now.

2.1.7 Threats of Industry 4.0

First, the basics for realizing Industry 4.0 are examined critically. Afterwards, the possible threats of connected machines, plants and other devices over the internet are revealed in this topic.

Generally, there are a lot of different opinions according to the theme Industry 4.0. It strongly depends on the motivation of the observer regarding Industry 4.0, because in this context nearly everything is possible, the valuation reaches from bad and sceptical up to very good and positive thinking.[49]

Basic Problems

A big issue for realizing Industry 4.0 is an adequate infrastructure for data streams. Unfortunately, there are still a lot of machines and devices which are not internet ready, and as a consequence consistent data streams are not possible at the moment. Moreover, the costs of linking all devices in a company are too high for many of them nowadays, as it can be detected by a simple cost-benefit calculation.[50]

Furthermore, it is not that expensive to build a new, so called smart factory, on the green field compared to implementing it in an existing plant. This plants have to cross link all their

[46] Cf. Spath, D. (Ed.), et al. (2013), p. 127.
[47] Cf. Spath, D. (Ed.), et al. (2013), p. 24.
[48] Cf. Schnitzler, L., Hohensee, M. (2013), online source [28.04.2016].
[49] Cf. Taschek, H. (2016), online source [09.05.2016].
[50] Cf. Taschek, H. (2016), online source [09.05.2016].

present and often old equipment. In this case the cost squeeze for new infrastructure often rises very high.[51] Therefore, in many cases the implementation of new technologies that are needed for Industry 4.0 are getting on the end of the line compared to other upcoming investments.

Skilled workers in the field of IT, engineering and programming are very important, because there are too few of them available on the labour market nowadays. In the context of Industry 4.0, a lot of highly skilled workers will be required to implement all the technical innovations in the near future.

Due to new technologies, the flexibility of the companies should increase. An essential condition therefore is that the employees agree to flexible working hours.[52]

The high complexity of business processes is another negative aspect of Industry 4.0, as it rises the transaction costs in many economic cases.[53] To counteract this issue, new information technologies are necessary to handle more complex processes in an efficient way.

Possible Threats due to the Overall Linkage

Counterfeiting is a big problem in the industry and will grow regarding to a higher linkage over the internet, if there are no new protecting measures.

By 2015, the International Chamber of Commerce (ICC) expects the value of counterfeit goods globally to exceed to $1.7 trillion. That is over 2 percent of the world`s total current economic output.[54]

Industry 4.0 will make the situation of counterfeiting in some areas even worse than it is nowadays. Unfortunately, the necessary protective measures such as a globally accepted trust infrastructure that will allow consistent verification and authentication methods will be available in years. A possible way to fight against counterfeiting is to focus on smart products, where the added value lies on the additional services.[55]

The rising cyber-criminality is strongly related to counterfeiting. Cyber-crime contains hacking, virus attacks and generally all crimes by using the information technology (IT) against the user or against the technology itself.

Cybercrime is a growing industry. The returns are great and the risks are low. It can be estimated that the likely annual cost to the global economy from cybercrime, considered the whole world, is more than $400 billion.[56]

[51] Cf. Taschek, H. (2016), online source [09.05.2016].
[52] Cf. Taschek, H. (2016), online source [09.05.2016].
[53] Cf. Schmidt, R., et al. (2015), p. 22.
[54] Cf. Thiel, C., Thiel, C. (2015), p. 111.
[55] Cf. Thiel, C., Thiel, C. (2015), p. 119.
[56] Cf. Intel Security (2014), online source [09.04.2016].

2.1.8 Conclusion Industry 4.0

Industry 4.0 is a very interesting and fascinating topic, especially for the production industry. Some experts call it the fourth industrial revolution and others only see it as an evolution of partly existing infrastructure in companies. Therefore, Industry 4.0 offers a conversation topic for experts all over the world, who provide a lot of visions how the future of production and economy will look like.

The positive facts of Industry 4.0 are that it could emerge a higher efficiency and a higher flexibility in the production. In the whole economy there will be an upheaval, which influences it in a positive way. The negative side of Industry 4.0 is the topic of cyber-crime. The job situation for production workers could also be negative influenced, because according to the higher grade of automation and the rising number of robotics, some workers are maybe replaced by these technical devices. It contains counterfeiting, hacking, viruses, and various other dangerous possibilities to harm the economy. How the whole visions, experts predict, will be transcribed can only be a guess. Because there are at some areas of several companies too low resources like well skilled workers, too high costs for changes and often also the motivation of the management level does not exist.

To sum up, Industry 4.0 is a big chance for the whole economy, especially for the western countries which have high labour costs and therefore, need a high productivity of their industry. But the threats cannot be neglected, so it can only be a guess how the industry will developed in the next few years exactly. For Wacker Neuson Industry 4.0 also provides a many chances, but the production of construction machines still requires a lot of manual work.

2.2 Work Instructions

Work instructions are one of the main linkage between the engineering and the production department. At early engineering steps, it is very important to consider the sequence of assembling a machine or a product. In order to this sequence, the work instructions for the final assembly on the shop floor will be generated.

Taking a closer look at the process of providing instructions as a knowledge sharing process, the focus is on making the recipient or rather the worker understanding the assembly sequence in the same way as the instruction sender or rather the engineer.[57]

2.2.1 Definition

There are no uniform definitions for work instructions according to any standard or textbook, but some definitions from the literature can give a good overview what work instructions should offer.

[57] Cf. Haug, A. (2015), p. 171.

“Individual work instructions are very specific on to an industry or company.”[58]

“A Work Instruction is a document that guides workers on how to perform an assembly task. It shows what elements must be joined, what tools must be used and what procedures and rules should be followed to do the work correctly.”[59]

“Work instructions are a set of step-by-step instructions distributed to shop-floor workstations and production assembly lines that describes the operations and rules needed to assemble parts.”[60]

“Work instructions should be very detailed on “how” to accomplish a specific job, task or assignment. For example a work procedure could be developed for assembling the final housing of a product with step-by-step instructions including such detail as the torque requirements of the fastening screw.“[61]

“A work instruction describes both, the sequence of operations to be performed by the workers and fundamental and critical parameters of the operation (drawings of components, torques to be applied, sealing system characteristics, etc.).”[62]

Work instructions are therefore the most important equipment to communicate the technical tasks from the engineering department to the shop floor. The balancing between very detailed and easy to read instructions should be considered, because the workers have to understand the difficult engineering tasks as good and fast as possible.

2.2.2 Standards for Work Instructions

There are not many general standards for work instructions. Most of the big companies or concerns have their internal specific standard for work instructions customized for their products.

Although, one general standard how work instructions are classified in the documentation structure of ISO 9001, is provided in the literature (see Figure 12).

[58] Anderson, C. (2016), online source [19.05.2016].
[59] Serván, J., et al. (2012), p. 633.
[60] Cf. Wheatley, M. (2006), online source [13.05.2016].
[61] Anderson, C. (2016), online source [19.05.2016].
[62] Cf. Serván, J., et al. (2012), p. 633.

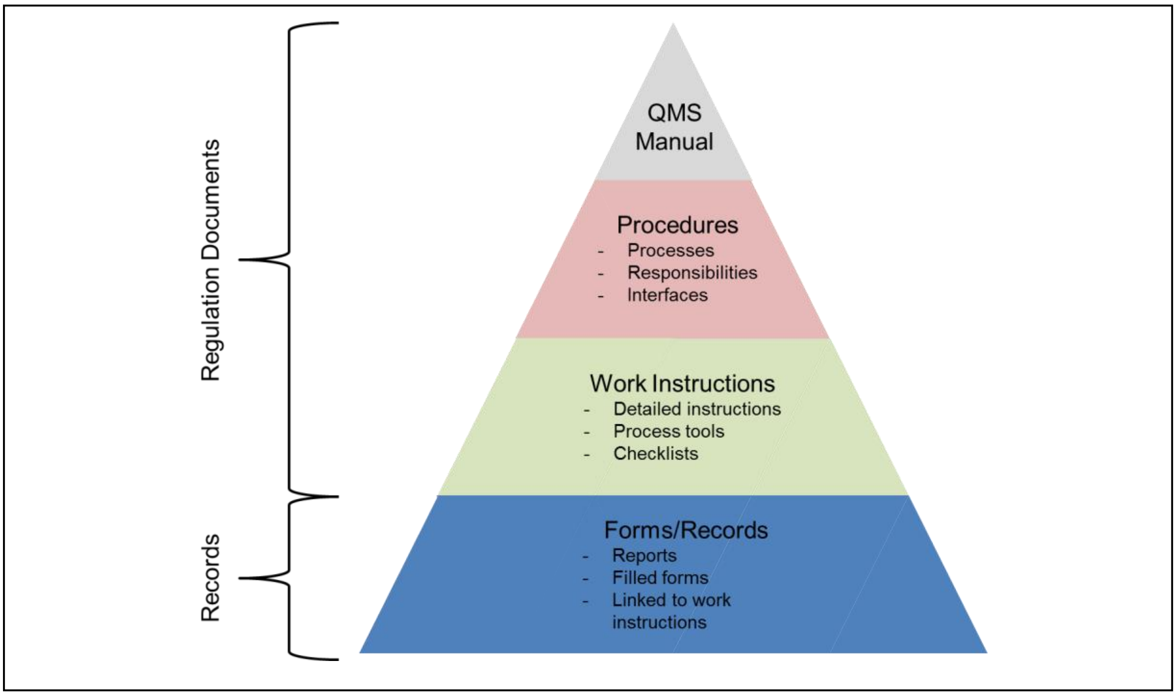


Figure 12 : ISO 9001 classification with work instructions, source: Babb, G. (2014), online source [15.06.2016].

2.2.3 General

Work instructions are generally presented as a multilevel, hierarchical and structured list where each level can include several kinds of information. The complexity of work instructions is determined by several factors like the number of products, the people involved, the range, the parts and manufacturing operations.[63]

A work instruction steps through three phases during its lifecycle, which are considered in this chapter: Creation-Phase, Use-Phase, Maintenance-Phase.[64]

Creation Phase

The creation phase is mainly used by the production planning department, where all kind of needed data and process for the work instructions is collected.

These data and information can be divided into three main elements: Product information, resource information and process information.[65]

Product information is created by the design and engineering department and contains all technical information of the product like 3D-data and models, metadata of all parts, 2D-plans, cable diagram, etc. In most cases, the product data is stored on a server or on a special data base, where all involved departments have access to.

[63] Cf. Wheatley, M. (2006), online source [13.05.2016].
[64] Cf. Serván, J., et al. (2012), p. 634.
[65] Cf. Serván, J., et al. (2012), p. 634.

Resource information is generated or delivered from the industrial design department or from the supplier who adds data to the supplied parts. This information contains jigs, 3D models, needed tools for assembly operations, machine data and sometimes software.

Process information is created by the industrial design department. It comprises detailed instructions about how to perform the assembly processes and a set of rules and procedures to be used.[66]

Use Phase

Work instructions assist the worker on the shop floor at assembly tasks. The instructions have to contain all necessary information a worker needs in a clear and comprehensible manner. Furthermore, the worker should be able to have access to information behind the work instruction in some special cases, like a plan of the whole electricity of the assembled machine.

Maintenance Phase

Keeping the instruction on the current status regarding to design changes, error correction, changed tools and new or revised versions of any part is the function of the maintenance phase.

Modifications of the work instruction lead to a significant amount of documentation that create a lot of work and costs for the companies. Although, a good maintenance of work instructions is very important for quality, productivity and rework issues. Therefore, it has to be executed in a very accurate way.

2.2.4 Quality of Work Instructions

The quality of work instructions is a crucial issue because low quality work instructions are a significant disadvantage in all directions of a production. Higher costs, multiple rework time, fewer quality and lower productivity are the main drawbacks if the quality of the work instruction is low. In this topic the threats of low quality work instructions are headed and afterwards the chances and significance of high quality manuals are discussed.

Low Quality Work Instructions

If employees have to do their work upon poor quality work instructions, they are less efficient and have lower job satisfaction. More specifically, poor quality data or information is claimed to have negative effects, such as less customer satisfaction, increased running costs, inefficient decision making processes, lower performance and lowered job satisfaction.[67]

[66] Cf. Serván, J., et al. (2012), p. 635.
[67] Cf. Haug, A. (2015), p. 170.

Furthermore, the most important issue are accidents, which result in a higher and severe sickness rate of the workers. Work instructions are not being contrived to help the worker learning the tasks by heart and recall that after use for further assemblies or work pieces. The most efficient use of work instructions, for a company with unique product portfolio, is to perform the assembly work step-by-step by using the instruction.

A framework of work instruction quality shows where the problems of instruction deficiency are (see Figure 13). The theme is divided into five key issues, namely the intrinsic problems, the representational, the unmatched information, the questionable information and the inaccessible information. These five issues cover most problems and can therefore give a perfect framework to analyse the work instructions in an effective and transparent way.[68]

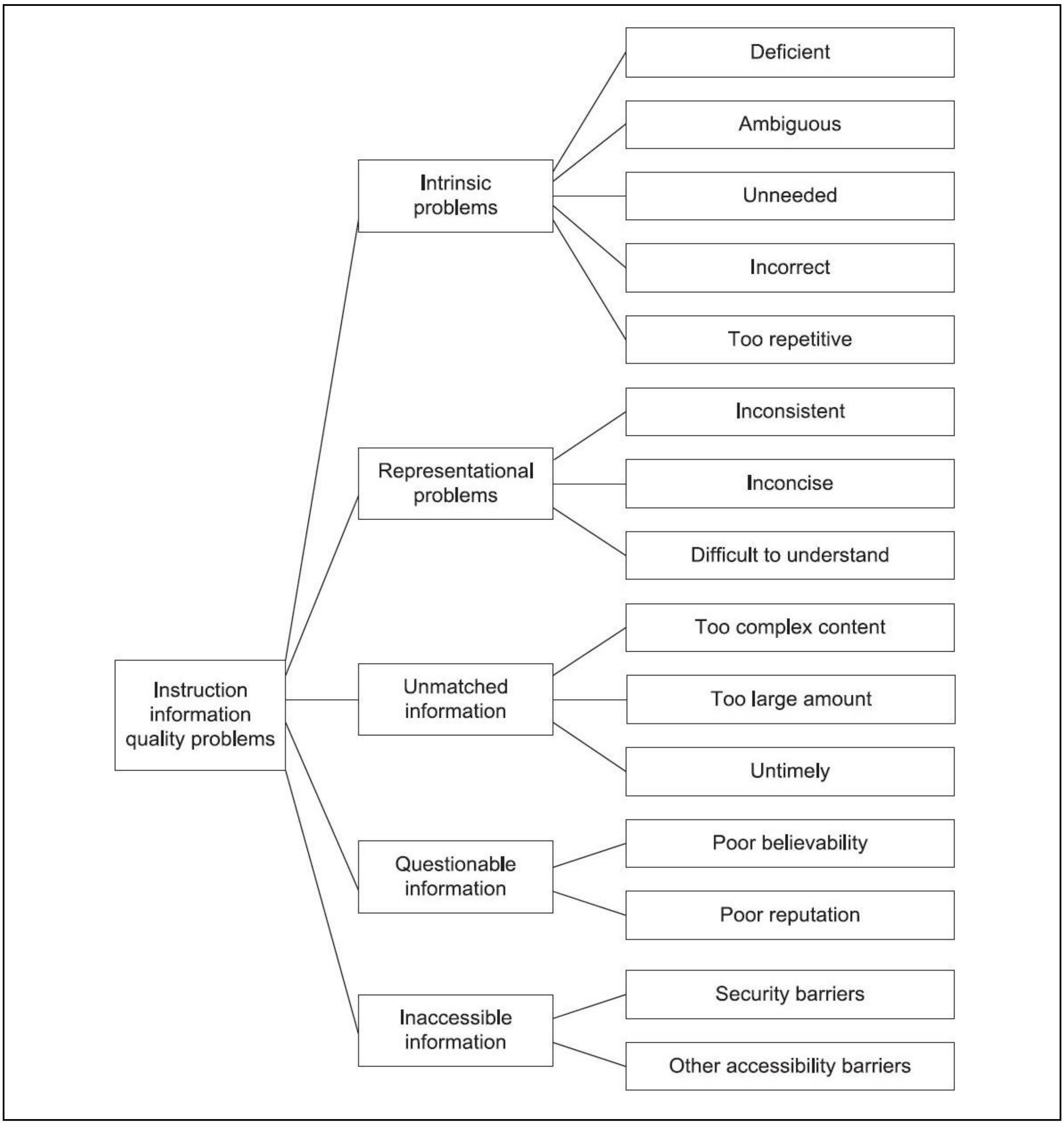


Figure 13 : Framework of low quality of work instruction, source: Haug, A. (2015), p. 175.

[68] Cf. Haug, A. (2015), p. 175.

High Quality of Work Instructions

High quality of instruction information and data in producing companies is a key factor for good productivity and perfect quality of the goods. Nevertheless, many companies are working with a bad preparation of their work instructions in their everyday business. If the listed problem issues are considered and avoided as good as possible, companies can gain a lot of benefit out of this topic. A high quality of work instructions is able to lead directly to a higher quality of the products and a higher productivity in the company. Furthermore, the potential is given to get maybe lower rework costs, rise customer satisfaction, maintenance work will be easier and last but not least the employees will be more satisfied and more productive.

The efficiency of work instruction systems and processes has a direct and significant impact on enterprise business performance.[69]

2.2.5 Digitalization of Work Instructions

Paperless systems for work instructions are around now for about 25 years, but there are a lot of companies still using sheets of paper on the assembly line for instructions. Nowadays there are more options to go paperless than ever before like mobile hardware platforms, new software tools and gadgets like tablets and the Google Glass, which make it easier than ever before to go paperless.[70]

In this chapter the strengths and obstacles of digital (paperless) work instructions on the assembly line are considered. Furthermore, the needed infrastructure and the data structure which has to be available are described.

Why to Use Paperless Work Instructions

“An estimated 90 percent of manufacturing companies still use and struggle with Microsoft`s Office tools for the creation and management of assembly work instructions every day.”[71]

Word, Excel, and Power Point are great programs for creating letters, spreads sheets, and presentations but they were never structured for managing and distributing complex manufacturing documentation. The whole information and documentation made by Microsoft Office applications are getting bloated, cumbersome, and very difficult to author, update, and distribute electronically.[72] Therefore, special programs should be used to create paperless or rather digital work instructions in order to generate the highest possible profit out of the change from paper based to paperless work instructions.

[69] Wheatley, M. (2006), online source [13.05.2016].
[70] Cf. Weber, A. (2014), online source [09.05.2016].
[71] Lifecycle Technology (2016), online source [14.04.2016].
[72] Cf. Lifecycle Technology (2016), online source [14.04.2016].

Strength and Opportunities

Major benefits of digital work instructions are less unnecessary paperwork, faster communication flow and easier maintenance.[73] Paperless work instructions allow to deal with more complex assemblies in a faster way, as some very complex devices are only realizable with digitalization.

If global concerns and operations are considered, it becomes even more challenging to deal with paper based work instructions, because in this case keeping the data and information current all over the concern is very difficult.[74]

The downtime of the production systems is shorter when engineering changes or maintenance activities occur, because of better and faster actualization and communication. The improved communication also supports the realization of a central data management system for work instructions between the engineering and the concern or global production sites.[75]

Another benefit is to always have the latest version of the instruction on the workplace due to digital actualization and not having to change paper sheets. The sheets sometimes causes confusions if for example the old instruction is left or forgotten on the workplace and irritates the workers. Security benefits regarding counterfeits are also gained by eliminating the possibility for the employees to take paper instructions out of the company.

Workers have to sort through multiple pages of built paper to get the right instruction for the specific work task often. Confusion easily occurs and it can happen consequently that the wrong parts are mounted or other failures appear.[76]

Summing up, the implementation of paperless work instructions is a good possibility to improve product quality and to save costs due to less complications with instructions. But there are also negative aspects regarding paperless work instructions, which are discussed in the next chapter.

Obstacles and Threats

As mentioned above there are also downsides regarding paperless work instructions. One of the biggest obstacles that has to be mentioned are costs, because they deposit in various areas. The initial investment and set up of a paperless system is rather expensive and in addition to that it also requires extra time to train the operators.[77]

Furthermore, most companies have to guarantee to realize the return of investment (ROI) in a reasonable period of time. Only with high-tech tablets it is possible to realize the flexibility regarding handiness as it is given with a sheet of paper on the work place, which

[73] Cf. Weber, A. (2007), online source [25.05.2016].
[74] Cf. Roberts, M. (2013), online source [07.05.2016].
[75] Cf. Roberts, M. (2013), online source [07.05.2016].
[76] Cf. Weber, A. (2007), online source [25.05.2016].
[77] Cf. Weber, A. (2007), online source [25.05.2016].

is very important for assembling huge machines like airplanes or big construction machines. The use of computer based technique is always related to breakdowns and cyber problems of all kinds, because many systems work via internet and are consequently easy to attack. Therefore, it is still useful for main and important work steps to have a backup of paper based work instructions.

In most cases, costs for software updates and licences are very high so that it has to be considered to get, for example, free lifetime upgrades in order to avoid obsolescence of the system.[78] Older workers are said to be sceptical regarding new technology on the workplace, so it is very important to convince them and have their support. Otherwise, the implementation of a new system will not work in the desired way.

Summing up, the main things to be considered are to have an eye on the costs of implementing paperless work instructions and to convince the employees to support the change of the system.

2.2.6 Automatic Generation of Work Instructions

The generation of high quality work instructions is a time and cost consuming task when utilizing shared setups and tools. This fact motivates the need for automated generation of work instruction for the assembly line.[79]

In the last few years, the product lifecycles have decreased for a lot of products. The time for development and start of production has also declined according to the shorter lifecycle and the shorter time to market, which is needed to react faster on market changes or innovations of the competitors.[80]

Therefore, a system for an automatic generation (see Figure 15) of work instruction will be a very important tool in the future, because the needed resources for creating and maintaining work instructions will raise due to the headed facts above very fast. Regarding to this, the usual process of generating work instructions (see Figure 14) is going to be too time-consuming and, therefore, too expensive. In this case the employee who creates the instruction takes the material number and the CAD file out of the provided database. Following that a screenshot of the CAD file gets made and the material number for the correct part is searched. Afterwards this data is implemented into a word file, which will be in the end of this process the new work instruction. Now at Wacker Neuson it takes 4 to 8 weeks to create the instructions for one machine.

[78] Cf. Oeters, D. (2014), online source [29.05.2016].
[79] Cf. Kaipa, K., et al. (2012), p. 1.
[80] Cf. Mok, S. M., Ong, K., Wu, C.-H. (2001), p. 313.

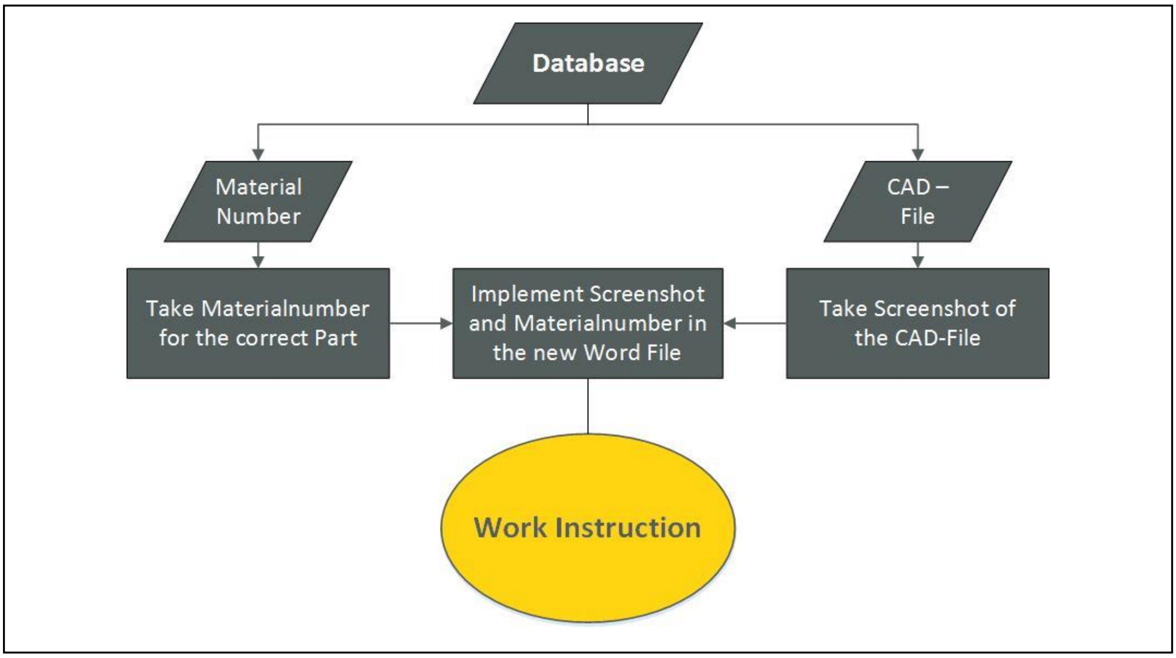


Figure 14 : Usual way to create paper based work instructions at Wacker Neuson, source: own representation (2016).

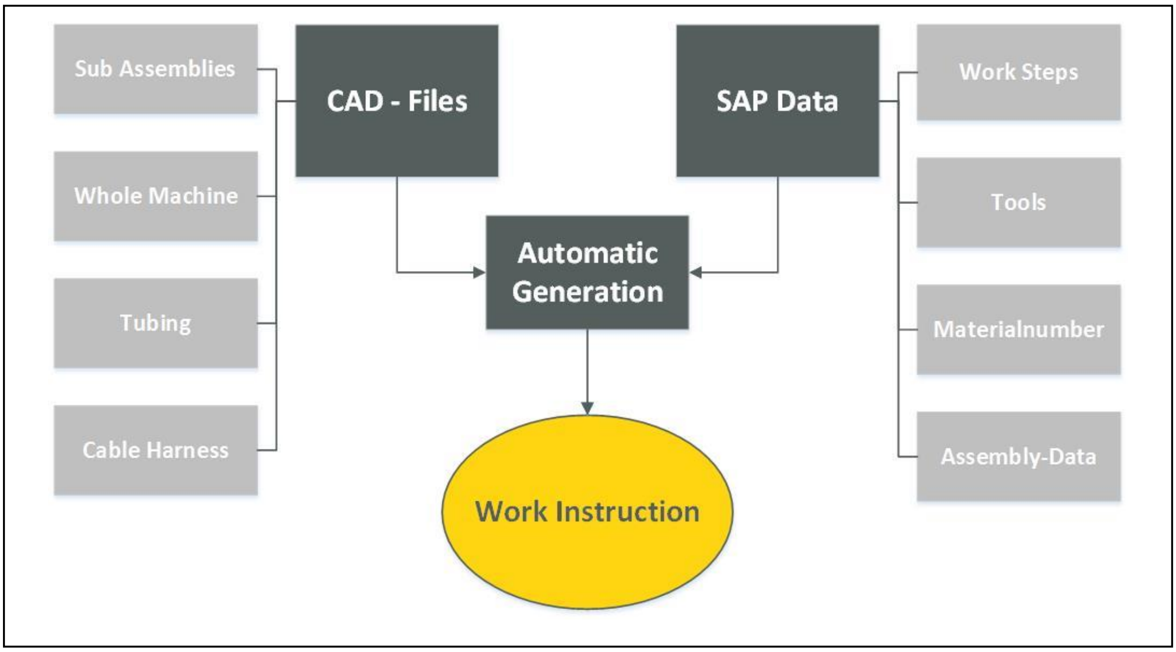


Figure 15 : Automatic generation of work instructions scheme, source: own representation (2016).

Required Resources

To implement an automation project cost effective and successfully, a product or assembly part must be designed for automation before actual manufacturing. In other words, a CAD/CAM approach that treats design-to-manufacturing as an integrated process is required.[81]

[81] Cf. Mok, S. M., Ong, K., Wu, C.-H. (2001), p. 313ff.

The whole product or assembly has to be available as a very detailed CAD model with all data clearly visible. Otherwise it is impossible to automate the process of creating work instructions. A data processing program where all production data assembly sequences and work steps are headed, is a main required infrastructure to provide a perfect input for the software that creates the work instructions.

Recapped, the required infrastructure is perfect CAD data in interaction with detailed production data including assembly sequences and work steps. Without having these two data types the possibility to implement a system is rather impossible in many aspects.

2.2.7 Work Instructions and Industry 4.0

In the context of Industry 4.0, work instructions are getting a new importance, due to the higher needed flexibility of the production systems. The customer can order completely individual products, which leads in the broadest sense to a lot size of one in production. For this future scenario, each order needs its individual work instruction. Regarding to this fact and in the case of high complex work tasks on the shop floor, it is senseless that a worker learns assembly tasks by heart. The worker uses the work instruction for each single work step of the assembly operation. To handle this high necessity of individual work instructions, a system that generates work instructions automatically is a main part of supporting the assembly line in the best possible way.

Virtual engineering, virtual assembly and a virtual mock-up are important for a fast product engineering and a short time to market. These three applications, especially virtual assemblies, are the basis for a perfect and faultless work instruction. Industry 4.0 and the accompany of an all over connection provides a lot of data and knowledge for a new level of work instructions. The prime topic is to have a software that fits perfectly to the existing and available data structures. If this requirements are fulfilled, work instructions can be provided automatically in a new and easily understandable way. This can lead to a higher product quality and lower rework costs, although, the products are more complex and individual.

2.2.8 Conclusion of Work Instructions

Despite the fact that all important topics in a company are getting highly automated, the topic of work instruction is often neglected, even in big companies. For example, there are sometimes entire machines or other assemblies drawn in CAD and getting animated. But the work instructions are still on a sheet of paper, handwritten or only visualized with pictures from prototype. According to the visions of Industry 4.0 and the constant rising complexity and individuality of new products, it is a very important task to have perfect, faultless and very detailed work instructions on the assembly lines. There are for sure pros and cons for the new way of generating work instructions, but the modern industry will not get around to implement new systems in the next years.

3 Maturity Model of Work Instructions

Creating a maturity model of work instructions should give a transparent overview from the bottom of no work instructions on the shop floor up to future visions of work instructions in context of Industry 4.0. The realized model is customized for Wacker Neuson, but it can be adapted for other companies with minor changes also.

3.1 Definition

“Maturity models describe procedures (processes) and practices for the provision of product development. Therefore, they provide the basis for the quality assessment of processes.”[82]

“With the help of maturity models, the executive manager and the executive director have the possibility to verify and refine the level of development and the maturity of their company`s process management. The status quo is going to be identified to generate out of it the areas of activity for the future of the company. A main basic thought is to measure already achieved success with the help of periodic measurements and to make it sustainable with exploiting the existing optimization potential.”[83]

To have a maturity model of a specific task like the one of work instructions can help a lot at a decision making process for future steps with all their pros and cons. It can be useful to detect tasks, where a need for action is required to keep pace with the competitors. A maturity model therefore is a kind of framework for future decisions and should show where the status quo of the considered company is located.

3.2 Maturity Model (whole model)

The steps “status quo” and “automated generation of work instructions” are main steps of the maturity model regarding this master thesis. These two steps show the start and the aim of the created concept for Wacker Neuson in the practical part. Generally, the model should show where the journey of work instructions will lead the company in the next years and which steps are possible to realize in a short timeframe (see Figure 16).

Therefore, a research regarding new, existing and future technologies was made and sorted into sixteen steps which constitute the realized model. In this chapter, each step of the model gets viewed in a detailed way to provide a good overview of the technologies in terms of work instructions. To get a faster and better overview of the maturity model, all sixteen steps were deposited in a visual way (see Figure 17).

[82] Cf. Grande, M. (2011), p. 113.
[83] Cf. Christ, J. P. (2015), p. 195.

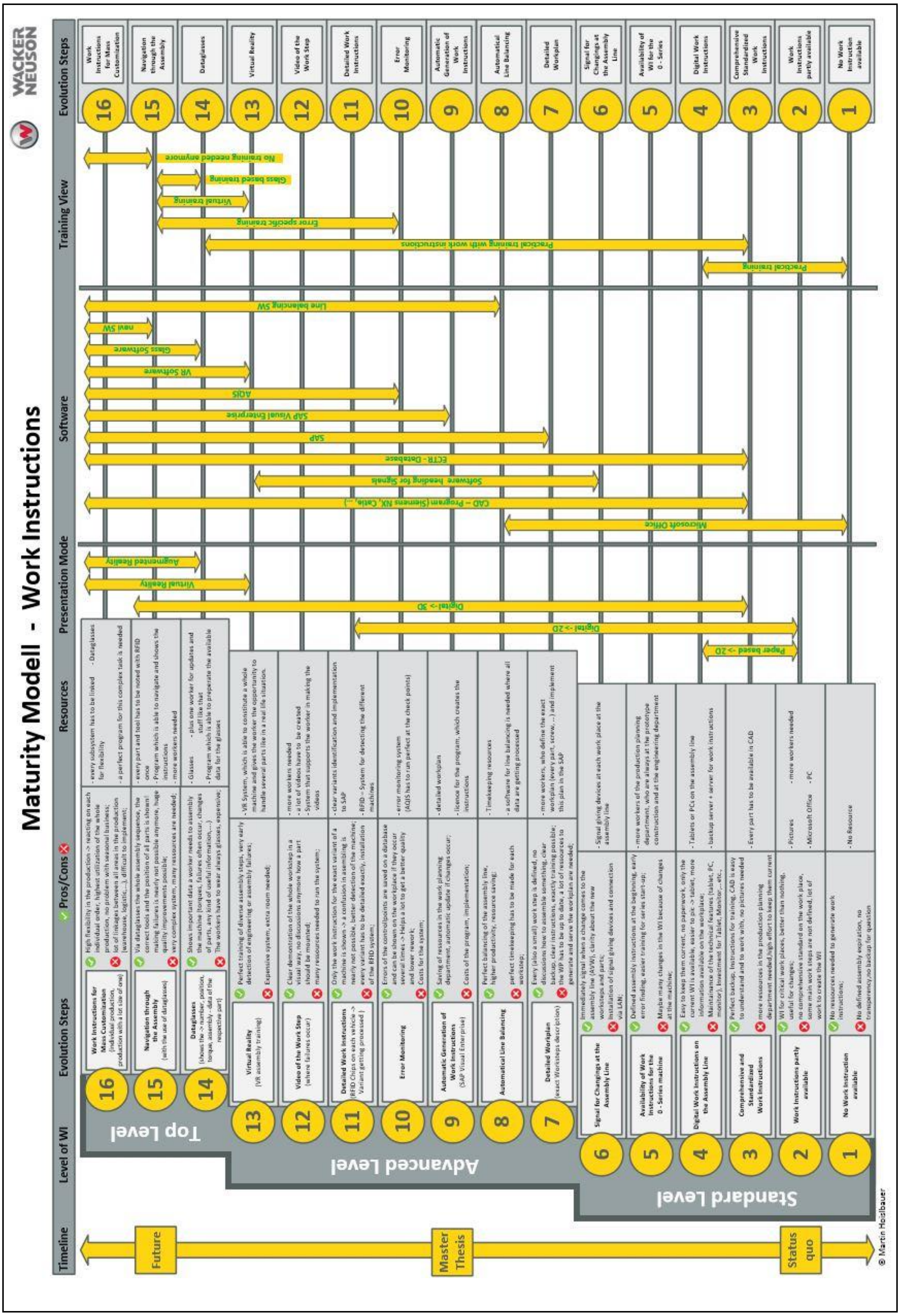


Figure 16 : Maturity model of work instructions for Wacker Neuson, source: own representation (2016).

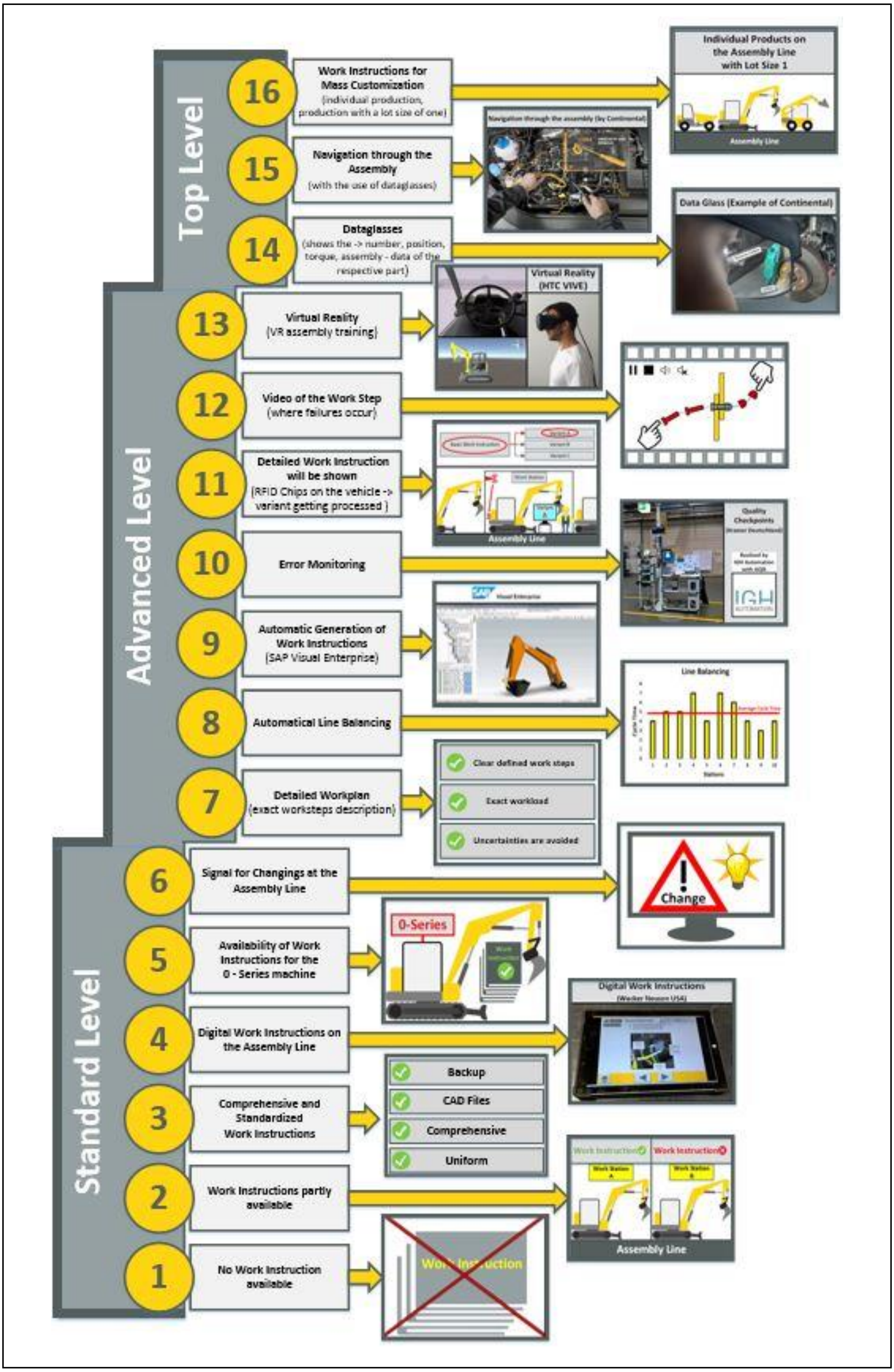


Figure 17 : Maturity model of work instructions visualized, source: own representation (2016).

3.3 Maturity Model (timeline, levels, evolution steps)

The timeline of the Maturity Model is divided into three main steps, namely the status quo, the aims (master thesis), and the future part. It should show where the technique of work instructions begins, where the state of the art is and where the future begins. At the end of the timeline, this future part is representative for all new technologies and visions (see Figure 18).

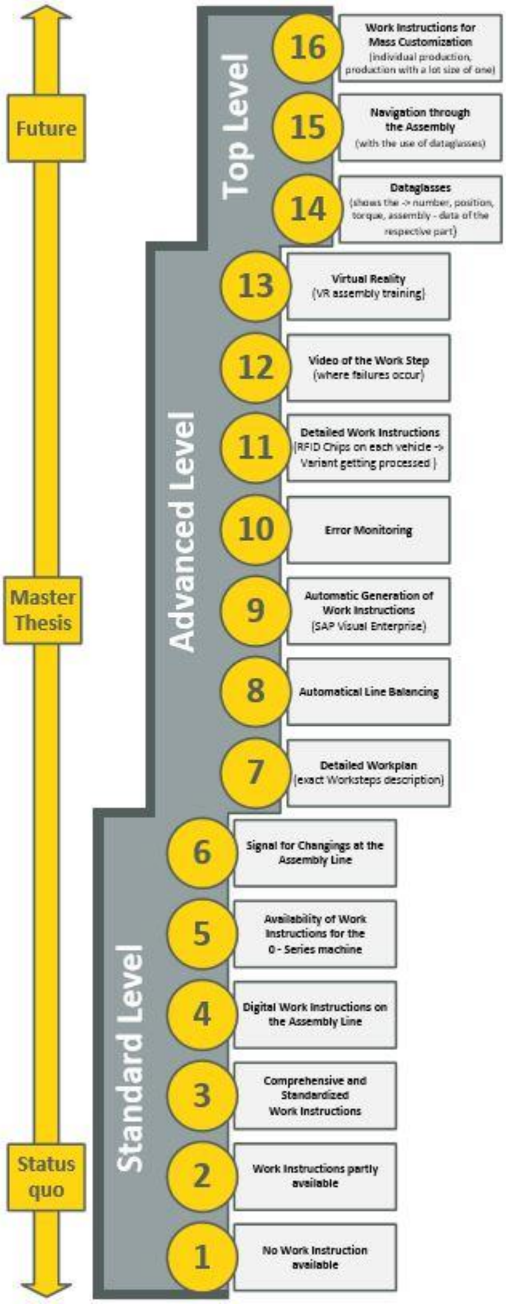


Figure 18 : Timeline and levels of the maturity model of work Instructions, source: own representation (2016).

3.3.1 Status Quo

The status quo shows where the company stands regarding to the consulted topic in the maturity model. Wacker Neuson is now on the 2nd step of the model, the partly availability of work instructions on the assembly line. This status is no bad mark as it may looks, because the workers on the shop floor are very well trained and the assembly line operates relatively good in context of the very complex machines. To have the possibility to reach better quality and a lower quantity of rework time at the end of the assembly line, Wacker Neuson needs to ascend in the maturity model.

3.3.2 Master Thesis

The step "Master Thesis", respectively the automatic generation of work instructions, is the desired goal for Wacker Neuson Linz. To reach this goal, several steps have to be realized beforehand, like it is presented in Figure 17. The goal was chosen due to the complexity of the machines and the ensuing revealed big amount of work instructions. Another big issue are the technical changes of several parts during the production period of one type.

In connection with incomplete work instructions, many failures and rework operations occur, which lead to high costs and a lower quality of the built machines. Perfect work instructions would help to solve this problem.

3.3.3 Future

The future part starts for each company at another point, but the essential future steps for the industry are the last two to three steps of the model. By now, they exist in most cases in hypothetical visions or prototypes in research projects and are only at some high technological companies in action at the daily production. At Wacker Neuson, these future technologies will become topical in some years after realizing important basis steps before.

3.4 Levels of Work Instruction Technique

The shown levels of the evolution of work instructions are classified in a standard level, an advanced level and a top level (see Figure 17). These three levels should show roughly at which main steps a new level can be reached and what the company has to do or implement in their production in order to reach it.

3.4.1 Standard Level

The standard level is the most common level because the majority of companies are located there according to their used methodology to generate work instructions. The main indicator for this level is the lacking detailed work plan, where the machine is planed step-by-step to be able to realize the work load in an exact defined way.

3.4.2 Advanced Level

The beginning of the advanced level is characterized by a detailed work plan for all machine or product types, which are built on the assembly line. The end of the level is marked with the steps virtual reality for training the workers and having a video of special work steps on the assembly line (see Figure 17). This level provides a lot of useful technologies, which are feasible with a manageable budget.

3.4.3 Top Level

Hardly any company acts on this level, because of the high investment costs of the very new and often not fully developed applications and technologies to transfer work instructions to the assembly line. These technologies are often only visions or simple prototypes in any research departments, but it is inevitable to be always up to date and have an eye on future concepts.

3.5 Evolution Steps

The steps of the model are in most cases based on each other and show which requirements are needed to reach the next higher step. Some steps can also be realized before the previous step or even before some more steps beforehand are fulfilled. But there are also preconditions which are very important for following steps. Therefore, it is advisable to skip a step only as an exception, because of possible disadvantages afterwards. In this chapter, all steps are described with all their required resources and their pros and cons are listed.

3.5.1 No Work Instruction Available

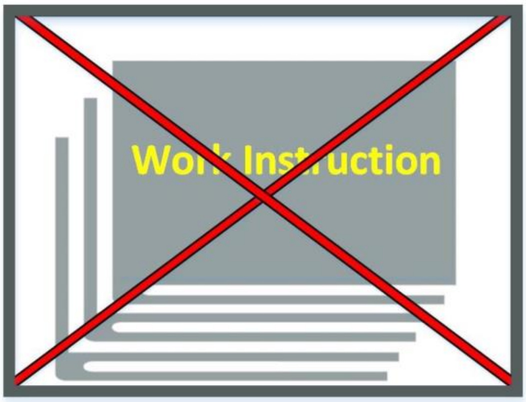


Figure 19 : No work instructions available on the shop floor, source: own representation (2016).

No work instructions available is the lowest step of the model (see Figure 19). This state can occur at companies which build their products in a simple workshop and not on an assembly line with a high amount of produced pieces. Therefore, these companies can build their products in a lot size of one, but in a very slow and unproductive way.

Pros:

Having no work instructions also means that there is no workforce needed to create these instructions and therefore a saving of resources is possible.

Cons:

The main problem of having no work instructions are quality issues all over the production or assembly line. Having no work instructions means to have no standard how to assemble or manufacture a machine or a work piece, which often leads to a high rate of failures and a lot of rework. At assembly lines, the impact is much higher because of the high frequency the devices are produced. If there are questions coming from the workers how to mount something, it is necessary to have a good backup where they can look up the right way to mount the work piece.

Resources:

Nothing required.

Summary:

Having no work instructions is possible at small companies with individual production, but if the production has a high number of pieces and a higher complexity, work instructions are indispensable to get a satisfying output and a high quality.

3.5.2 Work Instruction Partly Available

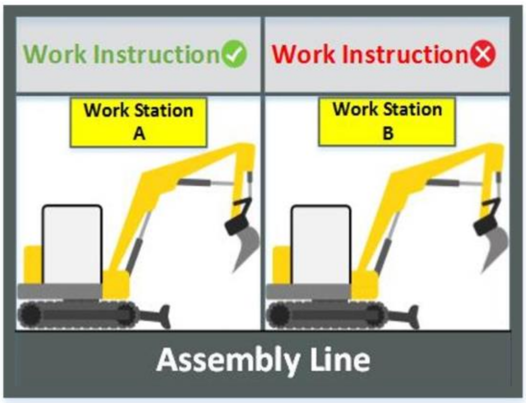


Figure 20 : Work instruction partly available on the assembly line, source: Wacker Neuson (2016)., modified

Partly available work instructions means that there is no full coverage regarding work instructions given on an assembly line. Instructions are available in positive cases at the most important and most complex stations of the assembly line.

Pros:

Due to the partly available instructions, the quality issues are getting better. If changes of any parts of the assembly occur, it is useful to have instructions for them to prevent producing failures. Furthermore, it is more than helpful for the training of the workers to have work instructions which serve as a reference back for them.

Cons:

The not existing overall availability of work instructions (see Figure 20) can easily lead to failures and a high amount of rework.

Resources:

To create work instructions, real pictures or CAD files of the assemblies or rather the parts are required. Also skilled employees are necessary to realize that step. The software is in most cases the common Microsoft Office package.

Summary:

Partly available work instructions make sense for critical work places, but in the end a comprehensive standard and work instructions for all workplaces would be the better solution. Generally, this step can be seen as an interim solution.

3.5.3 Comprehensive and Standardized Work Instructions

Figure 21 :Comprehensive and standardized work instructions conditions, source: own representation (2016).

After implementing this step, work instructions are available at each work station of the assembly line. As far as possible, pictures on the instructions should be replaced by CAD files in order to get a comprehensive and uniform standard (see Figure 21). It is important for the workers to have a good back up for all kind of upcoming questions regarding any work step or part.

Pros:

Having these instructions, is the basis to be able to produce good quality and to realize a lower rework time at the end of the assembly line.

Cons:

Compared to traditional steps, more resources at the production planning department are needed. Every change of parts or any assembly sequence has to be updated on the work instruction of the concerned station of the assembly line. Moreover, all parts have to be available in CAD, also tiny screws and wires.

Resources:

Employees who create and keep the work instructions up to date are required. CAD-data of each built vehicle, machine, or assembly, has to be available for the workers of the production planning department. These workers also need a license for the CAD programs.

Summary:

A comprehensive standard of work instructions is a main step towards better quality. The workload for the production planning department will raise, due to more work instructions. Nevertheless for big companies it is absolutely essential to have comprehensive and standardized work instructions at the production in order to reach the quality targets.

3.5.4 Digital Work Instructions on the Assembly Line

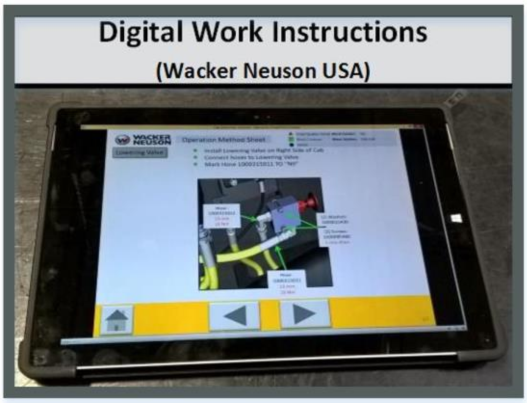


Figure 22 : Digital work instruction on the assembly line, source: Wacker Neuson (2016)., modified

In this step, no paper based work instructions are used anymore on the assembly line. They are replaced by electronic devices like tablets, which are able to show the instructions digital. The required equipment for this step also builds the basis for many further steps of the maturity model.

Pros:

This step provides benefits in keeping the instructions always up to date on the workplace. Outdated work instructions are no longer there if a new one is available, because no old paper based instructions can be left or forgotten there. Having a tablet, that is linked with the network of the company, on the work place makes it much easier to access a lot of useful information without leaving the current workplace (see Figure 22). If, for example, a big machine is assembled and the worker has to work on or under it, a tablet can be taken along and provides there a database of information.

Cons:

To get a digital infrastructure, the company has to invest much money in this new technology. Also the maintenance of all needed devices to realize the digitalization leads to higher costs. Tablet PCs or conventional PCs are in danger to get affected by a virus or a hacking attack, which cannot happen with paper based work instructions.

Resources:

Tablet PC or big monitors at the assembly line are needed to get the digital work instruction to the work place. A database for all the generated work instructions and the required CAD data has to be installed in the existing IT infrastructure to be able to handle the data in a satisfying way. The electronical devices on the workplace have to be linked with the database and with the production planning department of the company. Consequently, the IT department needs more resources to keep the whole system running perfectly.

Summary:

Digital work instructions on the assembly line are gaining many benefits regarding updating the instructions and communicating changes of any part of the assembly faster to the workers. The required technical devices lead to high costs, but it there is a good chance to get a fast return of investment due to the realizable benefits.

3.5.5 Availability of Work Instructions for the 0 - Series Machines

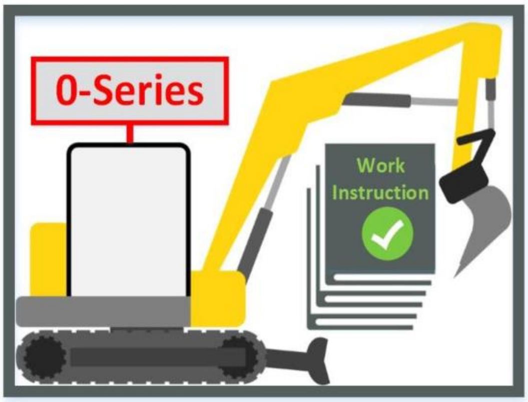


Figure 23 : Availability of work instructions for the 0-Series machines, source: Wacker Neuson (2016)., modified

The availability of work instructions for the 0-series machines should provide the engineers and the workers benefits before even the first serial machine will be mounted on the assembly line. Therefore, this step should offer a kind of training and is not directly connected to the daily used work instructions on the assembly line. But these 0-series instructions are the basis for them.

Pros:

Well defined assembly instructions at the beginning of producing a machine help a lot to find errors at an early stage and often even before the start of production. Another benefit of having work instructions for the 0-Series machines (see Figure 23) is a good training for the workers of the production before even one machine is built on the assembly line.

Cons:

Many changes of several work steps can occur because of having the work instructions at such an early stage. According to this, the workload for having good and current work instructions will raise.

Resources:

More employees and engineers with a good technical knowledge, who are only responsible for these work instructions are needed.

Summary:

Having work instructions for the 0-series machines helps a lot to find errors early which leads to a better quality. Although the workload will be more, this step will be effective in the end.

3.5.6 Signal for Changes at the Assembly Line

Figure 24 : Signal for changes on the assembly line, source: own representation (2016).

A signal for changes is for example a lamp, a gyro light or a horn that gives a signal if an important change of an assembly task takes place on the assembly line and has to be fulfilled from that point on. The installed infrastructure can also be used for other tasks like signalising the break of the workers or an important failure at any machine. This signal will be sent from the production planning department.

Pros:

Having an immediate signal if a change comes to the assembly line, the workers know exactly when or rather from which machine on they have to perform the new work steps the change requires. This helps to avoid failures regarding the new work task.

Cons:

Installing these signal devices on each work place of the assembly line and the connection of them via LAN or WLAN generates costs for the company. After installing this system, it will cause costs also, because of the maintenance and the support of it.

Resources:

Signal devices which are connected via LAN have to be installed at each station of the assembly line. Furthermore, a software to control and to send out the signals is required.

Summary:

Getting a signal at the assembly line (see Figure 2424) if changes occur is very helpful to realize changes at the correct time. This helps to produce a better quality and to achieve a lower rework time of wrong built machines.

3.5.7 Detailed Work Plan

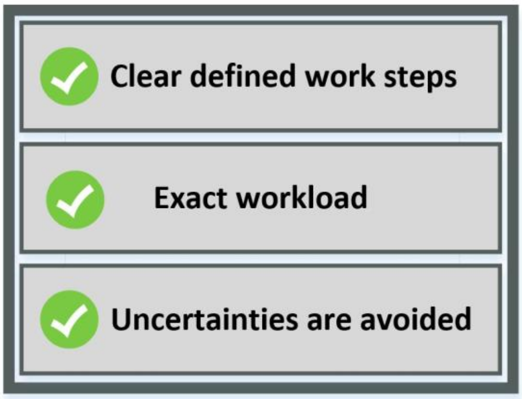


Figure 25 : Detailed work plan conditions, source: own representation (2016).

A detailed work plan where every work step is clearly defined is necessary for many further steps of the model. Every step, also mounting tiny screws or using a cable tie to fix something, is noted. This has to be done to plan the assembly very exactly. It is also the basis for all new programs in terms of creating work instructions automatically, having a clear documentation according to the workload of each worker or by realizing an automatic line balancing.

Pros:

The detailed work plan provides a perfect standard for the workers to assemble all machines in an exactly given way (see Figure 25). There is no scope for the workers to assemble a machine in another way, because also the smallest work step is indicated on their work instruction. Having all work steps planned in detail is the basis for producing parts or building products at really high quality, because each machine will be assembled exactly the same way. The workers have the possibility to get an exact training according to the detailed work plan, which can also help new and unskilled workers a lot to get faster used to their new work.

Cons:

A lot of resources are needed to realize a detailed work plan where each part, including also the tiniest screws and wires of an assembly, or a machine is shown and described. In most cases, this plan has to be implemented in the data processing program SAP, where the data can be used in a comfortable way. Additionally, this implementation is very time consuming. Changes of any parts are getting very complex due to the high amount of details.

Resources:

Many more employees at the production planning department are required to realize the detailed work plan for each product of the company. A suitable version of SAP or any other data processing program is also very important to be able to work productive with this generated data.

Summary:

Implementing a detailed work plan, reaching from the smallest screw up to big frame parts of a machine, can be seen as one of the main steps and as a basis to realize further steps of this maturity model. In order to realize high quality, a strict standard according to assembly tasks is also necessary for producing high quality products.

3.5.8 Automatic Line Balancing

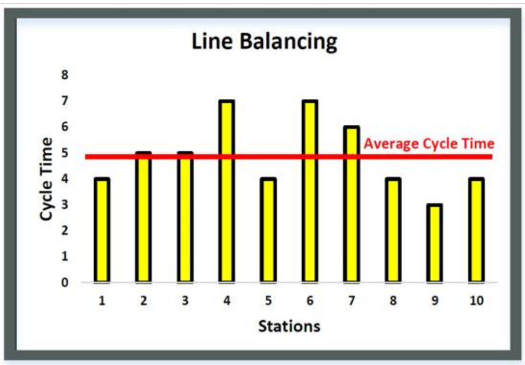


Figure 26 : Line balancing of an assembly line, source: own representation (2016).

Line balancing is a very important task in the production to reach the best productivity and to ensure that each worker has about the same amount of work. Realizing an automatic line balancing can help the production planning department a lot to adjust all needed parameters in a perfect way.

Pros:

Higher productivity and savings on resources can be achieved through a perfect balancing of the assembly line (see Figure 26). The time of each station at the assembly line is, after performing the line balancing, about the same. This helps a lot to get a higher utilization and productivity of the whole assembly line.

Cons:

A complete and exact time keeping of each work step has to be made to gain most profit out of this step. If changes of parts occur, it is necessary to update the time of the new work step. The required software in most cases quite cost intensive.

Resources:

A software for line balancing that is combined with the time data of all work steps and all tools required for the particular work step is needed.

Summary:

Automatic line balancing is a very helpful tool to optimize the utilization of the assembly line and also helps to generate the perfect workload and its corresponding work instructions for each station of the line.

3.5.9 Automatic Generation of Work Instructions

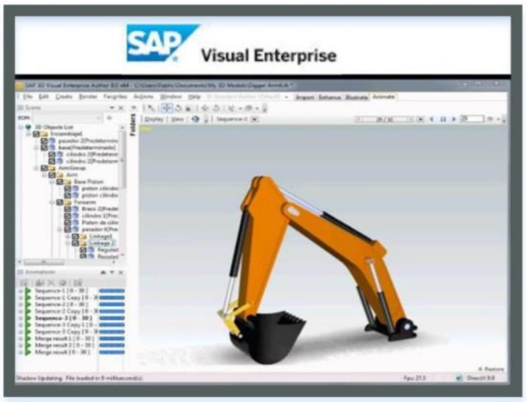


Figure 27 : Automatic generation of work instructions with SAP Visual Enterprise, source: Siemens (2014), online source [22.06.2016]., modified

The required work instructions for all assembly tasks on the assembly line should be generated with a special software automatically after realizing this step of the model. The aim of the concept, which was developed in the practical part of this thesis, are automatic generated work instructions. This means that the developed concept stops at this step of the maturity model.

Pros:

Generating work instructions automatically saves resources in the work planning department. A main benefit is the automatic update of the instructions if a change of any part or directive occurs, because there is no manual work required to keep them actual. For this, it is necessary to use a uniform standard of work instructions and to keep them up to date.

Cons:

A negative aspect are the high costs of the software to realize the automatic generation. The implementation of the detailed work plan, which forms the basis for this step, is very complex, because it has to be linked with the used software at this step.

Resources:

The license for a software which is able to realize the automatic generation is required for some work places in the work planning department (see Figure 2727). A detailed work plan of all assembly steps is the fundament for the use of this software in a productive way.

Summary:

To implement an automatic generation of work instructions some main steps have to be fulfilled before to keep the used software running in a satisfactory way. If this main steps are transcribed, the potential for saving costs and having better work instructions is rather high.

3.5.10 Error Monitoring

Figure 28 : Quality checkpoint on the assembly line with AQIS software, source: Wacker Neuson (2016)., modified

Assembly errors are detected on quality checkpoints at the assembly line. At these checkpoints, main functions of the product are audited to find the errors with as little checks as possible. These errors will be saved on a data base to show the instruction at the work place where the failure occurred with an additional information.

Pros:

These extra shown instructions and information help the worker to avoid the same error in the future and provide therefore the possibility to improve the quality of the built products.

Cons:

The costs of the required program are rather high, which means about EUR 2000 licence costs a year for one work place. Furthermore, the technical devices for the checkpoints (see Figure 28) are expensive. The checkpoints need free space on the assembly line, where space is bare anyway.

Resources:

Licenses for the software are required to gain profit out of the generated data at the checkpoints. The checkpoints have to be robust and functional to make it simple to store the appearing errors on the assembly line.

Summary:

The stored data of occurring errors can help the production a lot to improve the workers skills and to produce better quality. The workers can learn a lot out of their failures and can avoid them in the future. Some workers are not that satisfied about this check of their work. Apart from that, their bonus payment is among other things depending on the produced quality, which means a motivation for most of them.

3.5.11 Detailed Work Instructions

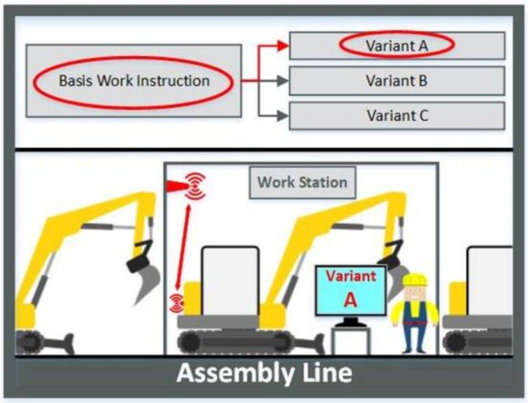


Figure 29 : Detailed work instructions on the assembly line, source: Wacker Neuson (2016)., modified

Due to the rising number of machine variants with all their specific technical features the variants of work instructions are also rising. A basis work instruction for one type of a machine does not fulfill the requirements for good work instructions anymore. The work instructions of a machine type are divided into different variants based on the different configurations of the machine.

Pros:

The worker on the assembly line can only see the relevant work instruction of the actual machine that gets built at the moment (see Figure 29). Only the detailed instruction should be shown for the specific machine type and variant, which gets built to the worker. Therefore, the worker cannot mix up any instructions, which should be positive according to produce a better quality.

Cons:

Every work instruction of a variant of a machine has to be created precisely in order to be provided to the worker very detailed. A RFID or a bluetooth device has to be installed on the assembled machines to send a signal to the computer to show the worker the right instruction. This required systems cause additional costs for each machine.

Resources:

Clear variant identification in SAP or any other data processing program is necessary to be able to provide the right work instruction for the worker. A system to identify the machines with bluetooth, or RFID devices has to be installed on the machines like it is mentioned in the paragraph before.

Summary:

Building the wrong variant or parts of another variant on a machine or assembly should be nearly impossible with this system. The complexity of work instructions will raise again, but in return benefits according higher quality and lower rework time will be present. A main disadvantage is the more work for the production planning department and the costs for the identification system.

3.5.12 Video of the Work Step

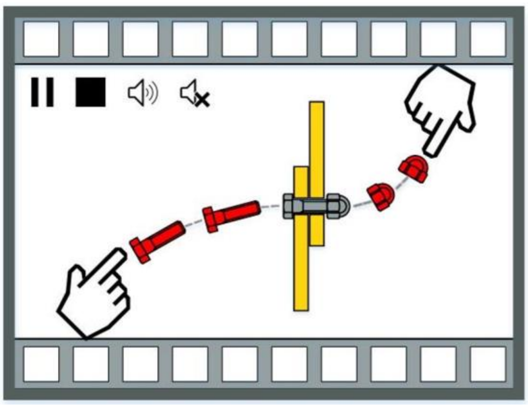


Figure 30: Video of a work step, source: own representation (2016).

A video of a work step shows how the workers have to fulfil the shown assembly task exactly, like it is shown in Figure 30. To see the work step animated can help the workers to understand it much better like having only a picture or a CAD file and a declaration on the work instruction.

Pros:

If errors occur frequently, the production planning department has the possibility to create a video of the problematic work step to be sure the worker know exactly what to do in the future. To train new workers better with videos of difficult work steps constitute also a big benefit.

Cons:

The software and the infrastructure to display the videos on the work place are expensive. Moreover, resources in the work planning department are needed to generate videos.

Resources:

A software to create the videos of the critical work steps is necessary at the production planning department. Additionally, screens or tablets on each workplace are required to show the videos direct at the station where the error occurred.

Summary:

Having a video of a critical work step is a very good basis for the worker to avoid the error in the future. A video can show much more information than a picture or a standard work instruction is able to. Creating videos is a lot of work and needs many resources. Nevertheless the benefits, like a perfect training and a better understandability of difficult work steps, can be high.

3.5.13 Virtual Reality

Figure 31: Virtual reality with the HTC VIVE, source: Wacker Neuson (2016)., modified

This step has no direct impact to the work instructions on the assembly line but it should provide a training of diverse assembly steps to the workers. This gets realized with special virtual reality systems where whole machines, based on CAD data, can be implemented in the virtual world (see Figure 31). Also tools can be implemented and therefore a virtual assemble training of special variants of a machine type, which get built very seldom, can be realized. Therefore the workers should have no problems if this special version comes to the assembly line only once or twice a year. At the development process of machines this system also can be used in cooperation of the engineering and production department, because a machine has to be built up assembling friendly.

Pros:

Many failures regarding engineering or assembly tasks can be detected at a very early stage of the development process of a product, which can save a lot of engineering and development costs. To train the workers with this system also can help a lot against producing failures at the assembly line.

Cons:

To get a useful virtual reality system in a company, it is necessary to have an extra room with many different applications, where the employees can act with it freely. Furthermore, the system is very expensive because the technology is very new and needs high performing IT systems.

Resources:

A separate room for the virtual reality system is necessary. Furthermore, one employee or a service worker, who is used to operate with this new technology has to be available at the company.

Summary:

Virtual reality systems can provide the company many advantages regarding assembly or development tasks. They also can help to detect errors at an early stage of the development process and to make the products more assemble friendly. It is useful to use this system in a good cooperation between the engineering and production department.

3.5.14 Dataglasses

Figure 32 : Data glass with displayed information, source: EtrucKing (2015), online source [28.06.2016]., modified

Dataglasses are a kind of augmented reality and show information in the fields of vision of the user. These glasses can show for example important data to a worker who assembles a machine. This data can reach from torque, often occurring errors, changes of parts, to a lot of other useful information (see Figure 32). Also the whole work instruction of easy parts can be superimposed on the glasses. This means the worker will be leaded through the whole assembly process with this device.

Pros:

With dataglasses, the worker has both hands free to work while the information or instruction is shown. This is a big benefit and can lead to more productivity. Providing better information with the glasses can also lead to a higher quality of the built products.

Cons:

Wearing this glasses the whole day can be uncomfortable for the workers eyes, because they can be tired after some hours. This can also be observed if someone works the whole day with the PC and the eyes get fatigued after several hours. To realize the whole system is an expensive project, but it is possible that the dataglasses are provided cheaper in the future. Another negative aspect are data protection tasks, which have to be clarified with the workers.

Resources:

Dataglasses with a perfect software for the production have to be available for most of the workers on the assembly line. Employees of the work planning department have to run the whole system which needs a lot of resources.

Summary:

Dataglasses provide the worker a lot of useful information by having both hands free to work. The available technology is not that far developed to be able to wear the glasses a whole work day without any defaults. Therefore, the responsible persons have to be careful if they order such a system.

3.5.15 Navigation through the Assembly

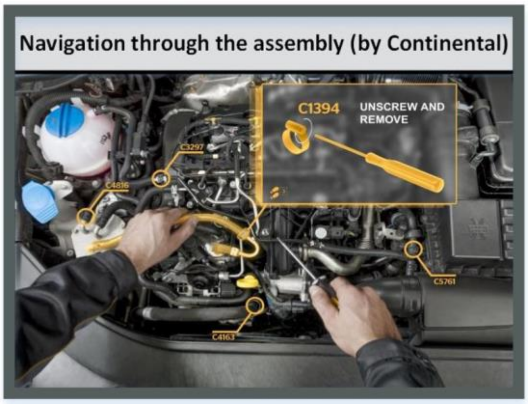


Figure 33 : Navigation through the assembly with dataglasses, source: Continental (2016), online source [03.07.2016]., modified

This step should provide all required information for each work step directly to the worker. Via dataglasses the whole assembly sequence, the correct tools and the position of all parts is shown to the worker who gets navigated through each single work step (see Figure 33). The workers does not need much training for the job at the assembly line anymore if this system gets realized.

Pros:

Nearly no failures are possible anymore, which means a possibility of huge improvements regarding quality and lower rework at the end of the assembly line.

Cons:

Navigation through the whole assembly is a very complex system and needs a lot of maintenance if any product is added to the assembly line or gets changed. Dataglasses are often not that good for the eyes of the user like it is mentioned in the step before. The system can also slow down the assembly process if there are work tasks with the same sequence repeating all the time, because skilled workers will be faster without the system in this case.

Resources:

Dataglasses for most of workers on the assembly line are required to be able to transfer the information and instructions to them. The software and the sensors to run the glasses in a productive and useful way is the main necessary resource.

Summary:

If the whole system works perfectly, it will be a real revolution in production, because the workers do not need special skills and training anymore. Every assembly step will be shown to them in detail. Therefore a very good quality improvement and a lower rework are possible with this system. At small batch sizes this system has the highest impact by improving the quality numbers. But at productions where the same work steps remains the time, this system is maybe misplaced due to its high costs. Furthermore, it can also slow down the assembly process like mentioned before.

3.5.16 Work Instructions for Mass Customization

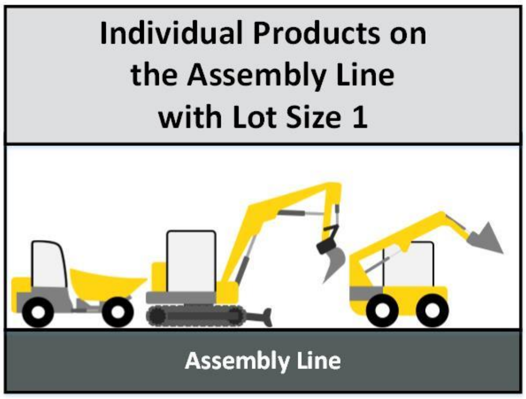


Figure 34 : Lot size one production on the assembly, source: Wacker Neuson (2016)., modified

For mass customization a production with lot size one is necessary (see Figure 34). Providing always the exact work instructions for this very individual products is a rather difficult task. To implement this type of production, many steps before have to run perfect to guarantee a good basis for this last step of the model. Also each subsystem has to work perfectly to keep the whole production running smoothly.

Pros:

Mass customization can offer many possible benefits for a production, like a high flexibility at reacting on each individual order, highest utilization of the whole production, no problems with seasonal business and a perfect customer satisfaction.

Cons:

Every subsystem has to work perfectly to keep the whole production running smoothly. A lot of linkages between all areas in the production, like the warehouse, logistics, work planning department, and the suppliers have to fit in an ideal way, which is often very difficult.

Resources:

A production line, which is created for a lot size one production with all its linkages to other departments is required, because it is difficult to upgrade a given production line to fit for this kind of production. Some main steps of the maturity model have to run perfect to realize this step in a satisfactory way.

Summary:

Work instructions for mass customization is the highest step in the maturity model of work instructions, due to the high effort to realize it. In this case all systems which a production requires have to cooperate perfectly and hardly no failures should occur. But if this step will be implemented in a production, many benefits will arise like it is mentioned before.

4 Practical Research

The practical research of this thesis focuses on the production department of Wacker Neuson Linz GmbH. The priority is on work instructions used at the assembly lines and the way they are created. After examining the current state, a concept will be designed for Wacker Neuson to improve the performance of their system of using and creating work instructions.

4.1 The Plant

Wacker Neuson Linz GmbH (see Figure 35) has a long tradition and was called Neuson Construction Equipment GmbH before the fusion with Wacker Construction Equipment AG happened.

Figure 35 : Wacker Neuson Linz GmbH, source: Wacker Neuson (2016).

History of the Plant in Upper Austria

- **1981** founding of Neuson Hydraulics GmbH
- **1984** the first Neuson Mini excavator was developed
- **1990** founding of the Neuson Construction Equipment GmbH
- **2007** fusion with Wacker Construction Equipment AG
- **2012** opening of the plant in Hörsching
- **2015** expansion of the development and engineering center in Hörsching

Core Data of the Plant

- Investment: 65 Mio. EUR
- Size of the plot: 17 hectare
- Built up area: 50.000 m^2
- Office building: 8.700 m^2
- Assembly lines: 5
- Assembly hall: 21.100 m^2
- Paint shop: 5.500 m^2
- Building period: 06/2011 – 05/2012

4.1.1 Products Built in Hörsching:

- 15 different models of **Compact Excavators** from 0,8 tons up to 14 tons (see Figure 36)

Figure 36 : Compact excavators of Wacker Neuson, source: Wacker Neuson (2016).

- 6 different types of **Chain Dumpers** (see Figure 37)

Figure 37 : Chain dumper of Wacker Neuson, source: Wacker Neuson (2016).

- 10 different types of **Wheel Dumpers** (see Figure 38)

Figure 38 : Wheel dumper of Wacker Neuson, source: Wacker Neuson (2016).

- 2 models of **Mobile Excavators** (see Figure 39)

Figure 39 : Mobile excavator of Wacker Neuson, source: Wacker Neuson (2016).

4.1.2 Shop Floor

The shop floor (see Figure A1, A4) of the plant of Wacker Neuson in Hörsching is divided into 5 assembly lines, one pre-assembly and the rework department (see Figure 40). The assembly lines (see Figure A2, A3) are called ML, which stands for “Montagelinie” and is a German expression. VM means “Vormontage”, which is the pre-assemly area. The rework department is called HF, which means “Härtefälle” in German.

On each assembly line, exactly determined types of machines are mounted to ensure a good productivity on each line. The machines are classified according to their weight, size, and technical specifications. Therefore, one line builds for example the three biggest and most complex types of excavators and another line builds the dumpers.

Overview of the Assembly Lines:

- **ML10** Takt time: 45 minutes
  Pieces per day: 11 pcs
  Type of machine: excavators from 0.8 to up to 9 to

- **ML20** Takt time: 63 minutes
  Pieces per day: 7 pcs
  Type of machine: all dumpers of Wacker Neuson

- **ML30** Takt time: 37 minutes
  Pieces per day: 13 pcs
  Type of machine: excavators from 2.9 to up to 5.3 to

- **ML40** Takt time: 17 minutes
  Pieces per day: 23 pcs
  Type of machine: excavators from 1.8 to up to 3.7 to

- **ML50** Takt time: 135 minutes
  Pieces per day: 3 - 4 pcs
  Type of machine: the biggest chain excavator with 14.5 to and the wheel excavators of Wacker Neuson

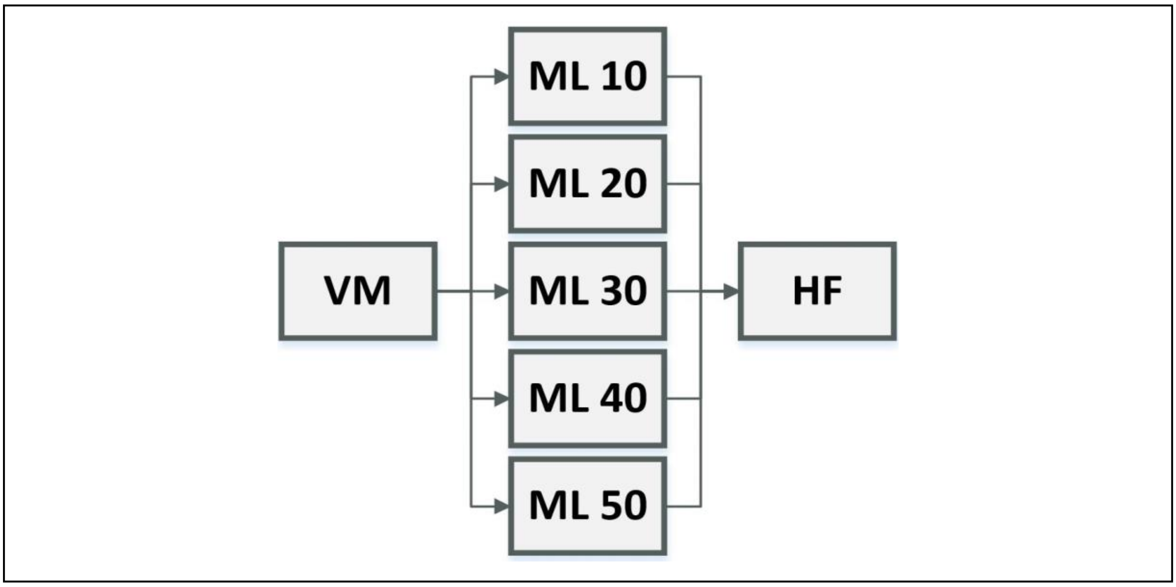


Figure 40 : Shop floor scheme of Wacker Neuson Linz GmbH , source:own representation (2016).

4.2 Work Instructions at Wacker Neuson (Status Quo)

At Wacker Neuson, work instructions constitute some problems in case of usage, creation, and standardization. The instructions are not uniform on the different assembly lines and often have different layouts. Furthermore, not every single workplace has its own work instructions.

To solve this problem on the assembly lines ML 50 and ML 20, projects are ongoing to generate instructions for each workplace and its workload. The currently used documents are mainly based on pictures of built machines. If the considered machine is available on CAD, some new instructions are made out of it. Instructions based on this kind of virtual picture are accepted widely by the workers, due to their good legibility and understandability. A new standard for getting better and uniform work instructions was implemented in September 2016, and is now the new guideline to generate paper based instructions for new machines. This standard (see Figure 43) is described more detailed in chapter 4.2.2.

4.2.1 Creation of Work Instructions

The whole CAD engineering data is available on the Engineering Control Center (ECTR), a data processing program, which is used in collaboration with the Siemens NX at Wacker Neuson. Siemens NX, former called Unigraphics, is the CAD program used by Wacker Neuson to design products.

Generating work instructions is a process, which claims a lot of manual work on the PC by now. First, all required data for the instruction is figured out in the ECTR data processing system. Afterwards, a screenshot (SS) of the CAD file and the material number is implemented in a word file. After arranging all numbers and pictures, the new work instruction is ready to use (see Figure 41).

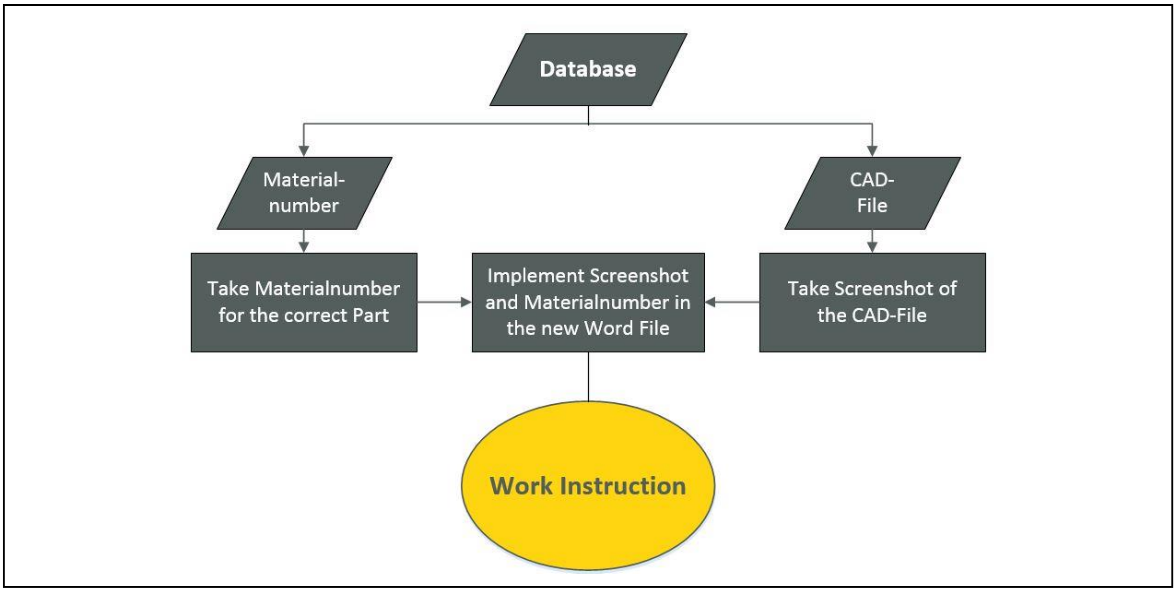


Figure 41: Usual way to create work instructions at Wacker Neuson, source: own representation (2016).

In Figure 42, a finished work instruction based on CAD data can be seen. In case of no available CAD data for a machine, the instruction is based on a simple picture of the assembly (see Figure 43).

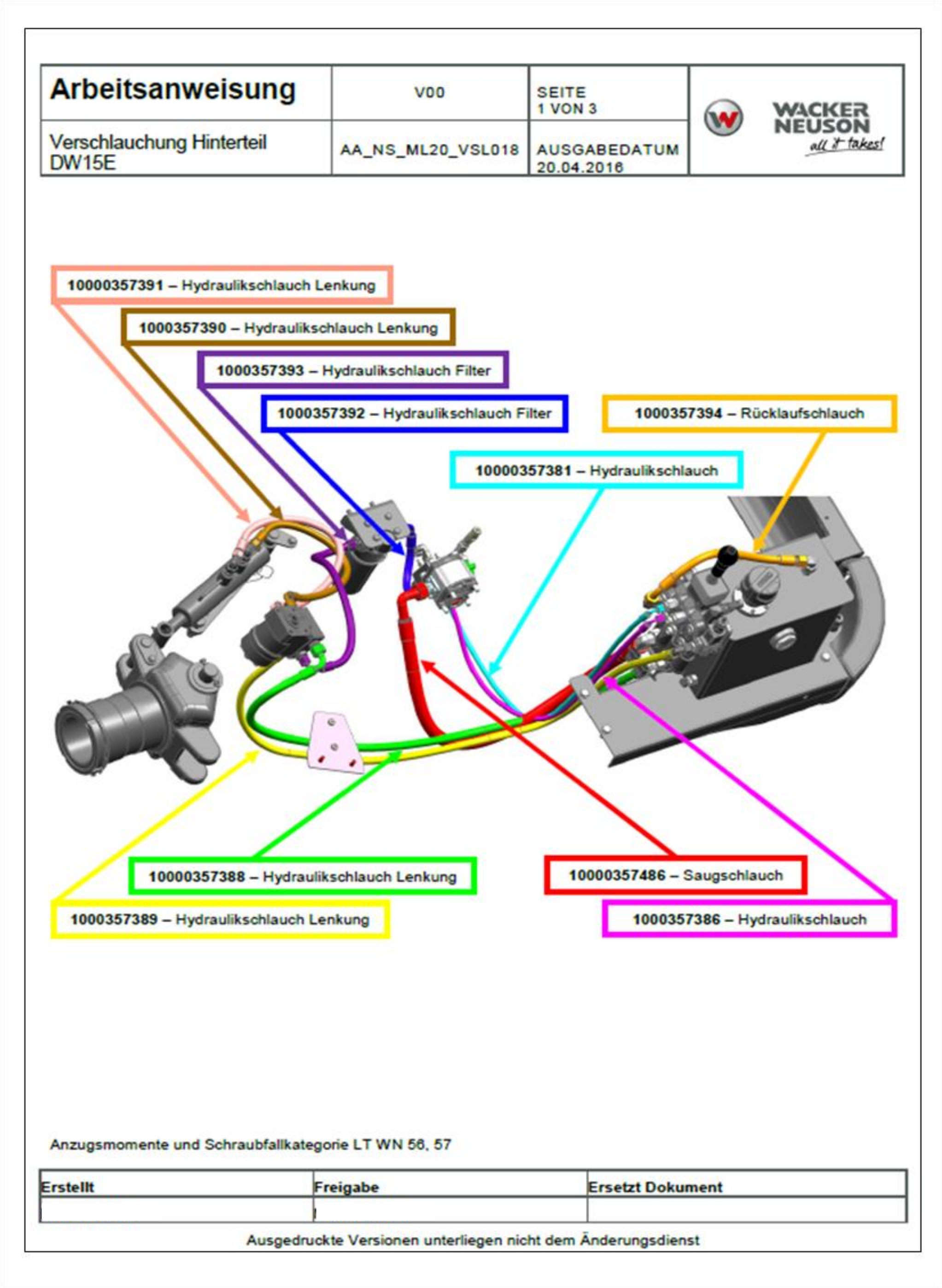
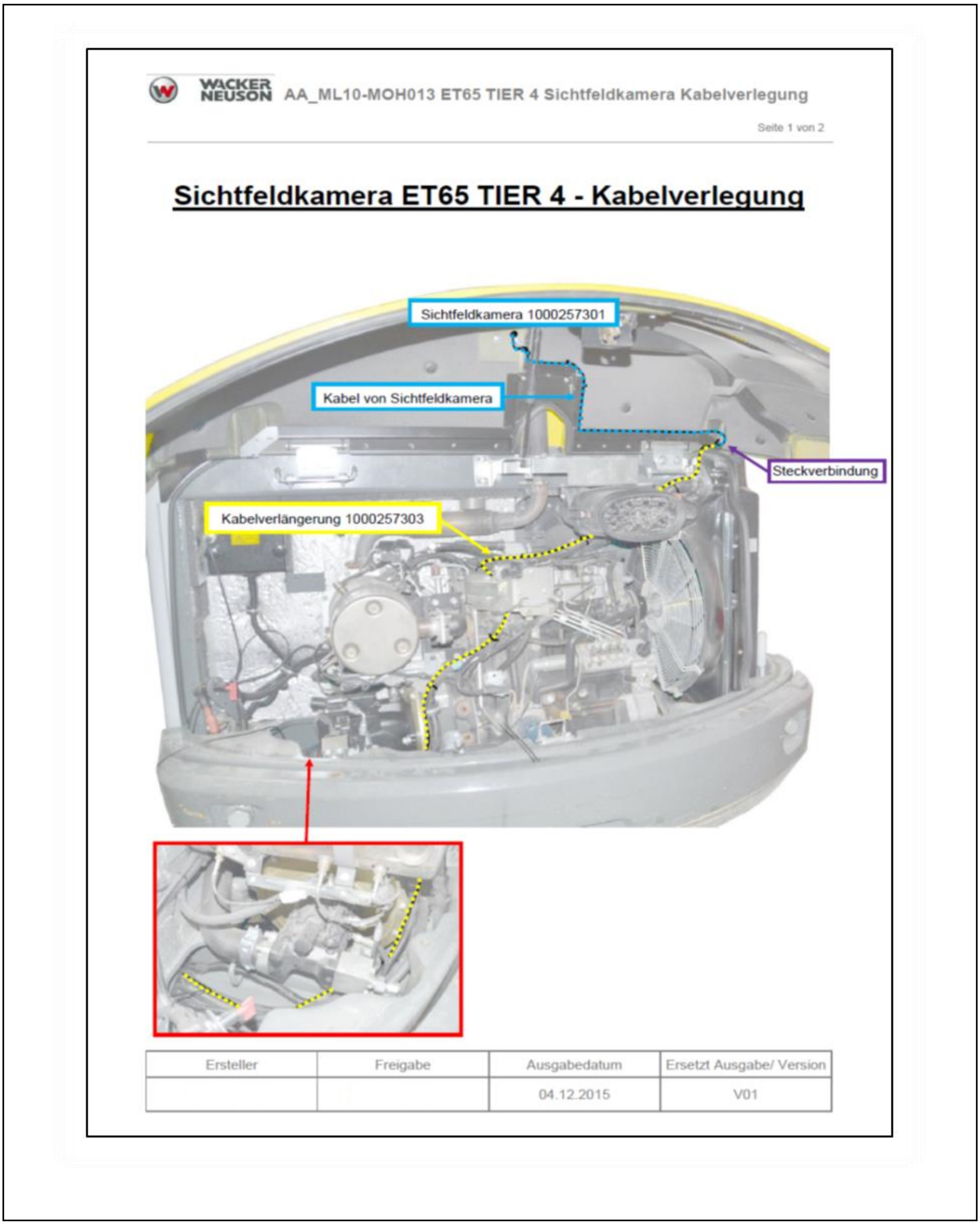


Figure 42 : CAD file based work instruction, source: Wacker Neuson (2016).



AA_ML10-MOH013 ET65 TIER 4 Sichtfeldkamera Kabelverlegung

Seite 1 von 2

Sichtfeldkamera ET65 TIER 4 - Kabelverlegung

Ersteller	Freigabe	Ausgabedatum	Ersetzt Ausgabe/ Version
		04.12.2015	V01

Figure 43 : Picture based work instruction, source: Wacker Neuson (2016).

4.2.2 Standard Used

Since September 2016, a new standard of work instruction is implemented to ensure that all new instructions are uniform (see Figure 44). The whole standard is pictured in Appendix Figure A5 – A10.

A main benefit of uniform work instructions is the recognisability of them. The workers know exactly where on the instruction special notes regarding torques, warnings, or any important changes are placed. This helps a lot to find all necessary instructions.

The new standard also requires the use of CAD data to generate an instruction. Only in cases where no CAD data of any part of a machine is available, like the tubing or the cable harness, pictures of the assembly task are allowed. A clear way how to create a work instructions and which important information, like relevant safety requirements, have to be on it is given. The layout of the work instruction is also defined and shows the worker of the production planning department exactly where special notes and advices are placed on the created document.

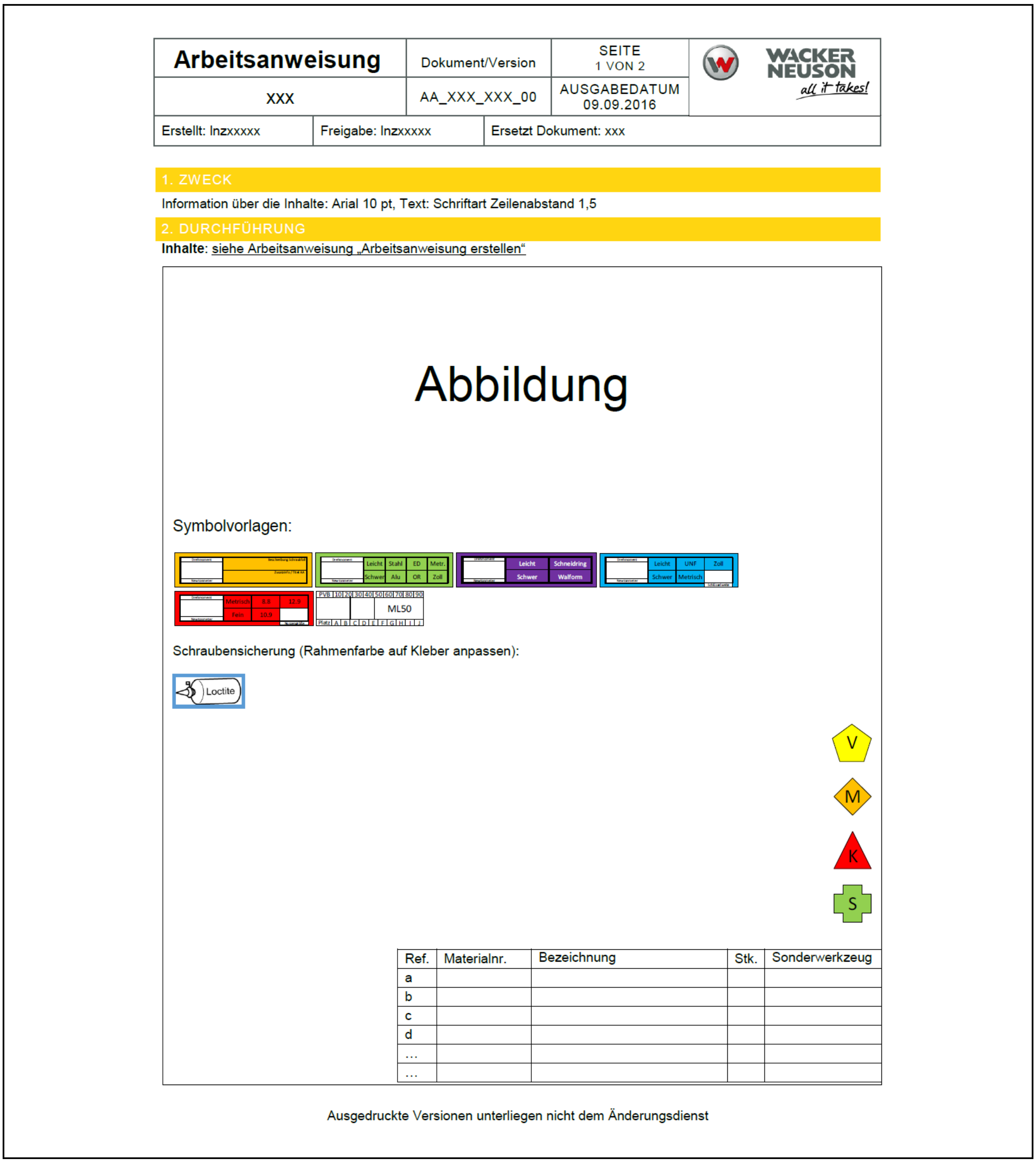


Figure 44 : New layout of a work instruction, source: Wacker Neuson (2016).

4.2.3 Update of Work Instructions

At Wacker Neuson, an update of a work instruction is called AVW, which means "**A**enderungs **V**er**w**altung" and can be called "change management" in English (see Figure 45).

This occurs frequently at new machines, where changes on several parts have to be performed which are caused by engineering failures and the redesign of some parts. This happens because some failures can only be detected as soon as a customer uses the machine in real life conditions. If a facelift of a machine type is made or new emission specifications come into effect, changes in the work instruction are necessary too.

The AVW takes actions when there is a need of change on any part or on the expiration of a work order. After this step, the engineering and development department carries out the change and creates a new part. Following that, the production planning department gets the whole information of the change and generates, the new work instruction and also adjusts the work order if it is needed.

After these two steps, the "NEW" instruction is transferred to the assembly line and at the same time the logistics department reacts and stores the new part on the right workplace.

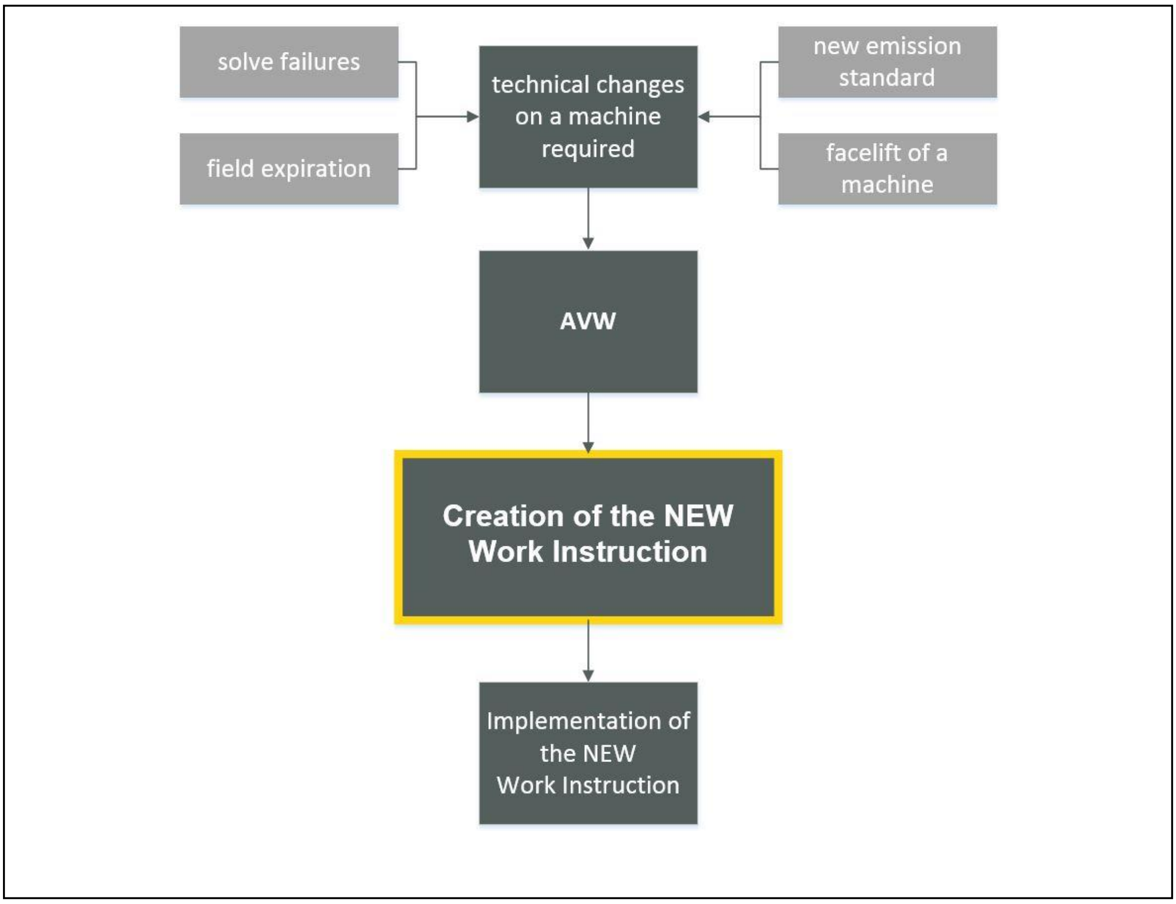


Figure 45 : "AVW" process, source: own representation (2016).

4.2.4 Ongoing Projects

At the moment the following projects are ongoing at Wacker Neuson Linz to improve their production regarding quality and productivity. All of them have at least a small linkage to the topic work instructions.

NX Viewer

The NX Viewer is a software from Siemens which provides a lot of helpful tools for creating work instructions based on CAD data (see Figure 46). Employees of the production planning department are able to colour the parts of an assembly CAD file differently to achieve a better visualization of the needed parts. One main advantage is that the employees who create the instructions are not able to change anything of the original engineering file, because the NX viewer provides only a file with visual data, which is enough for a perfect picture of the assembly task. A further benefit is that no mistakes can occur if a worker of the production planning department stores the file wrong or deletes parts of it.

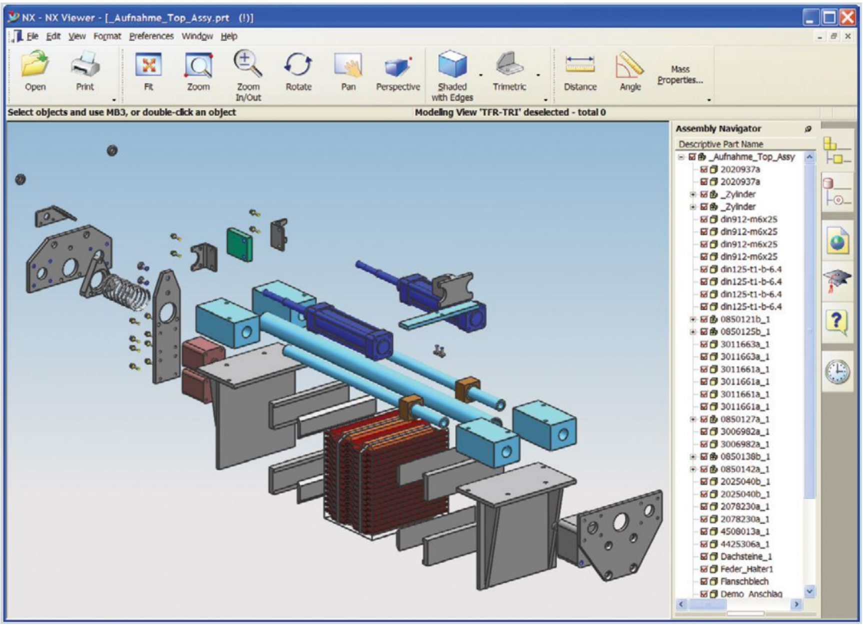


Figure 46 : NX Viewer, source: Siemens (2011), online source [22.07.2016].

AQIS

AQIS means Advanced Quality Inspection System and is a product of the company IGH Automation. The program should help a company to realize a better product quality by storing appearing mounting, logistics or engineering failures, which occur on the assembly line on a data base in order to react immediately if they occur frequently. AQIS is also able to lead through a difficult assembly task step by step as a kind of work instruction. This can be helpful for assembling a hydraulic control block of an excavator.

At the company Kramer in Germany, a member of the Wacker Neuson Group, checkpoints are installed on their assembly lines (see Figure 47). The checkpoints are positioned after all three stations, which are summarized to a group. After this group, the machine or the assembly will be checked regarding mistakes.

Therefore, many simple yes or no questions have to be receipt for the exact type and configuration of a machine. If one question is answered negative, the failure will be stored and processed afterwards. With this knowledge, work instructions can be created for work steps where a lot of failures occur to get rid of them as fast as possible.

Wacker Neuson Linz also works with AQIS, but not that intensive. There are checkpoints at some assembly lines, but the system is not used uniformly at the production.

Figure 47 : Quality checkpoint with AQIS software, source: Wacker Neuson (2016).

Tablets for Checkpoints

Tablets for controlling quality checkpoints will be installed in the near future to be able to handle the required work when a machine gets checked in an easier way, compared to the used PCs nowadays. A tablet enables the worker to sign up diverse quality issues while sitting on the machine and trying out several functions of it.

Bluetooth Devices

To identify each single machine, Bluetooth devices are installed on the machines. This also helps to show the exact work instruction regarding the machine type which is actually in line, if a system with digital work instructions is mounted on the assembly line. Such a system can also include all special variants and extra equipment required on the work place. Wacker Neuson uses this devices by now only at the warehouse of finished goods and not for work instructions. At the warehouse they help the distribution department to identify the machine very fast, which saves many working hours.

Holo Cube

The Holo Cube is a hall at Wacker Neuson Linz where a special equipment will be installed to show new machines in augmented reality. This allows the designer and the engineers to see the machine in its real size in a realistic environment before anything of it actually exists. For the production department, it is very helpful because they are able to check diverse assembly tasks and can react very early if a part is unable or very difficult to assemble on the digital mock up of a machine. In the future, workers of the assembly line will be able to train some main work steps virtually before the first prototype exists. The advantage is, that they are prepared for a faster ramp up. To be able to use this establishment for assembling parts virtually, the whole machine or rather the required assembly has to be available detailed in CAD.

4.2.5 Available Resources

The available resources at Wacker Neuson Linz, which are connected with the task work instructions, are listed in this chapter.

Computers on the Shop Floor

At each assembly line computers are mounted (see Figure 48). The assembly line ML 50 is the one where the highest number of computers are stationed (see Figure A11). An average of one computer at every second work station is common. These computers are linked with the network of the company. The infrastructure on the assembly line can also be used for creating a new providing in offering work instructions at the workplaces. By now the computers are used for booking machines and parts with SAP.

Figure 48 : Computer on a work place, source: Wacker Neuson (2016).

CAD Software

The CAD Software Wacker Neuson uses is a Siemens software called NX or with the former name of it Unigraphics. The aim regarding the concept below, should be to create the machines very detailed with the help of CAD, including all parts, also the wire harness and all the tubes of the hydraulic (see Figure 49). The software is able to realize this aim but the resources regarding work force are not fully given at the moment. By now all machines, which are built on the assembly lines are available in CAD, but only about 10 percent of them are available very detailed with really all parts. In the past only, the main parts of a machine where designed in CAD to have a rough virtual model.

Figure 49 : CAD software Siemens NX, source: Wacker Neuson (2016).

SAP

SAP is a data processing program where the main data for production and logistic tasks is stored. This program can be extended if any new tasks are required in the company. The data processing software of the eponymous company SAP SE is the worldwide leading solution in this field.

Microsoft Office

The Microsoft Office package is used to create work instructions at Wacker Neuson by now. Most of them are created in Microsoft Word. Nearly each computer at the company is equipped with this software package.

Hardware

Each worker of the administrative board has a laptop or PC to be able to use the network of the company. The engineering department has workstations with higher IT performance to ensure that the CAD programs work well. At the whole company, WLAN is installed which is very useful if tablets are used on the assembly line.

Employees and Engineers Creating Work Instructions

About 20 percent of the employees or rather the engineers at the production planning department are responsible for creating work instructions. To keep the instructions up to date, the heads of the production line are responsible too. Generally there is not enough workforce to ensure complete work instructions of a machine by the time it`s production is started. This fact is a drawback for producing a good quality from the beginning.

4.3 Developed Concept

To realize the aim of automatic generation of work instructions, the development of the concept was strongly inspired by the maturity model created before. The focus of this elaborated concept is clearly on having an automated generation of digital visualized work instructions. Therefore, the concept only contains some steps of the maturity model, which are important to reach the specific aim (see Figure 50). A well known status quo builds the base of the whole concept. Also a main basis to reach a good solution should be a certainty that everyone who works to reach the given aim should feel confident with this concept to get the best and most effective solution.

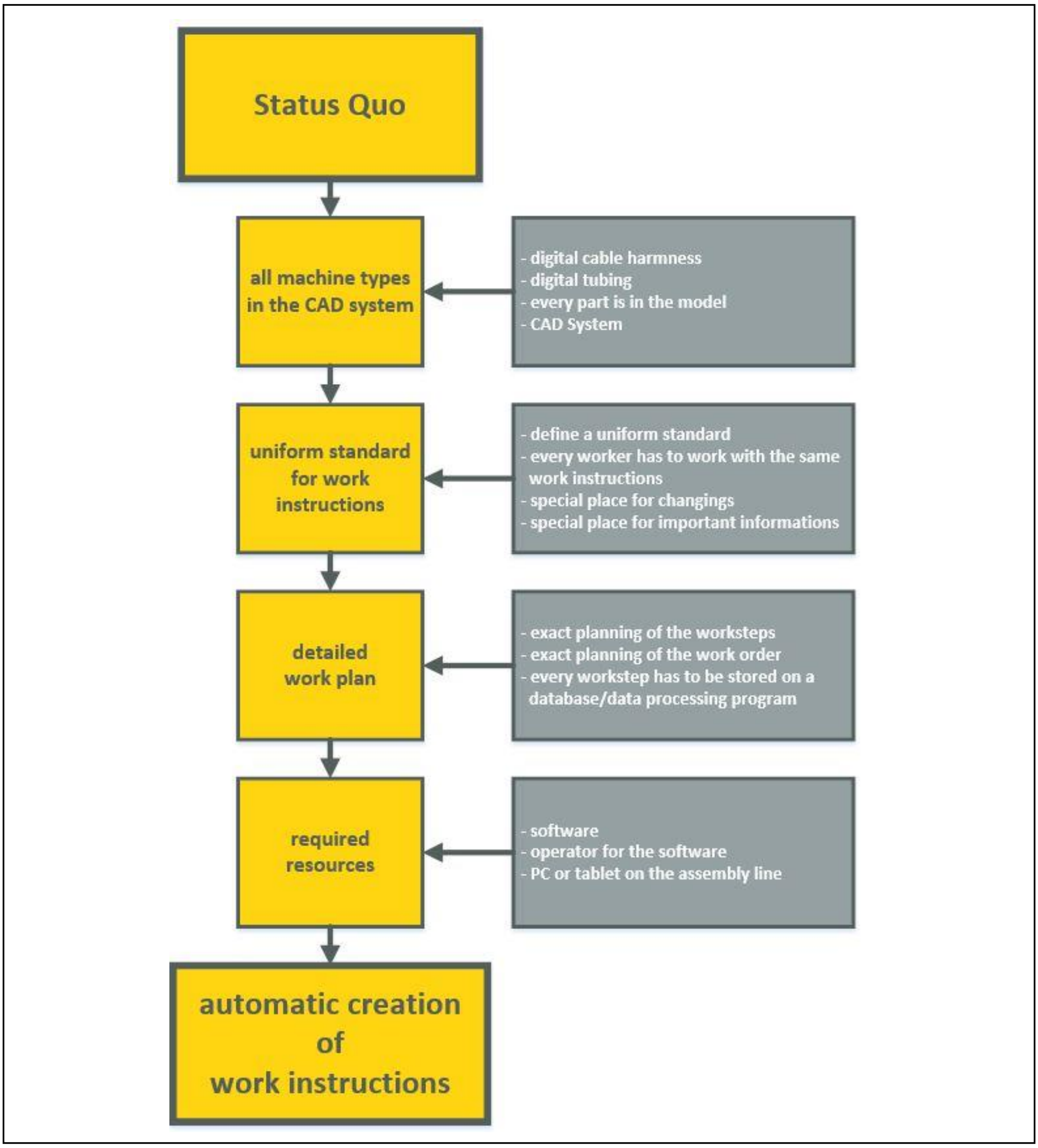


Figure 50 : Concept structure, source: own representation (2016).

4.3.1 Status Quo

The current state regarding work instructions at Wacker Neuson Linz was achieved by examining the whole production, the work preparation department and the usage of the instructions. To get a good overview of this complex topic, the workers who use the instructions were very helpful to get a feeling how they really work with them. After interviewing a lot of people who are affected with work instructions, a clear current state arise. To emphasize these facts, the heads of the assembly lines were interviewed again in detail. The actual status quo is the 2nd step of the maturity model, “partly available work instructions at the assembly line”. This step means that some work places of the assembly lines have no instructions or only old instructions. Six stations out of about sixty are prepared with digital work instructions, the rest of the production uses paper based instructions in folders. At the moment, three workers of the production planning department are creating instructions to ensure comprehensive instructions on each workplace in the future. Another two workers are creating digital instructions for quality checkpoints to get a better failure detection and an error memory. One more project ongoing at the moment deals with having a uniform standard of work instructions in the whole production, like it is mentioned in chapter 4.2.2. This should ensure that every worker knows exactly which workload is to do at first sight of the instruction.

A more detailed and more extensive actual state about work instructions at Wacker Neuson Linz is shown in chapter 4.2.

4.3.2 All Machine Types in the CAD System

CAD based work instructions are the fundament for a system that creates work instructions automatically. Now, most of the work instructions at Wacker Neuson are based on pictures. To get all required pictures, the workers of the production planning department have to wait for all variants of a machine which is produced on the assembly line. If changes on a machine occur, they have to wait until this new design is built for the first time to be able to take pictures of it. Therefore it is a very work intensive process for getting the right picture for creating a work instruction.

If the instructions are based on CAD files, the process would be much faster and more flexible. The workers get the necessary files from a data server where the engineering department stores and uploads the newest version of a machine regularly. All possible variants of a certain machine type are stored on this server.

The basis for working with CAD files instead of pictures are machines which are completely drawn and designed in CAD programs. Completely means that a machine should contain all parts like smallest screws, the cable harness, the whole tubing, and all extra parts different variants contain.

Reaching this standard also provides a perfect quality of the figure on the instruction, because pictures are sometimes not clear. Another benefit are the colours which can be used from the employees who create the figures, because they can mark important parts for the assembly workers.

4.3.3 Uniform Standard of Work Instructions

Like in chapter 4.2.2 mentioned, uniform work instructions are very important to ensure a good recognisability of them. It is much easier for a worker if there is no need to adapt to the new instruction. Instead of this, a well known layout of the instruction helps a lot to feel familiar with it. To be well informed about the instruction allows the worker to start sooner with the required work task and lowers the risk of forgetting something to do. The workers of the assembly line know exactly where the most important information are placed on the instruction. Therefore, it is more likely for them to perform with a lower error rate, because they hardly overlook important assembly information like torques, changes, or warnings. To run the program, that will be used to create work instructions automatically, in a satisfying way, it is important to provide this uniform standard.

4.3.4 Detailed Work Plan

A detailed work plan means that every step of the assembly is planned. The worker has a clear instruction how to assemble different parts. An assembly task is divided into all its individual parts, also tiny screws and other very small parts. Therefore, no freedom in fulfilling work tasks is possible for the worker anymore, which ensures that each machine is built in the same, accurately described way. Having this standard, a higher quality is achievable to reach. At the current state at Wacker Neuson, the workers often have a kind of freedom at some work steps, which can lead to an unprecisely assembled product. Consequently, a perfect defined work order ensures an exact assembling.

For reaching the goal of a detailed work plan, all assembly tasks of a machine have to be divided into single steps, which leads to a lot of work. Therefore, all new machines should include a detailed work plan from the beginning.

A complete and detailed plan can also include the duration of the single work steps. This enables an automatic line balancing of all the different stations of an assembly line, which leads to a higher productivity.

4.3.5 Resources Needed

To realize the aim of automatic generated work instructions, many different resources are required. They are listed and described below.

Software

The software for all required tasks is the base to reach the aim of automatic generated work instructions. The research of finding a software for this task was slightly directed by the IT department of Wacker Neuson. They set a scope of only focusing on software suppliers, which are already cooperating with Wacker Neuson. This should bring a benefit for Wacker Neuson because they do not have to adjust on a new supplier. Although, the biggest benefit should be that present suppliers know exactly what Wacker Neuson requires and can also build up on existing data from their already running software. Nevertheless, also programs from other providers where conducted, to ensure that there is no supplier on the market, who offers a way better solution then the already existing suppliers.

After an intensive research three programs from three different suppliers, which are already operating with their software at Wacker Neuson, were chosen:

- **Siemens EWI from Siemens**
  Siemens already runs the program NX at Wacker Neuson. The NX is the CAD software Wacker Neuson uses. Therefore, all machines are designed with this software. EWI means Electronic Work Instructions and is a software to create and maintain work instructions. It does not work overall automatically but the steps to generate work instructions are designed very user friendly. The application to show the instruction on the assembly line is browser based and, therefore, able to be used on each tablet or PC where a connection to the internet exists.

- **SAP Visual Enterprise from SAP**
  The company SAP runs the eponymous program SAP at Wacker Neuson, which is a well known data processing program a lot of companies use. All the production and the production planning data of Wacker Neuson is stored and administrated with help of this software.
  The SAP Visual Enterprise is a special software for work instructions and is able to generate them automatically by using the data of the SAP database. The main component SAP Visual Enterprise requires, for an automatic generation of work instructions, is a detailed work plan of all assemblies stored on SAP.

- **IGH AQIS from IGH Automation**
  As already described in chapter 4.2.4, AQIS means Advanced Quality Inspection System and is designed to realize quality checks at the assembly line. Furthermore, the program can be used to show work instructions digitally. The program is not designed for creating work instructions automatically, but it can be equipped with the data of a detailed work plan and its assembly sequences. At Wacker Neuson, AQIS is installed at some quality checkpoints and therefore the easiest and cheapest way to get digital work instructions. Although, the required functions are not fulfilled completely, this program could be a big benefit for the production.

To ensure to have the best choice and the best fitting program for Wacker Neuson, a Cost-Benefit Analysis with these three programs was executed (see Table 1). The required know how according these three software solutions was generated from an extensive research and through questioning the IT-department of Wacker Neuson. This department is well informed about technologies for the future, which was a great benefit regarding this software topic.

Six criteria according to different demands on the program were defined:

- automatic creation of work instructions
- browser based application
- simple data linkage

- maintenance of work instructions
- future solutions
- costs (investment, licences)

criteria	weighting	Ideal Program		Siemens EWI		SAP VE		IGH AQIS	
		Grade	Score	Grade	Score	Grade	Score	Grade	Score
automatic creation of WI	20%	5	1	3	0.6	4	0.8	0	0
browser based application	10%	5	0.5	5	0.5	5	0.5	5	0.5
simple data linkage	15%	5	0.75	2	0.3	4	0.6	2	0.3
maintenance of WI	15%	5	0.75	5	0.75	5	0.75	2	0.3
future solutions	15%	5	0.75	4	0.6	4	0.6	1	0.15
costs(licences, price)	25%	5	1.25	1	0.25	2	0.5	4	1
	100%		**5**		**3**		**3.75**		**2.25**

Table 1 : Cost-Benefit Analysis of the different software solutions, source: own representation (2016).

The criteria points are weighted according to their importance for the company to realize a good concept. The weighting was made with percentages, which means that all six points add up to 100 percent (see Table 1).

A very important criterion is the automatic creation of work instructions which is weighted with 20%. This criterion is only fulfilled if the given aim of creating the instructions automatically is achieved.

A browser based application for the linked devices on the assembly line is also important. Without it, the tablets or PCs would need an extra software to run the work instructions.

Simple data linkage from the database, where all the engineering data and the data from the production planning department is stored, to the chosen software is also a main point. If this is not possible, a huge work due to data conversion or program changes occur.

The maintenance of work instructions is necessary if changes on the assembled machine arise. To handle that, this function of the software has to operate in a good way.

The criterion future solutions should ensure a good program for future regarding further steps in the maturity model of work instructions. The software has to fulfill its task for several years. Therefore, it is important that the software provides also solutions for tasks in the future.

Costs is the last criterion, but also the most important one in this benefit analysis, because a fast return of investment should be possible.

These six criteria are graded according to their capabilities to fulfill the respective criteria (see Table 1). A grade of 5 points signs the highest or rather the best grade. The grades go down to 0 points, which shows that the considered software does not fulfill this criteria anyway. The ratings where performed according to the gained knowledge from the investigation of these three programs.

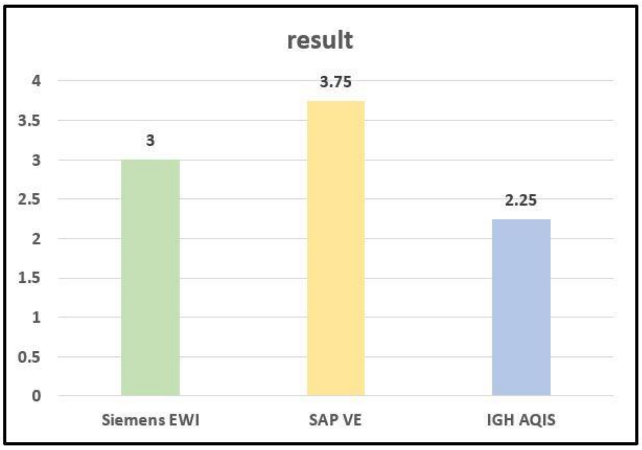


Table 2 : Result of the benefit analysis, source: own representation (2016).

The result of the benefit analysis (see Table 2) shows the SAP Visual Enterprise with a score of 3.75 on the top. Siemens Electronic Work Instructions is on the second place with a score of 3.0, which is 20 percent below the SAP software. At the end of the results is the software IGH AQIS, with a score of 2.25 or 40 percent below the software of SAP.

The SAP Visual Enterprise is according to the benefit analysis the best fitting software for a satisfying solution. This results because of the software fulfills the criteria automatic creation of work instruction and simple data linkage much better than the other ones. Another benefit are the costs of the software SAP. It is expensive with about EUR 8000 licence costs for one work place a year but still cheaper than the software of Siemens which EUR 10000 costs about a year for one workplace. IGH AQIS is much cheaper with about EUR 2000 a year, but this software cannot fulfill three other criteria in a satisfying way.

Although, the other solutions are in some points as good as the best one, SAP is the most convincing software in the end. Another claiming effect is that SAP would be the best solution if the criteria costs would be excluded. Therefore, this software solution is not only chosen because of a better price.

PC or Tablet on the Assembly Line

Another required resource are the PCs or tablets on the assembly line to be able to display the work instructions there. Using a tablet enables more flexibility and the worker can place it everywhere on the work place where it is needed. Commercial tablets are not resistant enough for the use in a production, therefore they need a special housing. Installing a PC on the work place brings the benefit of a faster network linkage, because the PC is linked via a fix LAN connection and not via WLAN. Another benefit for a PC is the not required battery in the device, which will not last long if such a device is used all day long.

However, a tablet is the better choice for Wacker Neuson due to the big machines that are built in this plant. Therefore the worker sometimes has to stay on or under the machine or is sitting in the cabin. This fact requires flexible work instructions, which can be taken to the place at the machine where the worker fulfills the work task. Due to the rising quality of tablets on the market and the fast enough WLAN at Wacker Neuson, the choice to use them on the assembly line will be an equitable decision.

4.3.6 Automatic Creation of Work Instructions

The aim of the concept is to provide an automatic creation of work instructions at Wacker Neuson. This aim should be realized by fulfilling the four tasks described above (see Figure 50):

1. All machine types in the CAD System
2. A uniform standard of work instructions
3. A detailed work plan
4. The required resources

Realizing this concept in the company can enable a lot of benefits according to the topic of work instructions, like the ones are listed below:

- Faster changes of work instructions

  If changes on a part of the assembly occur it is a big effort to rectify that on the instructions at the moment. The new technology of doing that automatically saves a lot of resources and guaranties a fast change of the instruction on the assembly line. This is especially important during the first months of building a machine because it can occur that several changes in one week are announced by the engineering department.

- Better maintenance of all work instructions

  Having all the work instructions up to date is very important to build machines with high quality. Also if new safety requirements or new tools come to the assembly line, the work instructions have to be maintained as well. Furthermore, the maintenance is much easier to realize with digital work instructions, because no sheet of paper has to be changed on the assembly line. If this is all made automatically, the whole production can profit from that.

- Overall uniform standard of work instructions

  By creating the work instructions automatically, uniform standard is easy to realize. Therefore, all the benefits a uniform standard provides can be used.

- Better traceability of failures can be realized (in connection with AQIS quality checkpoints)

  To ensure a high quality of the built machines, the work instructions can be easily connected with the installed checkpoints on the assembly line. For example, a signal can emerge, if a failure on the work instruction is made several times. Doing that with paper based or handmade work instructions would cause a very big work load.

- Saving of resources in the work planning department

  Another big benefit is the saving of resources in the work planning department. If the standard of comprehensive and up to date work instructions should be realized without an automatic creation of them, the required resources in the work planning department will raise very fast. Therefore, it is a good advice for the future to realize the automatic creation of the instructions to be able to save resources.

4.3.7 Time plan

In this chapter a rough time plan is given to get an approximate feeling when the concept can be realized. Therefore, each step of the concept therefore will be considered and planned with a variation.

All machines in the CAD System

This step of the concept is an ongoing project at Wacker Neuson and is going to be performed with all new machines, which had the start of production after September 2016 at the plant in Hörsching. The process to implement all machines completely in CAD will last for several years because some types of machines, where the production started a few years ago, are built for some further years. The instructions of these types are based on pictures in most cases. Changing them for the last years of their production would not make sense, because the production is running smoothly and the workers know exactly what to do. Another criterion why it does not make sense to change running machines is their high level of development. Regarding to this fact, a low rate of changes occur at them, because most failures are wiped out. The failures of these older machines will be detected because of customer feedbacks, service documentations of the dealers and the better knowledge about the built machine after building many of them for a longer time.

Uniform Standard of Work Instructions

Having uniform standards of work instructions is quite similar to have all machines in the CAD system. A new standard to create uniformly instructions of new machines at Wacker Neuson Linz runs since September 2016. The standard is made for all new machines but the old ones, which are produced since several years, have different, not standardized, work instructions. Creating new work instructions for these machines does not make any sense like it is the case at the step before (All machines in the CAD system).

Detailed Work Plan

Creating a detailed work plan for each assembly step is the most time consuming step of the concept. Each machine is divided in its smallest parts. Therefore, all the tiny screws, the tubing and the cable harness are observed. This is only possible with a detailed and complete CAD model of the considered machine. It does not make sense to create this work plan again for existing models. Only for new models, a complete work plan should be created before the production start to ensure entire work instructions for the new machine.

Resources Needed

The required hardware resources are installed in a few months. These include the existing WLAN in the production hall or the LAN connection, which is available at each second work place. Having experts for the chosen software (see Chapter 4.3.5) is more time consuming, because there are not many experts regarding this very new software by now. To train the existing workers would be the best choice in this case.

Time Plan

In the following table (Table 3), all required criteria are listed again. The time for achieving the particular task for the first time or for the first machine type is signalized by the blue bars of the table. The required time for reaching the tasks comprehensive in the company for all produced machine types is shown by the green bars. This shown time can only be estimated, but to reach all tasks fully, it would take as long as the now built models are replaced from their predecessor. The reason for that is, that it does not make sense to change the system of work instructions for a machine type which gets built since some years, because these types do not make much problems, like it is mentioned in the chapter “All machines in CAD” before. Construction machines at Wacker Neuson have a lifecycle up to 10 years. Therefore this long timeframe, to reach this kind of work instructions for each type of machine, was chosen. Wacker Neuson can realize the concept step by step or rather machine type after machine type (see Figure 51). It is also possible to realize the concept for all types of machines much earlier but therefore all machines, which are built at the moment have to be updated regarding their CAD data and a detailed work plan has to be created for them. It is also possible to equip the actual built types of machines only with digital work instructions and the new types with an automatic generation of work instructions. This is a decision of the management how fast they like to have this system realized at Wacker Neuson.

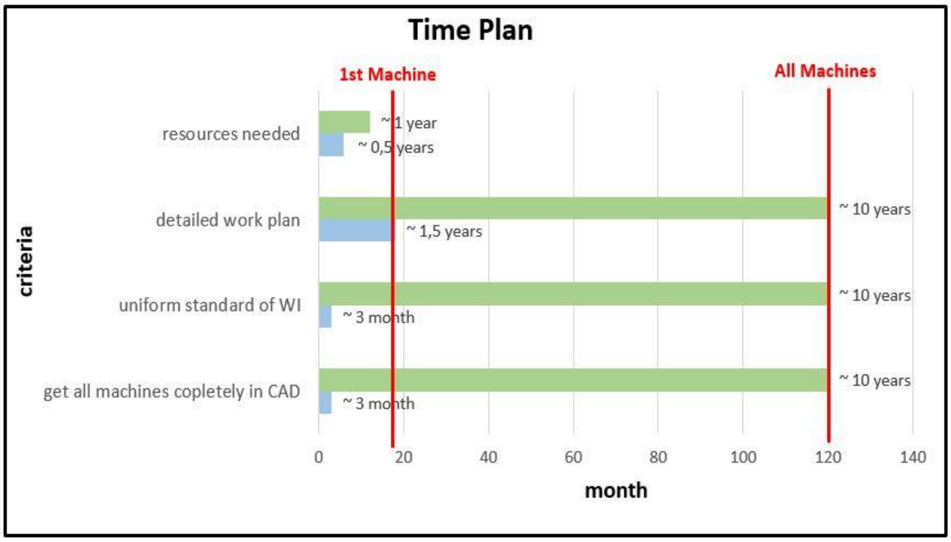


Table 3 : Time plan, source: own representation (2016).

This time plan (Table 3) only contains the variant of realizing the concept step by step only for new machine types. Therefore it can last up to ten years to have this concept transcribed for really all machine types getting built.

4.3.8 Implementation of the Concept

Figure 51 shows a plan in which sequence the concept should be implemented in the existing production of Wacker Neuson. If the project of a new machine type starts, also the concept implementation starts. A step by step version of implementing the concept is demonstrated in Figure 50. The loop, which is shown in the chart has to run through until all machine types are replaced by their successor to have the new system of work instructions comprehensively in the whole production in the end. Although it is not mentioned in the chart, a uniform standard of work instructions is also necessary as it is mentioned above. This standard is slightly restricted by the used software to realize the automatic generation of work instruction, because the layout of the instructions has to be customized for it.

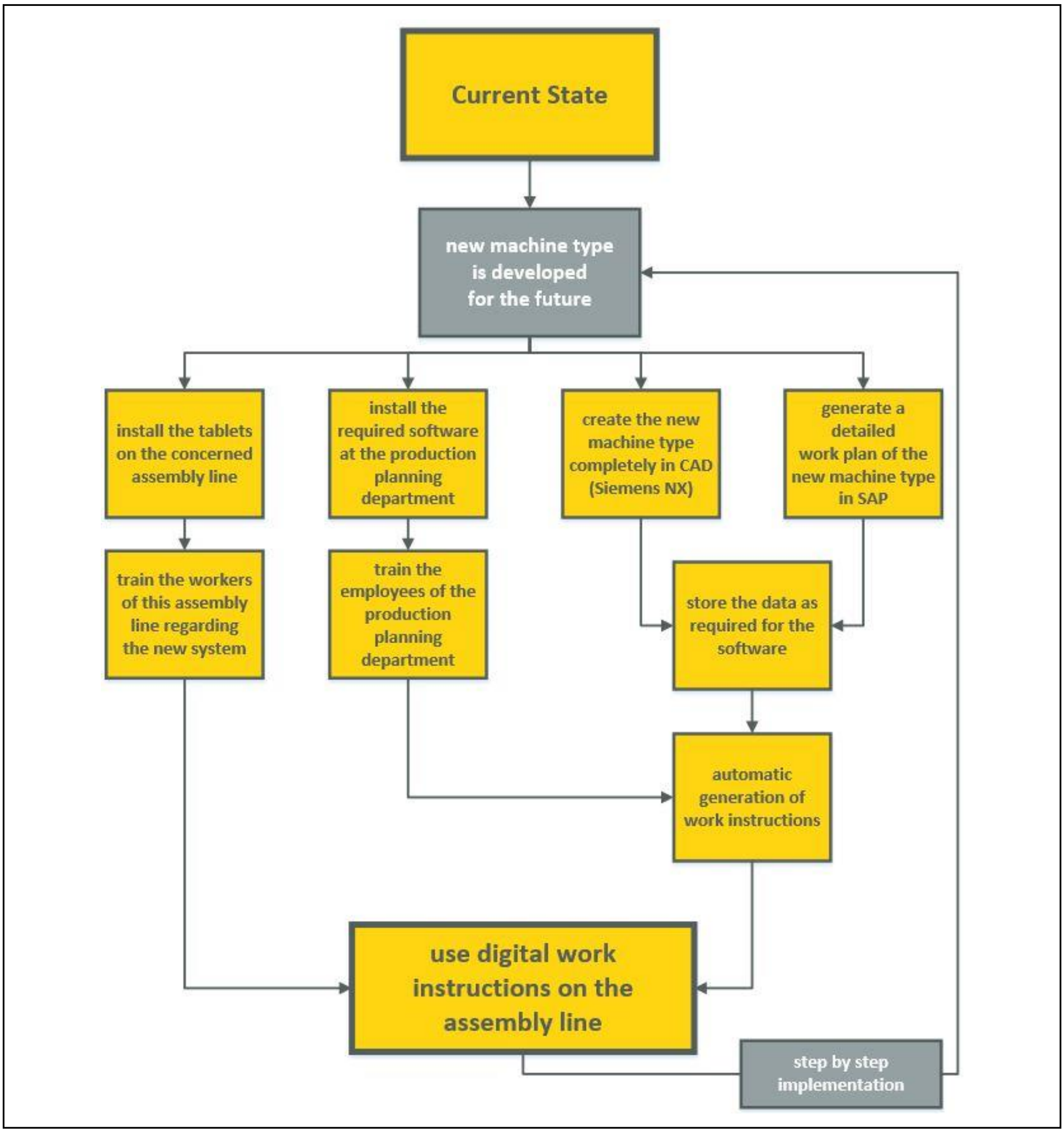


Figure 51 : Implementation plan of the concept, source: own representation (2016).

4.3.9 Costs and Potential Savings

The estimated costs for realizing the whole concept are described in this chapter. The Facts are based on a rough calculation to estimate the extent of the whole concept. Afterwards, the potential savings are pointed out to be able to calculate the return of investment. The calculation cannot be performed very detailed, because many different factors can influence the development of the concept positive or negative. Although, the calculation is made with all available data of the company as good as possible. Therefore, the following figures are rough indications and should only be a decision support for responsible persons. In the following calculation only the countable benefits and costs are considered, because the benefit of a higher quality according to a better image for the company and a higher customer satisfaction is difficult to calculate. Moreover, the costs for changes of work instructions in the lifecycle of a machine are not considered, because it depends very strong on the type of machine how many changes have to be made.

Rework Costs

The costs for the rework of some machines after the assembly line is a main cost driver each year (see Table 4), because the rework department is only responsible for machines which have failures. If failures occur in the production, they can be divided into assembly depending failures and into all other failures. All other failures include, for example, a logistic mistake, a production planning mistake, quality issues of supplier parts, and several more. The distribution between these two defined types is approximately fifty-fifty according to quality data of Wacker Neuson. Therefore, the mounting caused mistakes are responsible for the half of the rework regarding this available data. But these mounting caused mistakes cannot be avoided only with perfect work instructions. This is because the workers on the assembly lines are still humans and, therefore, it is unavoidable to have failures. Due to that fact, the rate of assembly depending failures, which are avoidable with better and actual instructions are set with 15 percent of the whole amount of rework. The factor of 15 percent is an estimated number according many opinions of employees at Wacker Neuson. At the rework department, the workers are well educated construction machine mechanics. Therefore, the costs per rework hour climbs up to about EUR 40 for one working hour at the rework department of Wacker Neuson in Hörsching.

If failures occur, the rework time is in most cases rather high due to the high complexity of the built machines. Sometimes a lot of parts have to be reassembled to reach the part, which is responsible for the failure. This happens, for example, if a failure at the tubing arise, because in this case the machine has to be washed completely again due to the hydraulic fluid on the machine. Because of the facts above the average rework time is quiet accurate 60 minutes for each machine produced at Wacker Neuson in Hörsching. This does not mean that every machine needs a rework, but if there is a rework required it is in most cases very time consuming. Therefore, an average rework time of one hour for each machine gets calculated.

Wacker Neuson in Hörsching has produced about 13,900 machines in 2014, the year with the highes amount of machines in the history of the plant. Therefore the number of 14,000 pieces was chosen for the calculation to be able to take into account a rising number of pieces in the next few years.

At the end of the calculation, the result for total rework costs, caused by all kind of failures, is a sum of EUR 560,000 (see Table 4).

Total Rework Costs	
[A] costs for one rework hour [EUR/h]	40
[B] average rework time / machine [h]	1
[C] machines built / year [pcs]	14000
[D] total rework costs / year [€] [A * B * C = D]	560000

Table 4 : Total rework costs per year in the plant Hörsching, source: own representation (2016).

Estimated Savings

The total rework costs can be divided into two kind of failures like it is mentioned before. Assembly depending failures which are avoidable with better or rather perfect work instructions are set with 15 percent of the total rework costs.

The saving potential at rework costs is therefore EUR 84,000 a year (see Table 5), if all assembly lines use the shown concept.

Estimated Savings of Rework Costs	
[D] total rework costs / year [EUR]	560000
[E] assembly depending failure rate [%]	15%
[F] estimated savings / year [EUR] [D * E = F]	84000

Table 5 : Estimated savings of rework costs, source: own representation (2016).

Costs for Resources

The costs for the required resources to realize the shown concept are divided into the costs for software licences, for hardware, training of the workers and maintenance (see Table 6).

Three work places at the production planning department need the software SAP Visual Enterprise to create the work instructions for all new machines. To handle this program, some workers of the department need a special training, which also causes costs. These two points generate costs of about EUR 8,000 for each license and about EUR 5,000 for the training of each worker who works with the new software.

Hardware costs are caused by the required tablets on the assembly line to display the work instructions there. Each assembly line has about 12 stations where the tablets are needed. To ensure that the workers can use the tablets as good as possible, two of them are required at each station. If all assembly lines have the new system running, 120 tablets have to be ordered. One tablet is calculated with EUR 500, because they also need a case against dirt and shocks.

To keep all the hardware running perfectly, maintenance costs for one year are calculated with EUR 30,000. This might be too much for the first years the system is running, but after some years the first tablets or the accumulators of them have to be changed. It can also be estimated that a tablet will not hold longer than 3 years, being used daily in the production. If this gets considered costs for new tablets are after three years EUR 20,000 average per year to replace the worn-out ones. The additional EUR 10,000 of maintenance costs are estimated and are chosen rather high to do not have any risk afterwards.

Due to the high effort of hardware and training, in the first year the costs for resources are high calculated with EUR 129,000. At the following years the running costs are 54,000 Euros a year, which are caused by maintenance and license costs.

Resources Costs	
[G] licence costs SAP VE work place / year [EUR]	8000
[H] work places with SAP VE [pcs]	3
[I] total licence costs [EUR] [G * H = I]	**24000**
[J] tablet costs [EUR]	500
[K] tablets on the assembly lines [pcs]	120
[L] total tablet costs (all assembly lines) [EUR] [J * K = L]	**60000**
[M] training costs / worker [EUR]	5000
[N] workers for work instructions [pcs]	3
[O] total training costs [EUR] [M * N = O]	**15000**
[P] maintenence costs / year [EUR]	**30000**
[Q] resources costs and running costs for the introduction year [EUR] [I + L + O + P = Q]	**129000**
[R] Running costs for the following years after the introduction year [EUR] [I + P = R]	**54000**

Table 6 : Costs for required resources, source: own representation (2016).

Benefit Calculation

The most important calculation is the benefit calculation, regarding the saving potentials, the costs to install and to run the system (see Table 7). Due to the high required investment the calculation for the introduction year is EUR -45,000. But the system should bring sustainability regarding quality and lower rework time and, therefore, it can be calculated over several years. Doing that, each year after the first one enables a benefit of EUR 30,000. Therefore, the return of investment considering only the savings of the rework time would be reached in approximately 2.5 years (see Table 8).

Benefit Calculation	
[F] estimated savings / year [EUR]	**84000**
[Q] resources costs and running costs for the introduction year [EUR]	**129000**
[R] Running costs for the following years after the introduction year [EUR]	**54000**
[S] benefit in the introduction year [EUR] [F - Q = S]	**-45000**
[T] benefit in the following years [EUR] [F - R = T]	**30000**
[U] return of investment(ROI) [years] [(-S / T) + 1 = U]	**2.50**

Table 7 : Benefit calculation of the concept, source: own representation (2016).

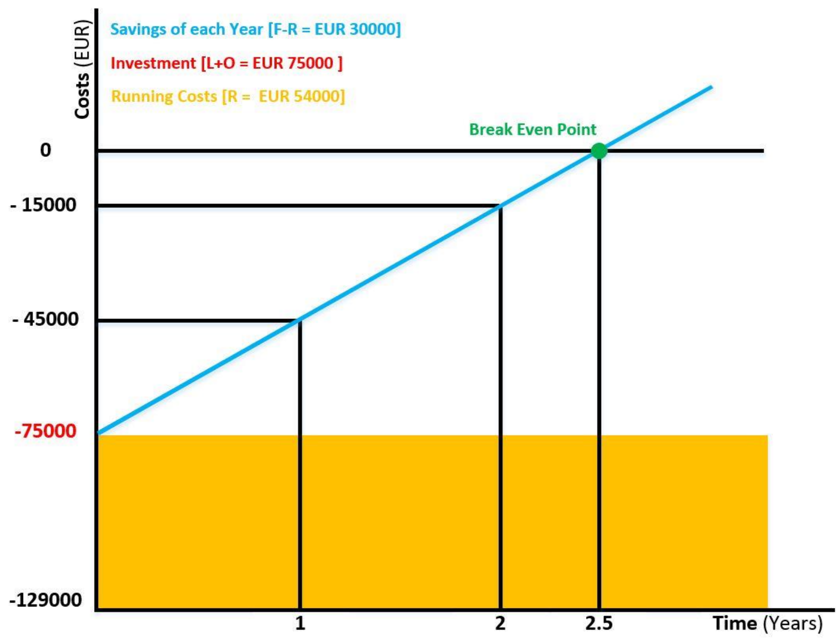


Table 8: Break even diagram of the benefit calculation, source: own representation (2016).

Conclusion of the Calculation

The used data for the calculation is the data of the year 2015 and 2016. All the used numbers regarding quality, rework and costs are taken out of quality reports at the company. To ensure data security for Wacker Neuson, only the required numbers of these reports are shown in the calculation above.

The figures of the calculation show a positive outcome. This calculation is an idealized one, because it was assumed that the whole production will be converted to this new system of work instructions at once. But this should happen step by step or rather machine type after machine type. According to that the savings will not be that high, but due to that also the resources costs are not that high. Considering that, the return of investment of about 2.5 years will attune as well if the concept will be implemented only partly at the beginning.

Some other issues can also distort the calculation slightly in the negative direction. This is for example a not considered ramp-up time for the whole system or a not mentioned theft of tablets, which could easily occur. There are of course also possible defaults like system failures or a not working software. Although, the calculated figures are positive and are able to absorb some negative issues, if the workers are open to work with this new system. The worst case regarding this fear would be a slightly longer return of investment.

4.4 Recommendation

To install this new system is a complex and expensive task, but if only the lower rework is considered, the return of investment can be realized in about 2.5 years. All the other benefits this system provides are not considered in the calculation before. The benefits are located in producing a better quality, enabling a better change management of work instructions, and ensuring better and actual work instructions without paperwork. Higher quality of the produced machines will lead to a better image of them on the market and improves customer satisfaction. This is worth a lot for the brand and the future sales of Wacker Neuson.

Now the change of work instructions at Wacker Neuson is a very time consuming and sometimes even an error-prone process. This leads to higher failures and costs in the production, which are caused by the higher administrative effort in the production planning department. At new and complex machines, the number of changes sometimes rises up to several changes a week. By changing the paper based instructions, sometimes failures occur if an old one is left on the work place and accidentally used by the workers. This problem can be eliminated too by implementing the shown concept. The issue regarding a very time consuming process to create the instructions and to keep them up to date or rather change them can also be reduced with this system. Therefore, a saving of costs in the production planning department regarding labor costs is possible too.

These advantages have to be considered in the decision finding process, although they cannot be calculated with defined numbers. But the positive facts will help to get a faster return of investment and a better sustainability in quality tasks, which is one of the most important influence factors for construction machines and the brand Wacker Neuson.

Therefore, the recommended concept should be implemented, beginning with new and complex machines, because these have the highest potential for savings. As considered in the time plan (chapter 4.3.7), it is the best solution to provide all new types of machines with this type of work instruction (see Figure 52, A12, A13), to ensure a uniform standard during the next years.

It can maybe last up to 10 years to implement this concept at each assembly line and for each type of machine, but also a partly implementation of it would bring a good benefit and can lead the company into the right direction in the near future.

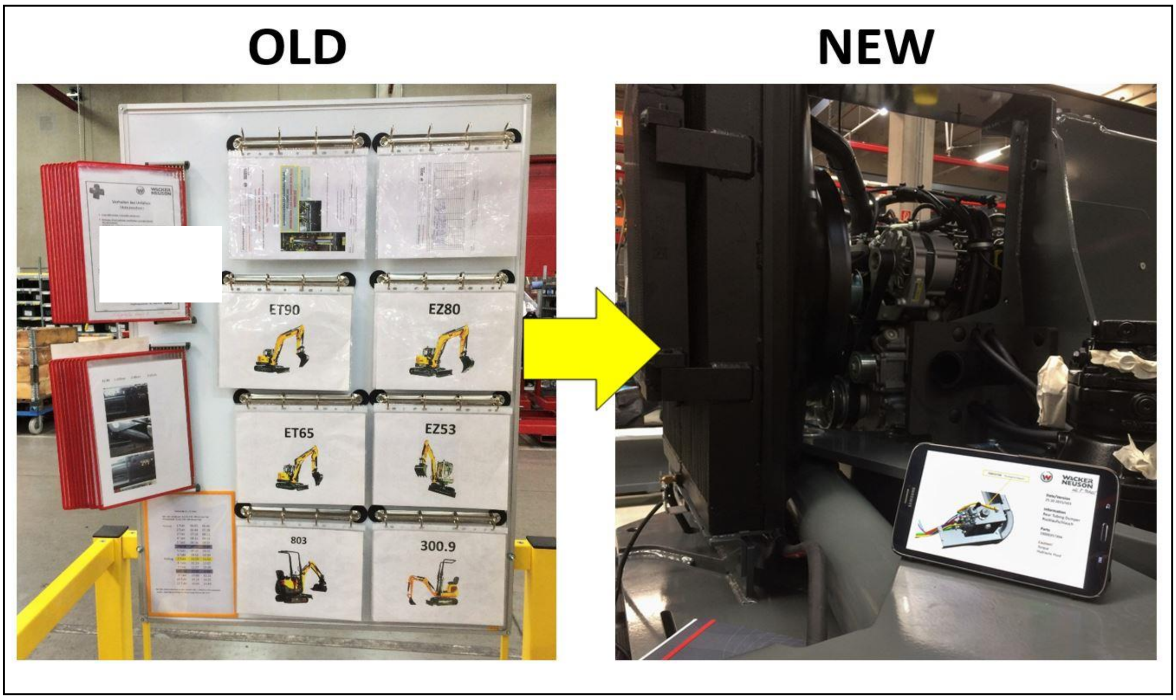


Figure 52 : Old and new work instruction, source: Wacker Neuson (2016), modified.

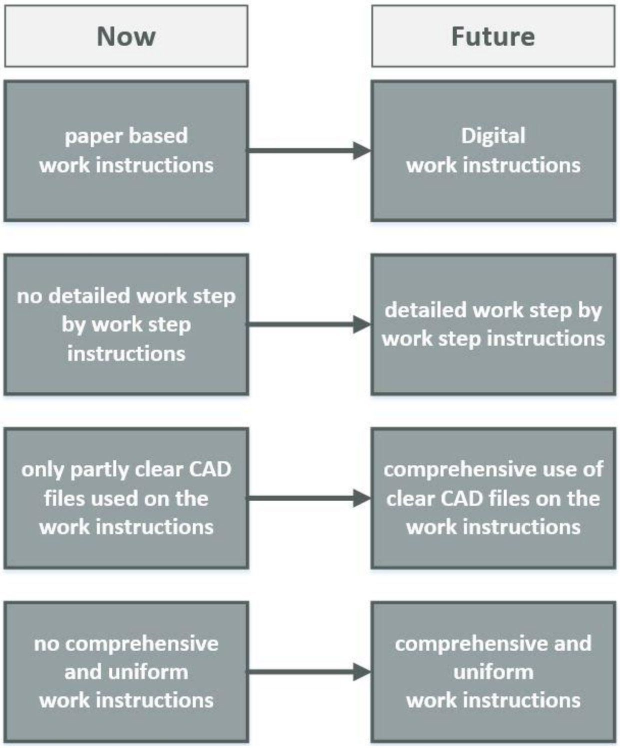


Figure 53 : Work instruction now and in the future, source: own representation (2016).

4.5 Benefits

The most important and possible benefits, which will arise if the concept is implemented are listed below. To get a good overview regarding financial aspects, they are divided into monetary and non-monetary benefits. This benefits should be seen as fundament for starting the concept at Wacker Neuson.

4.5.1 Monetary Benefits

These benefits should provide Wacker Neuson a financial advantage compared to the now available status quo of work instructions.

4.5.1.1 Directly Monetary Benefits

Directly monetary benefits should enable Wacker Neuson a directly and countable financial benefit after implementing the shown concept.

Lower Rework

Achieving lower rework often leads to better quality of the built products. This happens because a partly reassembled machine is often not that perfect than a machine, which does not need any rework. The reason for that are for example special tools on the assembly line, which enables the worker a perfect mounting. These tools are often not available at the rework department and therefore quality issues occur. The potential to save costs because of the lower amount of rework or rather extra work at a machine is quite high, like it is mentioned in the calculation before (see Chapter 4.3.9).

Savings at the Production Planning Department

The costs at the production planning department are to a large extend driven by creating work instructions for the assembly lines and to keep them up to date if changes at a machine occur. Due to the possibility of an automatic generation updating of these instructions, like the shown concept provides, the required workforce at this department can be reduced, which means a saving of costs. Another big advantage is, that the employees, who create instructions, do not have to take pictures of the machine because each part is provided virtual in a CAD file. Taking pictures requires also a lot of time by now, which can be easily saved.

Perfect Work Instructions

Having perfect instructions helps the production in many cases, like reaching the benefits mentioned above and also a better training of the workers is possible. Perfect instructions can enable a new worker to get faster used to the work. Also time savings can be realized, because the workers do not have to clarify uncertainties regarding old or bad work instructions.

4.5.1.2 Indirectly Monetary Benefits

Indirectly monetary benefits are very positive side effects of the direct monetary benefits listed above, but they also will entail financial benefits after having the concept running for some years.

Better Quality

One of the most important benefits is the higher achievable quality of the built machines. This higher quality can be achieved by the reason of less mistakes due to better work instructions on the assembly lines like it is also mentioned in chapter 4.4.

Achieving lower rework, like it is mentioned before, also often leads to better quality of the built products. This happens because a partly reassembled machine is often not that perfect than a machine, which does not need any rework. The reason for that are for example special tools on the assembly line, which enables the worker a perfect mounting. These tools are often not available at the rework department and therefore quality issues occur.

The better quality of the produced machines is directly connected to many other advantages, like a higher customer satisfaction or a better image of the brand regarding solid and robust construction machines.

4.5.2 Non-Monetary Benefits

These benefits will not bring a real financial benefit, but they can also be very important for the company.

Worker Satisfaction

The workers on the assembly line can profit a lot of these new kind of work instructions. For example, they do not have to struggle with old or incomplete instructions. The work tasks are often easier with clear and perfect instructions and therefore the worker do not need improvise.

Safety Issues

The safety of the work places at the assembly lines can be improved. Because with the new system it will be possible to show for example warning signs and clear symbols for wearing the required safety equipment directly on the work instruction.

Satisfaction of Company Visitors

Having excited visitors at the company because of a high technologized way of production is a benefit for the location in Hörsching. By extension there are also maybe high potential new employees, who like to work in such a modern work environment.

5 Conclusion and Outlook

At first, a literature research concerning Industry 4.0 and the topic work instruction was conducted to get an overview of these topics. Additionally to that, the research was extended to find possible solution for the given aims of Wacker Neuson. It has been shown that a system for paperless work instructions, which are generated and updated automatically, will be necessary to fullfill quality and productivity tasks. These tasks should also be able to realize if it is necessary to provide a lot of different variants of the produced machines in the future. In this case the generated knowledge about Industry 4.0 offers a good framework to act forward-thinking.

After the literature research, a maturity model of work instructions was created and customized for Wacker Neuson (see Figure 16, 17, 18). This model is divided into sixteen steps, reaching from “having no work instructions” up to “work instruction for a mass customization” with very individual products. The developed concept regarding better work instructions, is positioned in the maturity model between the status quo of “partly available work instructions" and the defined aim of the concept, which is an "automatic generation of work instructions".

The practical research is based on the maturity model and provides at the end the concept. This developed concept is beside the maturity model the main part of this thesis and contains apart from an implementation plan a cost-benefit-calculation as an economical part.

All machines in CAD, a uniform standard of work instructions, a detailed work plan and the required resources are the four main steps of it (see Figure 50). Having all parts (also small ones) of each machine completely as CAD data is necessary to link all parts with the used software for creating work instructions. A uniform standard of work instructions has to be customized for the used software. The detailed work plan should provide an exact planning of each single work step for assembling a machine. Therefore, also tiny screws and cables have to be considered. The required resources are divided into hardware and software components. Tablets on the assembly line as device to show the work instructions are chosen because they are very flexible. For the software, the program SAP Visual Enterprise was selected due to the good compatibility to the existing IT infrastructure, the possibility to create work instructions automatically and the suitability for future tasks (see Table 2).

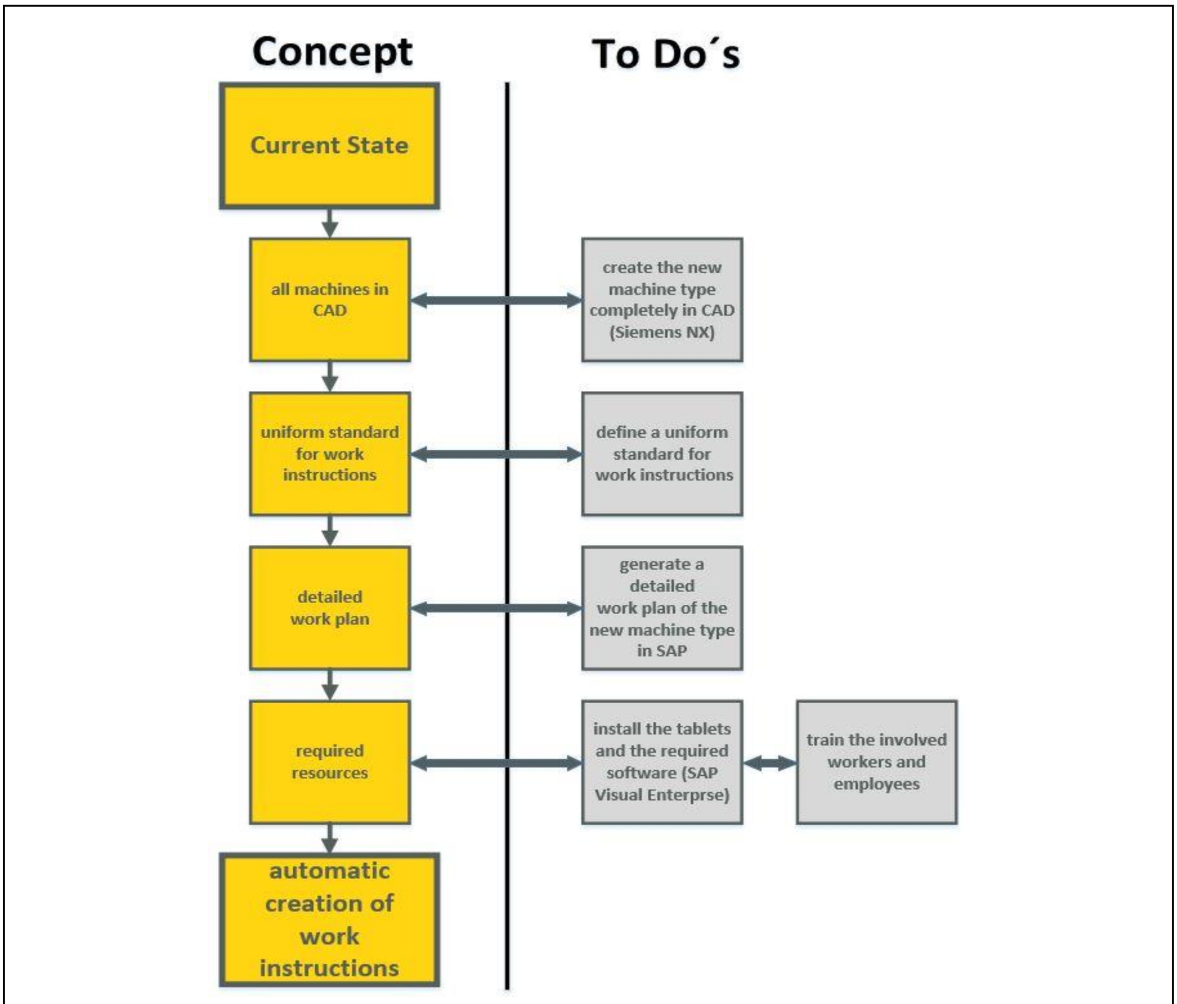


Figure 54 : Concept and implementation steps, source: own representation (2016).

After calculating the before mentioned economical part a return of investment of about 2.5 years and an estimated saving of about EUR 30,000 a year should be possible if the concept is fully realized (see Table 8).

Implementing the concept (see Figure 51, 54)) should start as soon as possible, beginning with the next new type of machine. This type has to be designed fully in CAD including the whole cable harness and also the whole tubing. Furthermore, all assembly steps have to be divided into a detailed work plan. For running the whole system, the required resources like tablets on the assembly line and the required software in the production planning department, have to be installed. After having fulfilled all further steps, the involved workers and employees should be trained well regarding all new features to be able to start the new system in a satisfying way.

At the end this thesis reflects a necessity to act in terms of changing the used system of providing work instructions on the assembly lines. To realize this concept like it is recommended in the thesis, all responsible persons should be convinced of it.

There are also possible threats regarding the concept, like a not working software or other system failures, which can occur easily at such a complex and IT based system. Also workers who are not satisfied with the new instructions could impair the work of the system.

Although, for the future it would be a good recommendation to equip the whole production with this new system. Moreover, further steps of the created maturity model of work instructions should be focused from the management. Not each step makes sense for the production of construction machines, but if the most appropriate ones are picked out, this model is a good framework for the future. Having the basis of a detailed work plan and digital work instructions once, the company has a perfect basis for the future and can build upon this state of the art technology.

To be generally fit for the future and able to grow or realize more variants of machines, the used technology in the concept is a required milestone. Otherwise, these future tasks will be very difficult to handle and the administrative work of creating work instructions will raise up to an almost unmanageable task.

Wacker Neuson is well advised to realize the shown concept. The management has to decide, whether this is done in smaller or bigger steps, but it would be great to start this project in the near future. All other tasks the thesis provides, Wacker Neuson can use for future decisions regarding the topic of work instructions in connection Industry 4.0.

6 References

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List of Figures

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7 Appendix

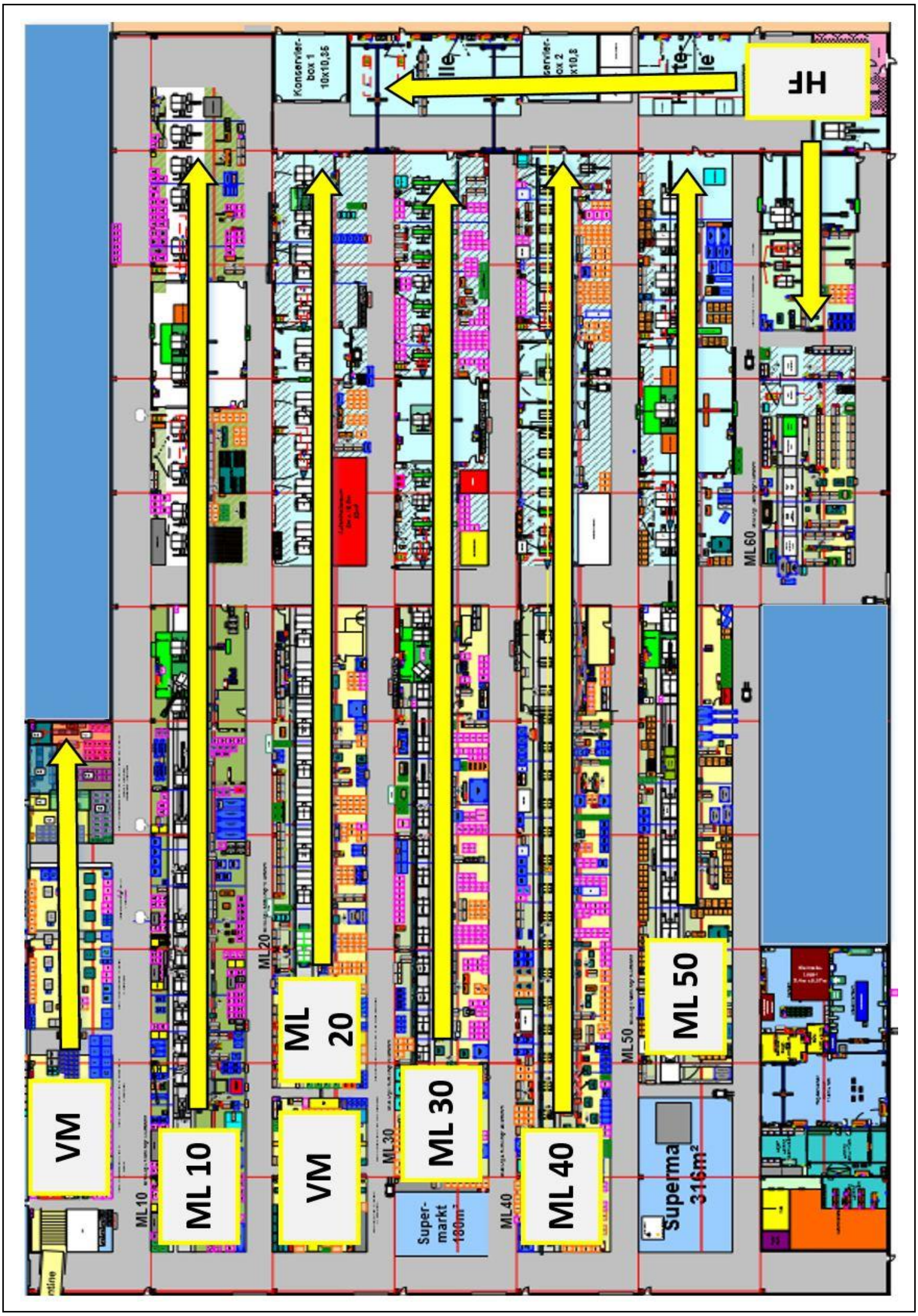


Figure A - 1 : Shop floor layout Wacker Neuson Linz GmbH, source: Wacker Neuson (2016)., modified

Figure A - 2 : Dumper assembly line at Wacker Neuson Linz GmbH, source: Wacker Neuson (2016)., modified

Figure A - 3 : Excavator assembly line at Wacker Neuson Linz GmbH , source: Wacker Neuson (2016)., modified

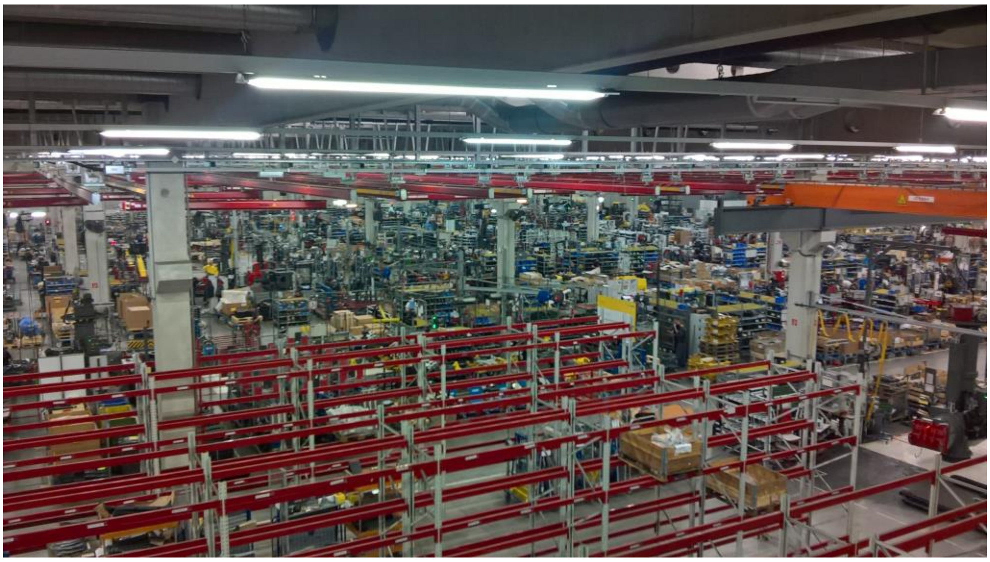
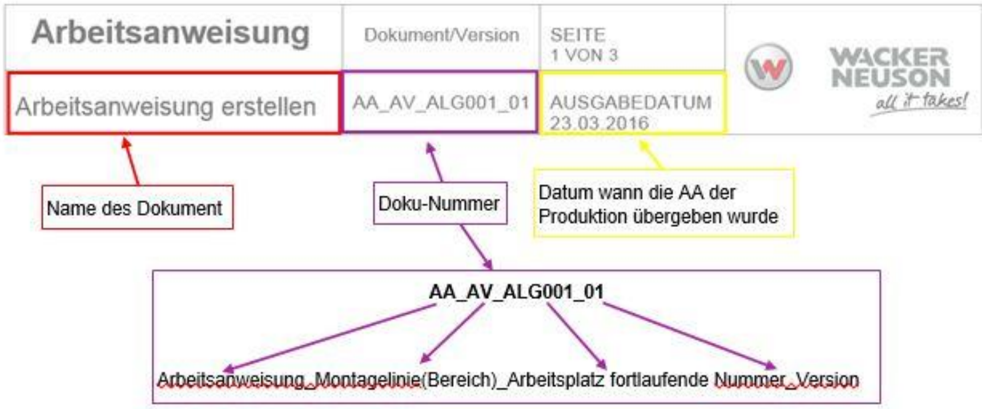


Figure A - 4 : Production hall at Wacker Neuson Linz GmbH,source:Wacker Neuson (2016).



Arbeitsanweisung	Dokument/Version	SEITE 1 VON 6	WACKER NEUSON all it takes!
Arbeitsanweisung erstellen	AA_AV_ALG001_01	AUSGABEDATUM 13.12.2016	

Arbeitsanweisung erstellen

Kopfzeile ausfüllen

Hinweise: keine Sonderzeichen im Namen oder der Doku-Nummer

1. ZWECK

Information über die Inhalte: Arial 10 pt, Text: Schriftart Zeilenabstand 1,5

2. DURCHFÜHRUNG

Text, BILDER

Inhalt AA:
Ziel der Tätigkeit soll aus Titel der AA (Name des Dokument) hervorgehen

1.Zweck:
Information über die Inhalte; ev. Ursache für AA (z.B. Übergangslösung)

2. Durchführung:
- Beschreibung Tätigkeit bzw. Arbeitsablauf -> Reihenfolge angeben wenn für Montage relevant
- Tabelle mit: Bauteile mit Referenzbezeichnung, Mat.-Nummer, Namen (wo sinnvoll), verbauter Menge und benötigtes Sonderwerkzeug
- Die Menge der angeführten Materialien auf einer Seite, ist im ermessen des Erstellers. Es muss jedoch sichergestellt sein, dass die durchzuführende Tätigkeit übersichtlich dargestellt wird.
- Qualität:
  Wenn relevant müssen eine oder mehrere dieser Symbole an der rechten Seiter der Abbildung in der unteren Hälfte und an der spezifischen Stelle in der AA eingefügt werden.
  a) Vorgaben: z.B.: Toleranzen — Vorgaben… V
  b) Hinweise: z.B.: Achtung Beschädigung oder Fehlfunktion möglich — Montage…. M

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Figure A - 5 : Standard of work instructions at Wacker Neuson Linz GmbH p. 1, source: Wacker Neuson (2016).

Arbeitsanweisung	Dokument/Version	SEITE 2 VON 6	WACKER NEUSON all it takes!
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c) Beeinflusst die Sicherheit zur Bedienung der Maschine Kunde.......

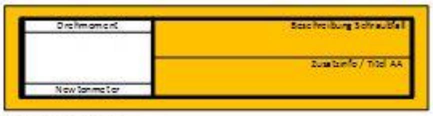
- Sicherheitsrelevant
  Wenn relevant müss diese Symbol an der rechten Seiter der Abbildung in der unteren Hälfte und an der spezifischen Stelle in der AA eingefügt werden.

  Verletzungsgefahr für Mitarbeiter: Sicherheit...

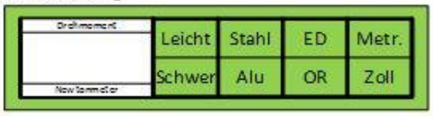
- Abbildungen zur Beschreibung der Tätigkeit in folgender Prio:
  a) CAD Zeichnungen
  b) Baugruppen Zeichnungen
  c) Fotos
  d) dif. andere Zeichnungen und Abbildungen

  Abbildung muss alle zu montierenden Komponenten in der beschriebenen AA darstellen. D.h. nur jene Punkte aufführen die in der Abbildung sichtbar sind (wenn nötig eine weitere Abbildung einfügen).
  Wenn notwendig zuerst eine Überblicksdarstellung und im Folgenden die Einzeltätigkeiten beschreiben. In der Überblicksdarstellung soll die Montagereihenfolge als auch Referenzbezeichnungen enthalten sein. Diese Referenzbezeichnungen muss in der Detailbeschreibung weitergeführt werden.

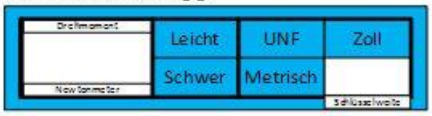
- Drehmomente:
  Kennzeichnung mit Aufklebesystem wenn Drehmoment nötig.
  e) Sonderverschraubung:



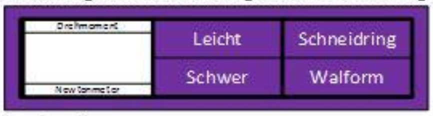
  f) Einschraubung:



  g) Schläuche:
  Blauer Aufkleber für Standarddrehmoment bei Schläuchen wird nicht verwendet da hier Drehmoment schlüsselweitenabhängig.



  h) Rohrleitung bzw. Sonderanzugsmoment bei Leitungen:



  i) Verschraubung:

Erstellt:	Freigabe:	Ersetzt Dokument
		AA_AV_ALG001_00

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Figure A - 6 : Standard of work instructions at Wacker Neuson Linz GmbH p. 2, source: Wacker Neuson (2016).

Arbeitsanweisung	Dokument/Version	SEITE 3 VON 6	WACKER NEUSON all it takes!
Arbeitsanweisung erstellen	AA_AV_ALG001_01	AUSGABEDATUM 13.12.2016	

Drehmoment	Metrisch	8.8	12.9
Normformatior	Fein	10.9	

Bezeichnungssysem mit dieser Kennzechnungen ist in seperaten Arbeitsanweisung beschrieben.
Material mit Aufkleber an Schüttenplatz kennzeichnen und Drehmomentschlüssel damit ausrüsten. Somit kann vom Material am Arbeitsplatz auf den richtigen Schlüssel geschlossen werden. Bei Komm-Wagen keine Bezeichnung am Lagerort möglich, daher Hinweis in AA!

Ziel AA:
Sollzustand der Bauteile
Leicht verständlich die Vorgehensweise definieren
Unterstützung für Einschulung
Gedächnishilfe
Sicherheit und Qualität gewehrleisen
AA weisen einen durchgehenden Standard auf.

Umfang der AA:
Der Umfang einer AA darf nicht durch Linebalancing(an andere Arbeitsplätze) trennbar sein.
Sollte die Tätigkeit einer AA durch Linebalancing auf verschiedene Arbeitsplätze verschiebbar sein, so muss diese in zwei oder mehr Arbeitsanweisungen aufgeteilt werden.

Bei Freigabe prüfen durch Technik der:
Plausibilität
Tätigkeiten bzw. Arbeitsabläufe
Materialien
Anzahl der verbauten Materialien

Freigabe: jede AA muss durch Technik freigeben werden!

Wichtig: **Jedes Word Dokument komprimieren um Speicherplatz zu sparen!!**

Fußzeile ausfüllen

Erstellt:	Freigabe:	Ersetzt Dokument
		AA-[...] vom [...]

Ausgedruckte Versionen unterliegen nicht dem Änderungsdienst

Name des Erstellers (keine Kurzzeichen)

Name des Technikers (keine Kurzzeichen)

Bei Änderung einer AA – altes Dokument eingeben

Freigegebenes Word Dokument unter:

E:\Production\Production\ARBEITSTECHNIK\Arbeitsanweisungen\Dokumentenstruktur_Neu\---Arbeitsanweisungen_not_to_be_changed

Erstellt:	Freigabe:	Ersetzt Dokument
		AA_AV_ALG001_00

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Figure A - 7 : Standard of work instructions at Wacker Neuson Linz GmbH p. 3, source: Wacker Neuson (2016).

Arbeitsanweisung	Dokument/Version	SEITE 4 VON 6	WACKER NEUSON all it takes!
Arbeitsanweisung erstellen	AA_AV_ALG001_01	AUSGABEDATUM 13.12.2016	

Im dazugehörigen Ordner der Linie und Unterordner des Arbeitsplatz unter dem vollständigen Namen der Kopfzeile speichern. Die den Bauteilen (aus der Arbeitsanweisung) übergeordnete Baugruppe muss im Dokumentennahmen angegeben werden.
Der **Dokumentenname** soll wie folgt aufgebaut sein:
Arbeitsanweisung_Montagelinie(Bereich)_Arbeitsplatz fortlaufende Nummer_Version_Name Arbeitsanweisung (BG-Nummer der übergeordneten Baugruppen)

Beispiel zur Bezeichnung des Dokuments:
AA_ML20_FWB_00_Schott-Verschraubungen (BG-1000324612 BG-1000325313).doc

Aus dem gespeicherten Word Dokument ein PDF erstellen und unter:

E:\Production\Production\ARBEITSTECHNIK\Arbeitsanweisungen\Arbeitsanweisungen PDF

Wieder im dazugehörigen Ordner der Linie und Unterordner des Arbeitsplatz unter dem vollständigen Namen der Kopfzeile speichern. Sie Dokumentenname wie oben beschrieben.

Mitarbeiter in der Montage haben nur auf die PDF Ordner Zugriff!!

Info: Arbeitsanweisungen die der Werksgültigkeit entsprechen und/oder für mehrere Bereiche gelten gehören unter dem Ordner/Struktur **Werksgültigkeit** abgelegt und an alle Bereiche in der sie gelten ausgeteilt!

Bei Änderungen einer Arbeitsanweisung – das Original nicht verändern – immer eine neue Version erstellen und alte Version ins Archiv verschieben!

Ablegung/Lenkung der Arbeitsanweisung

Pfad Dokumentstruktur – liegt im Unterordner der jeweiligen Montagelinie

E:\Production\Production\ARBEITSTECHNIK\Arbeitsanweisungen\Dokumentenstruktur_Neu\---Arbeitsanweisungen_not_to_be_changed

Erstellt:	Freigabe:	Ersetzt Dokument
		AA_AV_ALG001_00

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Figure A - 8 : Standard of work instructions at Wacker Neuson Linz GmbH p. 4, source: Wacker Neuson (2016).

Arbeitsanweisung	Dokument/Version	SEITE 5 VON 6	WACKER NEUSON all it takes!
Arbeitsanweisung erstellen	AA_AV_ALG001_01	AUSGABEDATUM 13.12.2016	

Ausfüllanleitung der Dokumentstruktur:

Doku-Nummer von Kopfzeile

Name des Dokument(soll identisch mit Kopfzeile sein)

Version

Für welchen Typ die AA gilt.

Dokumentenstruktur Arbeitsanweisungen
ML 10

ML 10

				Typenverwendung									
Arbeitsplatz	Doku-Nummer	Titel Arbeitsanweisung	Version	803	300.90	50z3	EZ53	6003	ET65	75z3	8003	EZ80	ET90
Fahrwerksbau													
	AA_ML10_FWB001	Vormontage DDF 8003	V01								x		
	AA_ML10_FWB002	Vormontage DDF 50z3 VDS	V01			x							
	AA_ML10_FWB003	Vormontage DDF 75z3	V01							x			
	AA_ML10_FWB004	Vormontage DDF 6003	V01					x					
	AA_ML10_FWB005	Vormontage 50z3	V01			x							
	AA_ML10_FWB006	Drehkranz Montage	V01			x		x		x	x		
	AA_ML10_FWB007	Drehkranz einstellen	V01			x		x		x	x		

Schulungsnachweis muss von Mitarbeiter unterzeichnet und dann archiviert werden. Im Ordner der AA!

Erstellt:	Freigabe:	Ersetzt Dokument
		AA_AV_ALG001_00

Ausgedruckte Versionen unterliegen nicht dem Änderungsdienst

Figure A - 9 : Standard of work instructions at Wacker Neuson Linz GmbH p. 5, source: Wacker Neuson (2016).

Schulungsnachweis	Dokument/Version	SEITE 6 VON 6	WACKER NEUSON all it takes!
Arbeitsanweisung erstellen	AA_AV_ALG001_01	AUSGABEDATUM 13.12.2016	

Mit der Unterschrift bestätigt der/die Mitarbeiter/in, dass Er/Sie die Unterweisung/Schulung verstanden hat bzw. bei Unklarheiten nachgefragt hat. Des Weiteren verpflichtet sich der Mitarbeiter/in die vorgegebenen Punkte einzuhalten. Auffälligkeiten, Abweichungen zu den Vorgaben in der Arbeitsanweisung und zur Umsetzung in die Praxis werden umgehend gemeldet.

Unterschrift der Beteiligten						Wirksamkeitsprüfung der Schulungsmaßnahme		
	Personalnummer	VORNAME	NACHNAME	Datum	Unterschrift	Name Verantwortlicher	Ja	Nein
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
14								
15								

Nach 3 Wochen ist eine Wirksamkeitsprüfung vom Verantwortlichen durchzuführen!

Erstellt	Freigabe:	Ersetzt Dokument
		AA_AV_ALG001_00

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Figure A - 10 : Standard of work Instructions at Wacker Neuson Linz GmbH p. 6, source: Wacker Neuson (2016).

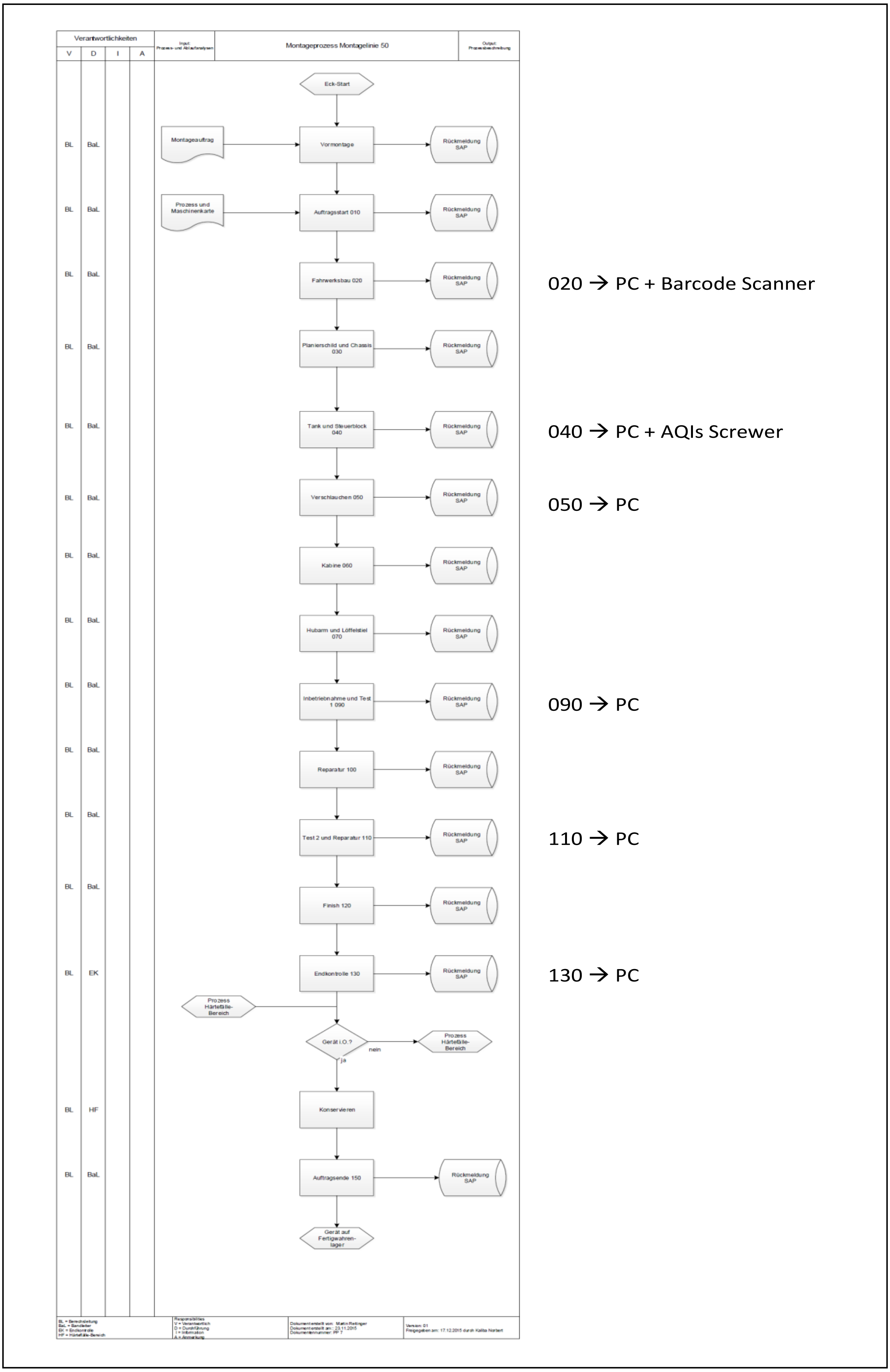

Figure A - 11 : PCs on the assembly line ML50 , source: Wacker Neuson (2016)., modified

Figure A - 12 : Status quo work instructions, source: Wacker Neuson (2016)., modified

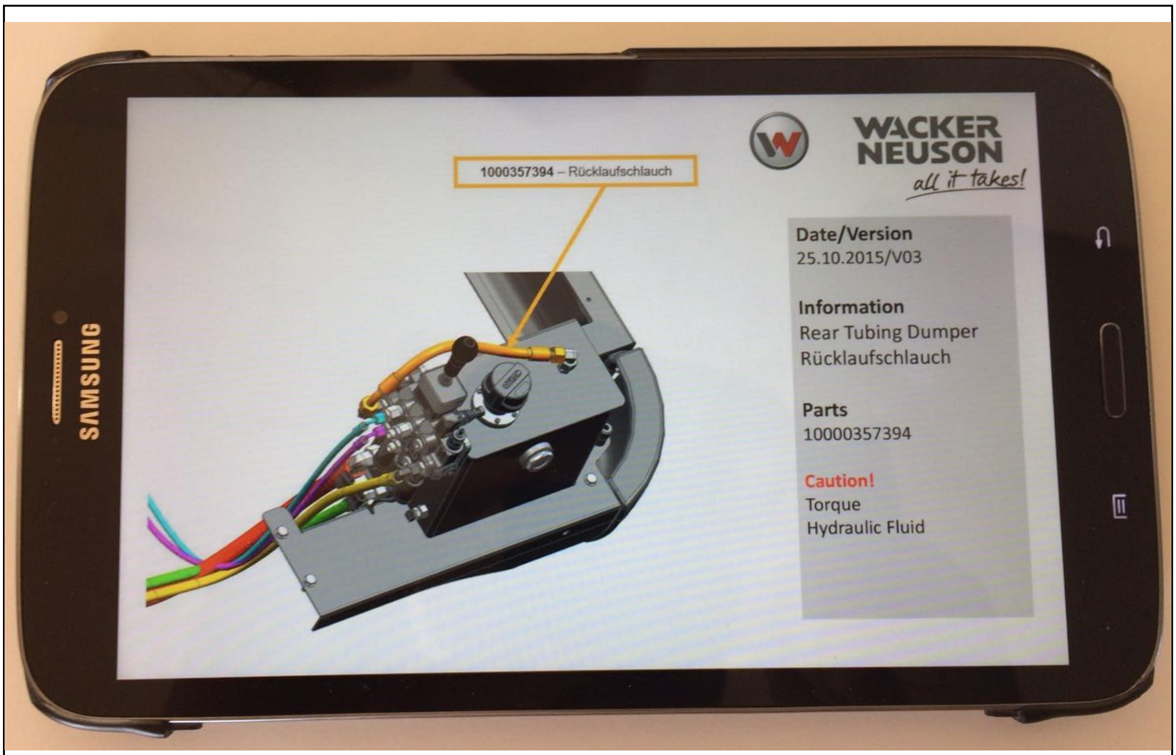

Figure A - 13 : New concept of digital work instructions, source: Wacker Neuson (2016)., modified