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Masterarbeit

Bardia Emad

Operational scenarios that implement Industry 4.0 by utilizing UAVs

Fakultät Technik und Informatik
Department Maschinenbau und Produktion

Faculty of Engineering and Computer Science
Department of Mechanical Engineering and Production Management

Bardia Emad

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University of Technology Sydney
Faculty of Engineering and Information Technology
Building 11, 81 Broadway
Ultimo NSW 2007

Erstprüfer: Prof. Dr.-Ing. Hans-JoachimSchelberg
Zweitprüfer: Prof. Dr.-Ing. Bernd Sankol

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Zusammenfassung

Bardia Emad

Thema der Masterthesis

Operational scenarios that implement Industry 4.0 by utilizing UAVs

Stichworte

Industrie 4.0, Smart Factory, IoT, CPS, Big Data, Tecnomatix Plant Simulation, UAV

Kurzzusammenfassung

Ein operatives Szenario in der Produktion wird nach einer umfassenden Überprüfung der Fallstudien von Industrie 4.0 und unbemannten Luftfahrzeugen (UAVs) erstellt. Tecnomatix Plant Simulation wird eingesetzt, um einen Algorithmus zu simulieren, in welcher die Kommunikation zwischen Endgeräten demonstriert und eine dynamische Auswahl für Produktionsprozesse in welchem zeit- und kostengünstigen Aspekten ermöglicht.

Diese Arbeit beinhaltet des Weiteren ein Produktions-Layout, das die wichtigsten Vorteile der Nutzung von UAVs visualisiert und im Anschluss bewertet. Dabei werden gezielt Risiken bei der Interaktion zwischen Mensch und Maschine aufgezeigt und im Anschluss mögliche Lösungsvorschläge ausgesprochen.

Bardia Emad

Title of the paper

Operational scenarios that implement Industry 4.0 by utilizing UAVs

Keywords

Industry 4.0, Smart Factory, IoT, CPS, Big Data, Tecnomatix Plant Simulation, UAV

Abstract

An operational scenario in production will be created after a comprehensive review of Industry 4.0 and unmanned aerial vehicles (UAVs) case studies; Tecnomatix Plant Simulation will be employed to simulate an algorithm that demonstrates the machine to machine communication and provides a dynamic selection for production processes in a time and cost efficient manner.

This thesis will also provide a production layout that addresses the main advantages of utilizing UAVs and subsequently evaluates them. Based on this, specific risks are shown in the interaction between man and machine and possible solutions suggested.

Abstract

Industry 4.0 is the current trend of automation and data exchange in manufacturing technologies. It combines modern production methods and communication technologies in real-time that anticipate significant improvements in all aspects of manufacturing processes. Industrial companies expect to become "Smart Factories"; however reorganization risks and machinery cost may defer or create resistance to the implementation process.

An operational scenario in production was created after a comprehensive review of Industry 4.0 and unmanned aerial vehicles (UAVs) case studies; Tecnomatix Plant Simulation was employed to simulate an algorithm that demonstrates the machine to machine communication and provides a dynamic selection for production processes in a time efficient and cost effective manner.

This thesis will also provide a production layout that addresses the main advantages of utilizing UAVs including:

- Faster transportation of goods by creating aerial fly zones
- Decreasing ground activities
- Increase flexibility in replacement of product parts
- Detect inefficient or hazardous work flow of operators and machinery
- Maintenance assistant: Support providing tools
- Inspection of inaccessible areas

This production layout demonstrates the concept of utilizing UAVs in production processes that can resolve organizational and technological challenges of Industry 4.0, however, occupational safety for human machine interaction needs to be considered. This approach classifies risks through benefit analysis and provides examples of solutions. This thesis concludes with a foundation targeted towards implementation concepts for Industry 4.0 that utilize UAVs in production processes. Although, further research is necessary to investigate the complexities of the Industry 4.0 trend.

Acknowledgement

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List of Abbreviations

AGV – Automatically Guided Vehicles

AR – Augmented Reality

BITKOM – Bundesverband Informationswirtschaft, Telekommunikation, neue Medien e.V

BSI – Bundesamtes fuer Sicherheit in der Informationstechnik

CBA – Cost Benefit Analysis

CeBIT – Zentrum fuer Bueroautomation, Informationstechnologien &Telekommunikation

CEO – Chief Executive Officer

CPS – Cyber Physical Systems

FAA – Federal Aviation Administration

FR – Financial Risk

GPS – Global Position System

HR – Human Risk

IaaS – Infrastructure as a Service

IoT – Internet of Things

IP – Internet Protocol

ITU – International Telecommunication Union

MTOW – Maximum take-off weight

NFC – Near-Field Communication

NIST – National Institute of Standards and Technology

NMI – Nautical mile

OEE – Overall Equipment Efficiency

PaaS – Platform as a Service

RFID – Radio Frequency Identification

RPAS – Remotely Piloted Aircraft Systems

SaaS – Software as a Service

UAV – Unmanned Ariel Vehicles

VDI – Verein Deutscher Ingenieure

VDMA – Verband Deutscher Maschinen-und Anlagenbau

1 Introduction

The 21st century has seen the rise of modern day technocratic revolution. Throughout the course of time, industries have resorted to employing machines to undertake workload that is more likely to be considered hazardous or relatively inefficient when compared to manual (human) labour. This kind of implementation of newer technologies works well to negate man-made errors as well as aid in effective resource management. Industry 4.0 is the beginning of a new era of 'smart' solutions; technologies that can be integrated with everyday industrial applications and have the ability to calibrate from feedback. The purpose of this thesis is to design, illustrate and implement an algorithm to cater to machine to machine communication, the basis of industry 4.0. The algorithm facilitates machinery to be able to report on its current status, operating with a sequence of feedback based on true or false conditions. This decision in turn positively decreases production flow time and paves way for dynamic, autonomous functioning of industrial equipment. These 'smart' units are also capable of tackling unpredictable or random events, should there be any.

Logistics forms an integral part of resource handling and it becomes vital to evaluate its specifics. The algorithm can be further illustrated by means of the Tecnomatix Plant Simulation, a software that allows simulation of factory environments, implementation of creative design, time warping and critical analysis of details that are more difficult to study in practice. The results are acquired in the most time and cost effective manner.

Additionally, the thesis focuses on introducing Unmanned Ariel Vehicles (UAV's) to better manage intralogistics. Arial transportation paves the way to a spectrum of opportunity, especially in this regard. The plant layout for implementation, mechanics and operational flow is explained in detail. As is in all cases, there are a variety of merits and demerits in such a 'smart' system integration. This information is discussed and documented. Based on the review of literature, the use of UAVs has proven to reduce cumulative production time, delivery time, and loss of resource or labour and is even capable of autonomous selection of the best possible delivery route. It does, however, entail the low probable risk of collision due to air traffic and has a relatively low weight bearing capacity. To assist the accurate estimation of the likelihood and degree of a fault in design, a risk analysis is performed and tabulated. It provides details regarding the safety of the workplace and workforce, standards, precautions and prevention.

The current scenario for intralogistics, transportation and handling of good or services remains primitive, there is no significant development or in-plant administration of UAVs. Industry 4.0 in conjunction with the systematic application of UAVs can successfully contribute to a breakthrough in industrial customization.

1.1 Aim

To design a concept of 'smart' utility and a framework of algorithms to effectively implement Industry 4.0 and to introduce the use of Unmanned Ariel Vehicles to perform transportation and handling of intralogistics under consideration of occupational health and safety.

1.2 Objective

Develop a layout of technical algorithms for industry 4.0 by utilizing Tecnomatix Plant Simulation software. In conjunction with the Benefit Analysis method to perform a detailed risk analysis.

1.3 Thesis Outline

The following Figure 1 visualize the approach of the elaboration.

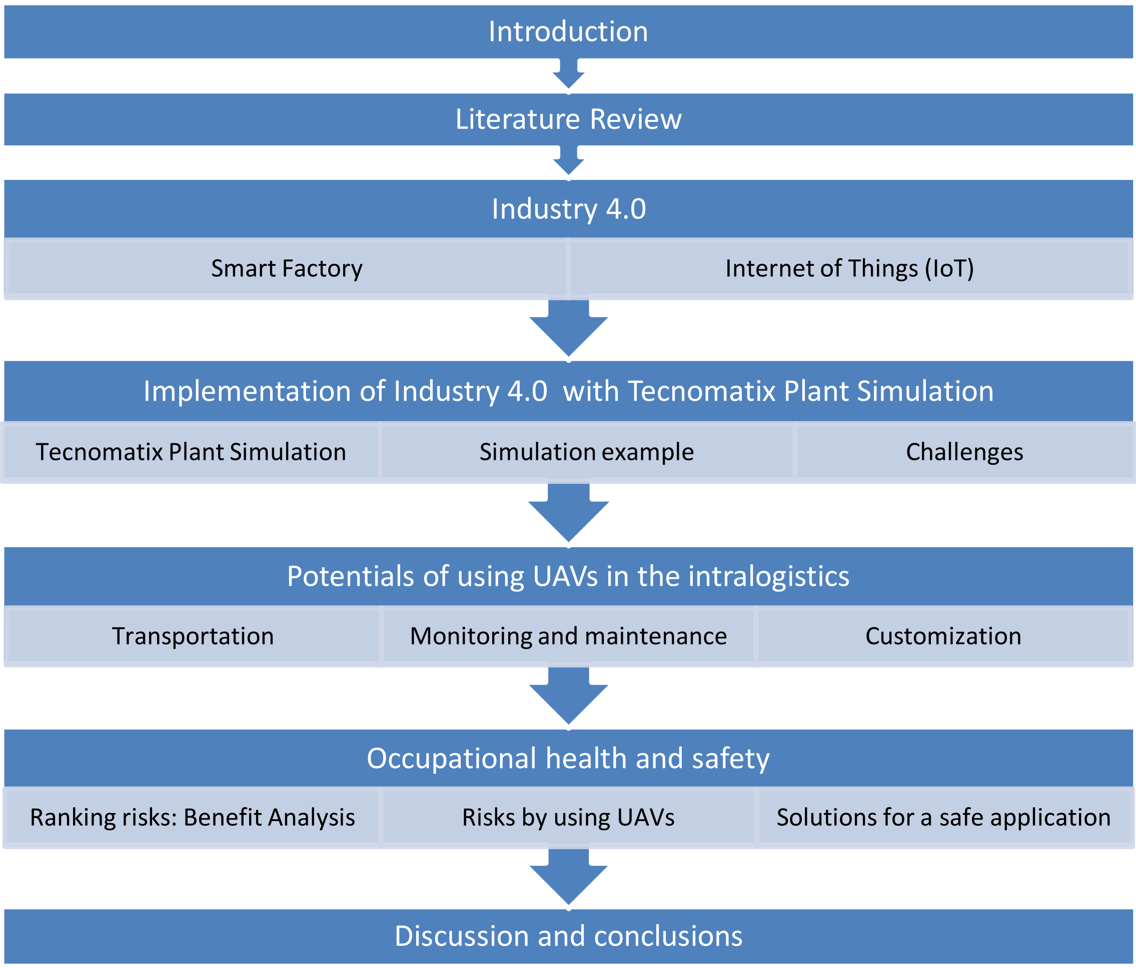

Figure 1: Thesis Outline

This thesis provides an introduction to the main topic under study. The relevance of the work and the driving force behind the concurrence of Industry 4.0 and UAVs is elucidated.

In the following second chapter, the utility of UAVs with references from a wide range of literature is presented.

The third chapter provides detailed theoretical support and information regarding access to online resources, cyber systems and smart factories. A recount of industrial history and its evolution is briefly explained. Newer applicable technologies for industry 4.0 are listed for reference.

Chapter four describes the Tecnomatix Plant Simulation software employed to execute the algorithms. The layout of the project is developed and the construction of the algorithm is shown with examples. A brief assessment of the challenges that may interfere with implementing Industry 4.0 is presented and an interim conclusion provides a concise report of the chapter.

The focus in the fifth chapter is an introduction to UAVs and provides different perspectives with regard to complexities of the UAVs are discussed. Based on the study of information presented in previous chapters, further data regarding the ease of the integration of UAVs in industry 4.0 is described. The visual of the proposed plant layout that utilizes the Tecnomatix Plant Simulation is tried, tested and recorded. The apparent advantage of using a simulation software is enumerated.

Chapter six provides details pertaining to data security, probable risks associated with the practical application of industry 4.0 and its critical analysis. Possible solutions are discussed.

The seventh chapter of this thesis summarises the acquired cumulative data and the corresponding results. It also presents an outlook to alternative situations and provides ideal recommendations.

2 Literature Review

Some studies about UAV's ability/capacity to deliver goods or human beings as a transportation system have been published. In addition, the use of UAVs in taking pictures at high altitudes or hard to reach areas as part of the surveillance is widely acknowledged. In this scenario, the UAV operates exclusively outdoors. Aside from the Audi Inc. research (pilot program) there is no further research about using UAVs in intra logistics.

Many companies are implementing Industry 4.0 in their production, but only a minority plan to do so in combination with UAVs.

The focus of this literature research is to find different sources that combine two aspects, for the factory of the future. The following sources are a selective few and therefore the list is not exhaustive. The basic concept for design of the environment in unison with the knowledge gained from the literature contribute to an ideal representation. This is a concept that integrates the use of UAVs as part of a Smart Factory to realize industry 4.0 and maximize its benefit.

There are sources that provide ideas for a benchmark of concepts. The following sources are listed, starting with the most significant one. For a better overview, at the end of this chapter, the pros and cons as well as the utilization of UAVs and Industry 4.0 is given in the form of a table.

Source 1: Express UAVs: Through the air (Audi Media Center) [1]

Due to infrastructural issues such as short of space or delivering issues such as re-ordering and the express delivery of goods, the company Audi Inc. is looking for a solution by using UAVs.

The company tested the UAV for intra logistical transportation of goods at Ingolstadt, Germany. On most occasions, the electric powered UAV flew straight on an earlier programmed testing ground through the production hall A3/Q2. To simulate unexpected circumstances, the direction was changed twice successfully. For safety reasons, the UAV was designed with four enclosed propeller systems. Additionally, the project was conducted on public holiday. The following Figure 2, shows the UAV carrying a wheel.

Figure 2: Transportation of a wheel for intralogistics by the UAV [1]

The most challenging part of the test is to manoeuvre without a GPS signal in an automotive factory. The safety regulations are especially high. Furthermore, the divisions: logistic, assembly and occupational safety have their own needs for aerial delivery.

The test was operated by specially trained pilots via remote control. Currently, an exclusive intelligent sensor is developed for the automotive industry and will support the needs of orientation. At first, the UAV will fly at 2.2 meters per second, which is similar to the speed of floor-borne vehicles.

Other important test projects towards a Smart Factory are camera-based UAVs for maintenance, the “follow me” function for trucks on the factory premises and high speed transport of a defibrillator for first aid.

Source 2: The drone start-up targeting oil and gas industry picks up another $5.7M (Sky-Futures) [2]

The company Sky-Future has been awarded by passing the most comprehensive SGS RPAS Safety & Compliance verification in the drone industry. SGS is the leading inspection, verification, testing and certification for oil and gas companies in the world. The company has 85,000 employees. Their clients include; Statoil, Shell, Total, BP, Maersk, and ConocoPhillips. This shows the huge market for the use of UAVs. [2]

However, what are the advantages of using UAVs instead of other devices? The most important advantages are listed below:

1. Inspection during a running process
2. Low pre and post-treatment processing
3. Video transfer in real time

4. Data can be used for a documentation
5. UAVs will be controlled by remote from the ground and are equipped with a live zoom function
6. Direction can be changed in real time by purchaser
7. Short testing cycles and low maintenance costs
8. Flexibility in testing of any technical constructions

Industrial constructions and artificial structures such as bridges, wind powered plants, power stations and factories require a high security standard. Therefore, maintenance in short intervals is the only option to guarantee safety. These facilities are more often built primarily focusing on function, thus, regular inspections could prove to be quite challenging. In these circumstances, professional UAVs equipped with sophisticated devices can inspect huge buildings and greatly aid companies in site maintenance. The ability to influence the UAV in real time makes it a valuable investment for inspections. The video material for a more detailed documentation is available. [3]

Source 3: Developer & Manufacturer of Flying Robots and UAV for Professional use (Airborne Robotics) [4]

For the inspection of an electrical tower two people are needed to guarantee the safety specification. Climbing such a tower can be risky and an expenditure of time. Sometimes helicopters are used. Similar to the check started from the ground, two people are needed. The costs for a helicopter hour are about 1,000 Euro (without including the cost of the crew).

The company Airborne Robotics specialised there AIR6 UAV with the possibility of equipping a camera with 12 to 80 megapixels, to take pictures in high quality even if they are greatly magnified. The following Figure 3 show the use of the AIR6.

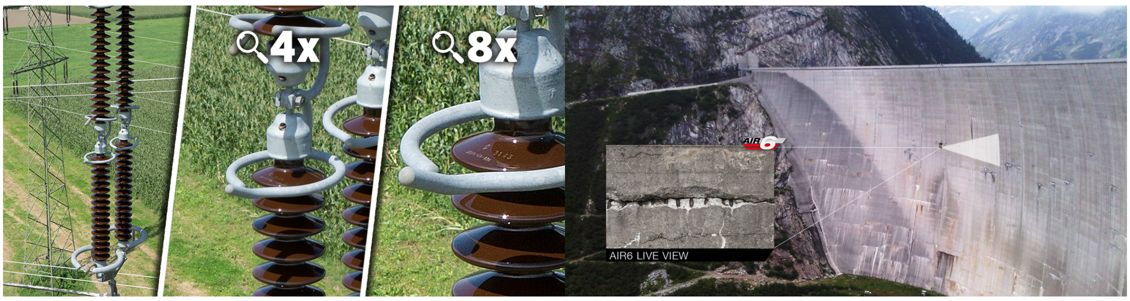

Figure 3: Magnified pictures of a transmission line and a barrage inspection by using a UAV.

The following Table 1 shows an overview of the frame conditions in which it can be used.

Table 1: Conditions for the Air6 UAV for inspection and maintenance

AIR6 UAV					
Max. load	Max. total weight	Max. flight time	Max. wind speed	Max. speed	Battery swap
2.2lbs (1kg)	11lbs (5kg)	18 minutes	22mph (35kph)	31mph (50kph)	Change in 30 second

The AIR6 can be controlled remotely with a DC16 as shown in the Figure 4 or flight autonomous after an aerial programmed in a GEO map.

Figure 4: Remote DC16 to control the UAV

The airlines EasyJet plans to use UAVs for the inspection of their Airbus planes too. Chef engineer Ian Davies explains the use of laser technology to check the surface of the body. Also UAVs can work at high altitude while workers have to use a ladder or a scaffold which is more dangerous.

Source 4: Self-flying taxi to transport passengers in Dubai (Ehang) [5]

Within this year, the technological improvements of UAVs become an interesting and realistic alternative solution to move goods and even humans.

In Dubai the Ehang 184 Drone was tested successful on February 20, 2017 and will start to autonomously transport one passenger and their bag with a weight up to 100 kg for up to 23 minutes, by July 2017. With a range for about 50 km and a high speed of 100 kph it is perfect for the intercity transportation. To call for a flying UAV taxi passengers have to enter their destination into an app. The taxi will fly by and pick up the passengers. On a screen it maps the destinations and hops from one set landing spot to another. To fit in a single car parking space, its propellers fold inwards, as shown on the right side of Figure

5. When it comes to the security question: Engineers have implemented a “fail safe” system. According to the company, in case of disconnection and malfunctions the UAV is prompted to the nearest place to land. Also the communication is via encrypted channels.

Also Las Vegas announces such plans. The following Figure 5 visualizes the UAV and gives an overview about the key parameters.

Figure 5: The Ehang 184. The propellers fold to fit in parking spots (right image)

The control unit will be a Tablet, as it is shown below in Figure 6.

Figure 6: Control pad which is installed inside the UAV

With the technological improvement, in 2013 Amazon CEO Jeff Bezos announced that packages will be delivered in the future with UAVs. The project is called Prime Air. The first known delivery with a Package drone has taken place on December, 2016. [6]

The Amazon Prime Air UAV is a helicopter and airplane hybrid of sorts. It can top an altitude of 100 meters and is capable of hitting speeds near 100 kph. After every delivery, the UAVs have to return for recharging. Since the idea is in its infancy, the current use will be limited for emergencies only. But as soon as the cost is brought to an acceptable level, there will be many flying postal helpers in the air.

Amazon designed more than a dozen different types of UAVs. Each is specialized for different environments. Depending on the needs, the range varies and so does the ability to carry a package's size. The maximum weight that can be carried is limited to five pounds (2.2 kg).

The idea is to have a helipad, which is declared as a delivery zone. This makes deliveries difficult / challenging for members of a flat or tower block. The UAV will stay out of the way of aircrafts, birds and other airborne obstructions. It is able to dodge by using integrated cameras and sensors. Amazon calls it their "sense and avoid" technology.

Delivery times between 3 to 5 days is already a practice of the past. A lot of companies forward goods on the next or even on the same day. In major cities Amazon offers a 1-hour service. By using UAVs, the delivering time could be reduced to 30 minutes, even in smaller cities.

An App will ask to clear (prepare) the delivery zone and counting down the seconds until the delivery takes place.

Source 6: Boiler inspection with UAVs - without GPS (Cyberhawk) [7]

Cyberhawk is specialized in industrial inspection by using UAVs. In 2016 the company executed the first internal space inspection of a boiler in Eastern Europe (Bulgaria) with a UAV named AscTec Falcon 8. Usually, this kind of visual inspection needs three to five days. Technicians conduct the inspection of the boiler by rope access and inspect suspended inside the internal structure of the boiler.

Under the challenging conditions of darkness as well as zero GPS signal, the pilot had to work with extreme precision to ensure a successful result.

As following, the Figure 7 shows the inspection of the boiler.

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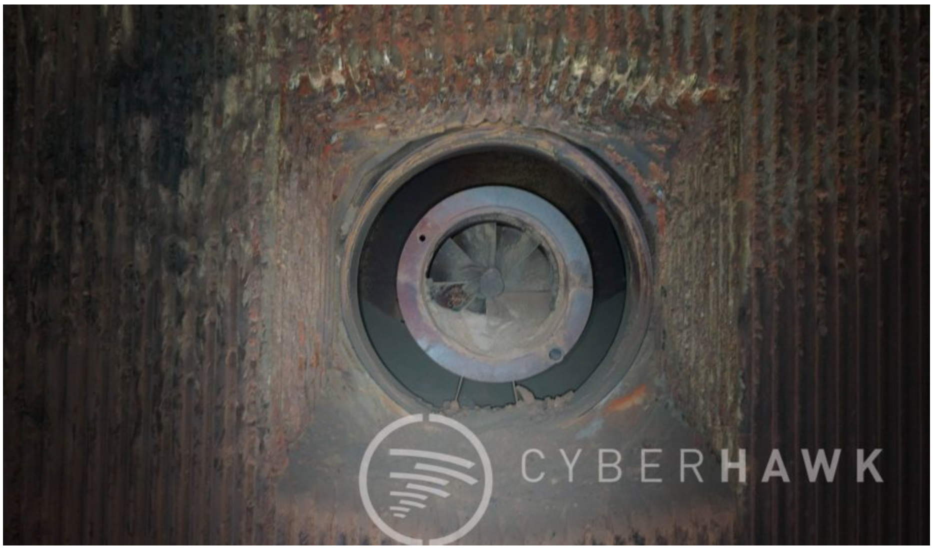


Figure 7: Successful inspection of a boiler with an UAV

As a summary, the author gives an overview of the advantages and disadvantages in the following Table 2.

Table 2: Research report advantages and disadvantages

Source	Advantages	Disadvantages
1	• Solution is based on self-made real industrial issues • Already successfully tested • Solution for flying without GPS • Thoughts towards Smart Factory with the "Follow me" function	• Pilot needed to control the UAV remotely • The result is not reproducible or predictable • Implementation only possible together with a complete new concept of Industry 4.0
2	• Passed the most comprehensive verification • Huge & young company that is investing a lot in the field of UAVs • Use of UAVs equipped with a camera to take HD pictures • Video transfer in real time • data can be used for documentation or to look up things afterwards	• Specialized function for inspection and maintenance • Only for the outdoor use with GPS available • Missing the link to Industry 4.0 • Pilot needed to control the UAV under challenging conditions of darkness
3	• High-definition pictures with up to 80 megapixels • The productivity is higher (the UAV is faster in the air by starting next to the application area) • Lower in cost (no helicopter needed and only one pilot instead of two workers that climbing up • Lower in risk of injuring the worker	• Only for outdoor inspection • GPS needed for loading geographic maps • Unstable in bad weather conditions • Pilot needs to control the UAV remotely • No link to Industry 4.0 • In case of finding an issue, the workers have to climb up anyway
4	• Successfully tested in February 2017 • Able to transport up to 100 kg over 23 minutes	• Only for the outdoor use • Need GPS signal to manoeuvre

	• No pilot needed (autonomous take off, flying and landing) • Special sensors have been developed just for this application	• Not applicable for the use of transporting goods in the intralogistics
5	• Successfully delivered packages autonomously • High speed with up to 100 kph • Many different types for different environments • In major cities only 60 min between the order and the delivery • Communication via App between customer and UAV	• Predefined delivering zone on the ground necessary • GPS signal needed • Due to being too expensive, the focus is on delivering medication or other emergencies
6	• Successful inspection of a boiler from the inside • Faster and cheaper because of no need of workers which access the boiler by ropes • Pictures in HD, even under hard circumstances • No risk to human life	• Pilot with a high qualification needed to fly the UAV via remote under challenging conditions of darkness and no GPS signal • Result is not reproducible • In case of an accident the many parts of the UAV can course trouble

This literature review has shown, that the Audi Inc. is about to implement UAVs as a part of its future production processes. For this, the automotive companies are changing their complete production program and reorganizing the factories. It is relevant from the advantages given by using UAVs that this concept will only work in a Smart Factory.

Most other companies have good ideas about using UAVs. However, many of them are related to UAV use for inspection as part of maintenance. Others on the other hand some companies are proposing the transportation of goods or humans outdoors with the support of GPS. The challenge will be to combine the two scenarios and make them suitable for their indoor use. The future industry needs an autonomous flying UAV, which will be able to take pictures as part of the maintenance, transport goods to eliminate errors or to save time and to monitor processes or machines to prevent probable faults before they occur.

3 Industry 4.0

3.1 Terminology and Historical Background

The term Industry 4.0 refers to the 4th Industrial Revolution and was first published back in 2011 as "Industry 4.0" by the German Government and a group of representatives from different industrial fields such as business, academia and politics. The idea was adopted by the German federal government to its ambitious policy known as 'High-Tech Strategy for 2020'. Further a working group was formed to advise on the implementation of Industry 4.0. [8]

For a better understanding of the history of Industry 4.0, an overview is given in Figure 8 about the industrial revolution in general. This will help to understand the future industrial production and the difference between the third and fourth revolution.

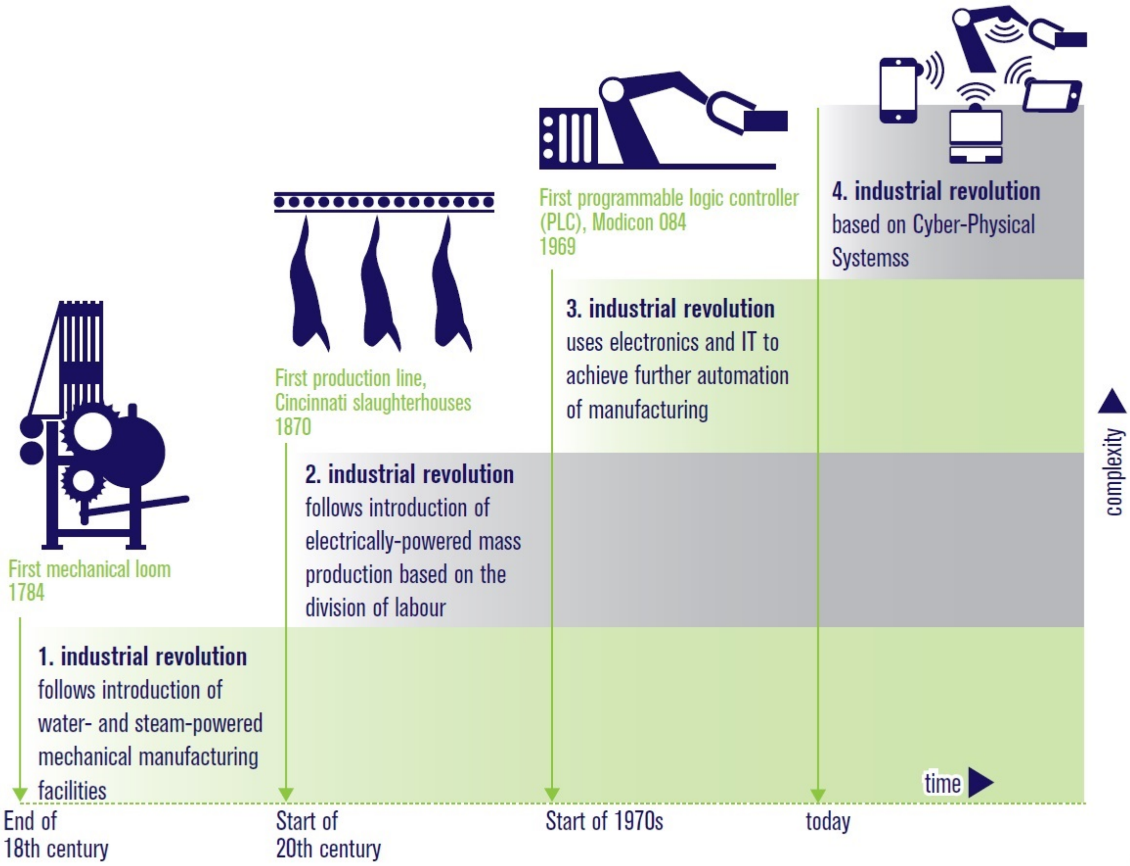


Figure 8: The four stages of the Industrial Revolution [9]

The First Industrial Revolution

By the end of the 18th century Great Britain introduced machines into production. Through steam-powered engines and water as a source of energy, production wasn't a manual procedure anymore. This allowed for faster production of goods in larger quantities.

Within this context the term "factory" became more popular and one of the industries that benefited a lot from such changes was the textile industry. It was the first to adopt such methods. At the time, it became firmly established as a huge part of the British economy.

The Second Industrial Revolution

This led to the Second Industrial Revolution in 1870, which introduced pre-existing systems such as railroads and telegraphs into industry.

It is also described through the division of labour in mass production, operated by support of electrical energy. For this reason, the Second Industrial Revolution is more often referred to as an organization driven revolution. It marks the development of the first production line by Henry Ford and a management line by Frederic W. Taylor, also known as Taylorism and Fordism. Once petroleum was available and had become increasingly important as fuel for cars, the mass production of the automobiles was possible at the same time.

The Third Industrial Revolution

Almost 100 years later, in 1969, the Third Industrial Revolution followed. Due to the uses of electronics and IT, a further intensive automation of manufacturing was born. It is often referred as the Digital Revolution, and describes the change from analogue mechanical systems to digital ones.

The Third Industrial Revolution is also known as the Information Age, because of a direct result of the huge development in computers and communication technology [10].

3.2 The global competition: economic Potential of Industry 4.0

The economic potential of industry 4.0 is regarded as positive [11]. Thus, by 2020 the expected sales will have increased by 20 to 30 billion Euros. [12]. However, an assessment of such effects is difficult because of several reasons. First of all, Industry 4.0 is not clearly defined and thus not clear at all. It is not only a single technological innovation. It is a combination of different technologies, which in their cooperation shows the full potential.

A few of these technologies are in the advanced development stage, their market ability is yet to come. [12]

From a technical point of view, Cyber Physical Systems (CPS) is the most important sector of Industry 4.0. The CPS are based on embedded systems or RFIP-tags with mini-computers, which are able to measure physical conditions such as temperature and pressure. This is possible through sensors. A processor uses this information and redirects to a predefined program action [13]. For example, physical actions through actuators could be changing the cooling system, if the environmental temperature is reached. On the other hand, UAVs could receive the information to replace a defective part autonomous. The goal is to build a connection between hardware and software, to control, regulate and monitor an earlier defined system. [13]

During the last years, embedded systems have been successfully miniaturized and arranged on a chip. Their performance has greatly increased at the same time as decreasing manufacturing costs. However, the most important innovation is that embedded systems are equipped with an IP address and connected over a communication interface to the Internet. This is how they become CPS and can be used in almost all objects. They receive their operational energy through various sources; light, vibration, magnetic or electrical fields. CPS technology can be used in blanks, semi-finished goods and embedded in finished goods. Thus they become smart and know for example where they are located and in which process of machining. The semi-finished good or more specifically the CPS, includes information about which machine is the next in the production line (assuming the machine also has the ability to communicate wirelessly). Real production processes can now be displaced virtually. This allows a production in real time, decentralized and not as it was usually centrally organized. [13]

The following Table 3, based on estimates from “Die Vierte Industrielle Revolution”, gives an overview about the possible savings. Most potential is seen by complexity costs.

Table 3: Estimation of the potential benefits of Industry 4.0 [14]

Costs	Effects	Potentials
Complexity Costs	• Reducing the machine complexity and trainings	-60 % to -70 %
Inventory Costs	• Reduction in safety stocks • Prevent Bullwhip & Burbidge Effects	-30 % to - 40 %
Production Costs	• Improvement in Overall Equipment Efficiency (OEE) • Process Control Loops • Improve vertical and horizontal Staff-flexibility	-10 % to - 20 %
Logistics Costs	• Increasing degree of automation (milk run, picking, etc.)	-10 % to - 20 %
Quality Costs	• Almost real-time quality control	-10 % to - 20 %
Maintenance Costs	• Optimization of spare parts inventories • Condition-based maintenance (process data, measuring data0 • Dynamic prioritization	-20 % to - 30 %

The idea behind Industry 4.0 is to provide a fully customized and cost-effective production process, which promises great added value. Due to continuous networking and digitalization of manufacturing and development, changes of any type and more important at any time are easier to perform than ever before. Because of this, the flexibility of all business processes will increase. The networking and digitalization also aids by increasing transparency of tasks, which in-turn leads to better information exchange and improves decision-making. The factory of the future, allows for better customisation under the same conditions. The customer will be his own developer and has the ability to change the product during the production in real-time. [15]

3.3 Smart Factory

Smart Factory is the most important part of Industry 4.0. To work efficiently however, it needs all the other components as well. For the technical realization of Smart Factory, innovations, investigations and new solutions in the technical field are necessary. The understanding of such technologies varies with perspective and the source.

The core idea of Smart Factory is to use software to link machines and facilities. Through intelligent communication between each other, working tasks can be organized automatically. This connection is within a factory and in the future could also be between production networks. The network persists usually out of several plants and includes supplier and customers as well. [16]

The Smart Factory requires a collection of fundamental technology, such as computing power, storage performance, broad band Internet and a cloud to develop and provide digital solutions in manufacturing. Furthermore, connecting key techniques such as (CPS), actuator and sensors are needed.

The following Figure 9 displays the necessary components that contribute to a Smart Factory.

Figure 9: Contributes of a Smart Factory

3.3.1 Cyber Physical System (CPS)

Cyber Physical Systems (CPS) can be defined as an assignment of real (physical) objects and processes with information processing (virtual) objects across global systems and round-the-clock connected information networks. [16]

CPS are, for example, already used in navigation software. To improve the routing, current traffic information is deviated from movement profiles via the mobile radio communication.

In the future CPS will be part of an intelligent power supply system which is regulating the power system. A better coordination will also make the traffic safer by decreasing the pollution through carbon dioxide at the same time. In the industrial production internet based systems will monitoring autonomous working production systems via remote control. [8]

The German government is supporting the research of essential aspects from CPS. Details about the framework are written down in Hightechstrategie 2020.

Another important module of Industry 4.0, are Embedded Systems, Cyber Physical Systems (CPS) and intelligent objects. Objects become intelligent, when they are equipped with sensors, identifiers, actuators, micro controllers and communication systems:

- Sensors provide data about the immediate surroundings of the object.
- Identifiers such as barcodes or RFID transponder identify distinct objects.
- Actuators move adjusting levers
- Micro controllers, as the most important part of the Embedded System, analyse the data, determine the situation of the object and make decisions about the next steps in the work process.
- Communication systems link the interaction between radio and cable networks.

In production and logistic intelligent objects could be for example containers or tools.

The following Figure 10 shows how complex CPS is. The communication is managed over the internet or intranet. To get information's, sensor technology and measuring systems in real time are needed. Due to the information, data for simulation can be collected. In other words, CPS describes the active interaction between physical devices, human beings and the digital world.

Figure 10: Complexity of Cyber Physical Systems

3.3.2 Horizontal and Vertical Integration

In the context of Industry 4.0, especially Smart factories, horizontal and vertical integration are often mentioned as two of the most important factors for successful implementation. In the modern factory, machines and equipment from different manufacturers are in action. This brings a different level of atomization, technology and communication standards. The following gives a definition with reference to the final report from Acatech, the National Academy of Science and Engineering. [17]

The horizontal integration refers to the consistent linking of the whole process steps along the value chain that involve an exchange of materials, energy and information both within a company as well as with suppliers, customers and service providers through IT systems. The challenges with the inter-company network are information exchange and know-how protection at the same time.

The vertical integration refers to the consistent linking of the IT system through different hierarchical levels (e.g. control level such as actuator and sensor, control, production management, manufacturing, execution and corporate planning levels). The challenge is to ensure the flexibility and configurability of the system in order to deliver an end-to-end solution. [18]

3.3.3 Cloud Computing

The term Cloud Computing is defined by the National Institute of Standards and Technology (NIST) as followed:

“Cloud computing is a model for enabling ubiquitous, convenient, on demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This loud model is composed of five essential characteristics, three service models, and four deployment models.”

With particular words, Cloud Computing describes the use of services and store that is not located on the personal computer rather somewhere in the Internet. The user is unaware of the exact location of the files stored but has access to them no matter what or where. The only requirement is an Internet connection.

In general, the Clouds are differentiated into Public, Private and Hybrid Clouds; the most relevant services are: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS).

The technical utilization of Cloud Computing is different: Consumer can use it for Emails, database, shared access to files, payment services as well as music and video streaming.

Companys and public authorities on the other hand, use it for basic office application, collaboration and project management.

3.3.4 Cyber Security

During the "Centrum fuer Bueroautomation, Informationstechnologien und Telekommunikation" (CeBIT)[1], the biggest exposition for communication technology in the world began an alliance for Cyber Security in 2012. The initiative is between the "Bundesamtes fuer Sicherheit in der Informationstechnik" (BSI)[2] and "Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V." (BITKOM)[3]. This cooperation aims to improve the Cyber Security in Germany. On the other hand, they sensitize the danger of Cyber Attacks. The biggest issue with Cyber Crime is, that the impact of the damage is not identifiable. For example, data theft in the form of knowhow will not be measurable until a long time has passed. According to a survey, over 70 % of companies have already been through an attack via the internet. However, the quantity, complexity and professionalism in this field is steadily increasing. The BSI and the ISACA Germany Chapter e.V started a praxis orientated project, to bundle the knowledge and define a general Cyber Security check. Basically, the check is structured into six steps as followed:

1. Placing of order
2. Determination of the Cyber Security exposition
3. Document security
4. Preparing local evaluation
5. Local evaluation
6. Post-processing/reporting

All details are defined in [19]

3.4 Internet of Things (IoT)

The idea of self-communicating products is not new. As early as 1966 the German physician, author and cyberneticist Karl Seinbuch explained it as:

"In a few decades, there will be hardly any more industrial products in which the computers are not connected, such as the nervous system is embedded in organisms." [20]

The term Internet of Things (IOT) describes uniquely identifiable physical objects (things) with a virtual representation in an internet-like structure. These are human but

[1] Engl. "Center for Office Automation, Information Technology and Telecommunication"

[2] Engl. "Federal Office for Information Security"

[3] Engl. "The Federal Association for Information Technology, Telecommunications and New Media"

also technical participants. For the automatic recognition of objects, an identification by means of electromagnetic waves (radio frequency identification, RFID) is used. An RFID system consists of a transponder which is located on or in an article and contains a unique identifying code, as well as a reading device which can scan the readout.

By replacing the now 30-year-old Internet Protocol (IP) of the fourth generation (Internet Protocol version 4, IPV4 for short), the introduction of Internet Protocol version 6 (IPV6) is setting new standards. Approximately 340 sextillion IP addresses were created by the new system. This is a number that is 39 digits long. In combination with the mobile Internet, ideal conditions are created for collecting data about humans and products. This data collection is called Big Data. [21]

The enthusiasm about the possible development of the concept of communicating and perhaps thinking things is limited by data protectionists. These voice the reservation that the gigantic number space created by IPV6 could be allocated to each Internet user for the lifetime of the same network address. This would mean a permanent monitoring, analysis and control. In addition, Big Data only works if many, rather inaccurate data are recorded, but overall the results are better or more representative.

Over the past decade, the Internet has evolved from a research network to a global communications network. During this time span, a large number of services and applications have emerged, which can no longer be seen in everyday life, especially on mobile devices. [22]

A study by the International Telecommunication Union (ITU) has identified the following data for 2012:

• 85.7% mobile subscribers (about 6 billion)

• 15.7% broadband users (about 1.1 billion)

• 32.5% households with cable-bound Internet use (about 2.3 billion) [23]

This enormous number of global participants in combination with the steadily growing number of different services causes an unimaginable collection of data. [24]

3.4.1 Big Data

The term Big Data developed in 2013 has become a kind of trend word. Big Data means that records exceed the capacity and ability of classical database software tools to collect, store, process, and analyse. Since this description is subjective, there is no metric that makes a statement about when a data record is a big data. This question varies according to industry, software and tools used in specific industries. [25]

In general, Big Data can be described by five dimensions:

1. Data volume (volume)
2. Data diversity (Varity)
3. Velocity data evaluation (Velocity)
4. Data sources (Reach)
5. Complexity (Variability) [26]

The amount of data is steadily increasing in our daily lives. The reason for this is the growth in the number of devices. Approximately 90% of existing data was generated in the last two years. Experts expect the world-wide data volume to double every two years. [25]

The data can pool in from various sources. However, most of the data is generated in the following areas:

• Recording of monitoring systems

• The use of bank or payment cards

• Communication in electronic form

• Homes that are technically interconnected (e.g. Smart Home)

• Collected data from authorities and enterprises [25]

However, in order to exploit the potential of the enormous data, a digital value-added strategy is required. Hardware, software and freeware applications combined with analytical methods are particularly useful. Standard databases require too many resources or time for the complex calculations. For this reason, the productive use of Big Data also had to be converted to analytical databases and parallelization techniques. At the same time, the costs for the storage and processing of the enormous amounts of data are hardly important anymore. Nevertheless, Big Data is far from being used by all companies for targeted analysis. A major challenge is the lack of suitable methods and the heterogeneity of the data.

The automotive industry is also generating more and more data. Here, they are used in part for the optimization of e.g. Maintenance intervals or fault analyses. Similar considerations can also be made in the field of boatbuilding. Up to now, boats are serviced at static intervals, independent of the running time or load. Damages occurring to the hull are repaired. This is often the case without the cause being established and future measures which would prevent a new error occurring. The targeted use of measuring technology, give rise to the possibility of real-time monitoring of the boat. For example, the position of each boat could be determined at any time. In addition, dependent data can also be recorded which can be used to identify a cause of damage. Other measuring devices in turn could determine the position of the boat, wind speeds, temperatures in and at the boat and forces generated by waves. Thus, the industry would be able to continuously improve in a kind of process reengineering.

3.4.2 Technology to communicate in Industry 4.0

The following figure gives an overview of the technologies applied to facilitate communication in Industry 4.0. This chapter focuses on its uses, therefore provides fewer technical details. In combination with CPS, machines could receive information about products and their specifications. A further process could so be prepared, before the product is there physically.

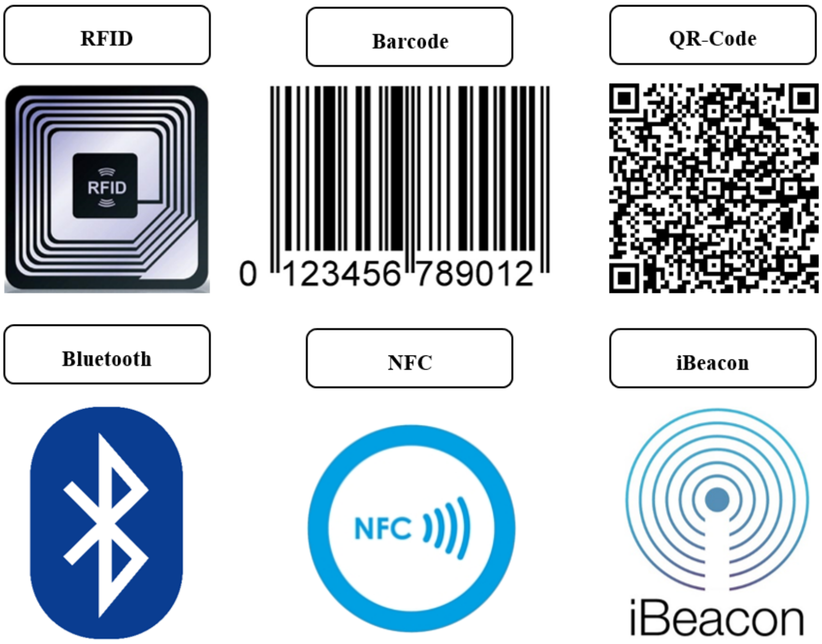


Figure 11: Overview of technologies used in Industry 4.0 to communicate [27] [28] [29] [30] [31] [32]

RFID

Radio Frequency Identification (RFID) is an automatic and contact-free identifying technique. Due to increasing cost for technology they are becoming more popular to be used in different fields such as logistics, supply chain, inventory tracking and access control.

RFID consists of a transponder, which again consists of an electrical data carrier and measuring/reading device. In addition, both devices have coupling elements called antenna. The respective data exchange occurs by magnetic or electric waves transfer.

The word transponder is a coinage and stands for transmit and response. The transmitter delivers 1 Bit information, as they were used in the 60s for theft-deterrent systems. With the addition of a memory, more complex data can be transferred. RFID’s can be read only if necessary and are writeable as well. The tag contains the specific serial number for every object.

Basically the transponder is of two different types: active and passive transponders. Active transponders are used to deliver information and data over several meters. The transponder has a power supply (battery). They are used to inspect incoming goods. Passive transponders on the other hand do not have their own power supply. The energy is generated by the reading device. Because of this, the maximum distance is limited up to 60cm.

The operating frequencies of passive RFID tags is different depending on their use. There are three main frequencies in which passive RFID tags operate. With regard to this, the range also differ as it is shown in the following Table 4.

Table 4: Frequencies of passive RFID tags

Passive RFID tags		
Name	Frequency	Range
Low Frequency	125 – 134KHz	1 – 10 centimetres
High Frequency & Near-Field Communication	13.56MHz	1 – 100 centimetres
Ultra-High Frequency	865 – 960MHz	500 – 600 centimetres

For active RFID tags there are also two main frequencies which is either 433MHz or 915MHz. The RFID tag most preferred by companies have longer wavelengths as in the range of 433MHz. It works better with non-RF-friendly materials like metal or water.

There are however, a few advantages of using passive RFID tags:

- Smaller in dimension
- Cheaper
- Thinner and more flexible
- A higher range of tag options
- Depending on the wear and tear, this type of RFID can last for a lifetime

Barcode

This is probably the most common technology, known from the supermarket. A Barcode is an optical data carrier to identify objects. Each bar or stripe stands for data information. To understand the information, data needs to be encoded and afterwards read out by an optical reading device. For this technology, Barcode and reading devices need to be at the same place. Additionally, during the scanning process, the code has to be accessible without any distortion/ obstacle in between. The Barcode is printed, so it cannot be reused again. [33]

QR-Codes

The QR-Code is an extension of the Barcode. An optical data carrier is needed as well. Compared to the Barcode much more information can be encoded and the data read-out is possible from any position.

With the invention of Smartphones QR-Codes have become more famous. For example, in Magazines, on Facebook for commercial use or to unlock WhatsApp Web.

Bluetooth

Another well-known technology is Bluetooth. Especially for the wireless and contact free exchange of music, photos and videos between Smartphones during short distances from up to a 100 meters. This technology is also used to connect Smartphones with earphones, or sound boxes as a wireless remote device. On the other hand, the Smartphone displays information recorded by the running shoe sensor. The current newest version is Bluetooth 4.0. Theoretically, data transfer with a speed up to 1 Mbit/s is possible. This type of connection, however, is not for a permanent delivery of information because of demands on a device's battery. Therefore, it is more suitable for short terms data transfer with the device returning into a power safety mode. This information could be for example the weather, the time or pulse rate. [34]

Near Field Communication (NFC)

This technology is rather unknown. It is often measured in combination with RFID tags, because it is based on the same technology. Their use is for the communication between different types of devices in a range up to 10 meters. The property of being writable and readable makes it interesting for the future. NFC is a technology that enables contactless payment. [35]

iBeacons

iBeacon is one of the current Industry 4.0 technologies. It has been developed as a standard by Apple. The placing of iBeacon on objects allows technology to virtualize an area. As soon as an object enters this area, information can be provided. On the other hand, information can be delivered to get specific information such as position and movement of the receiver. [32]

4 Implementation of Industry 4.0 with Tecnomatix Plant Simulation

4.1 Terminology

The term Simulation is defined by the VDI (Verein Deutscher Ingenieure) in the VDI-guideline 3633 as followed:

"Simulation is a copy of a system with its dynamic processes in a model capable of experimenting in order to reach knowledge that can be transferred to reality." [36]

The benefits are further defined in this guideline:

"Based on the effort of 0, 5 % - 1 % of investment costs for the simulation, 2 % - 4 % of investment costs can be saved." [36]

As previous planning errors are recognized and eliminated, the follow-up cost are less. Investigation of future systems can be made, even if they are not physically built yet. Furthermore, existing systems can be optimized to minimise risk during the practice. The behaviour of countless alternatives can be considered over the long term in time lapping mode.

Principle of event-oriented simulation

In reality, production process changes are dynamic. A system is dynamic, when its conditions are changing during the period of the simulation. These changes can occur continuously or at a distinct time. In the presented simulation example, the changes are generated with events. Therefore, it is called a distinct-oriented or an event-oriented simulation. [37]

The instant of time for an event is unpredictable. To simulate a stochastic process, as it happens in reality, the tool makes use of randomly generated parameters. However, it is also possible to simplify the process without randomly changing parameters. Therefore, it is a determined system.

The object in the program can be permanent or temporary. Permanent objects are, for example; machines, storage units or transportation routes. On the other hand, temporary objects are parts, workers or orders.

4.2 Tecnomatix Plant Simulation

Plant Simulation is a commercial event orientated simulation tool. The Frauenhofer Institution has 25 years' experience in the application and development of simulation systems. Siemens Lifecycle Management Software is focused on object-orientated development with standard software. The combined knowledge of Tecnomatix Jack, Intoside, Robcab and Plant Simulation was the foundation to develop a simulation tool such as Tecnomatix Plant Simulation. The program has the ability to create digital models of logistic systems to optimize its production. It allows modelling of production lines in 2D, 3D or both at the same time. Space and material flow can be optimized at all levels of planning. With advanced tools to analyse bottlenecks, waiting time and transport time, the user can generate various kinds of statistics and visualize them by using graphs and evaluations of different scenarios of the production. [38]

Based on the fact that Siemens allows only 80 material flow objects in the student version, this example will be presented in a simple simulation to transmit an idea for the use of UAVs, to realize Industry 4.0.

4.3 User Interface

The user surface of Plant Simulation is shown in Figure 12. However, for a better understanding utilized elements are listed separately.

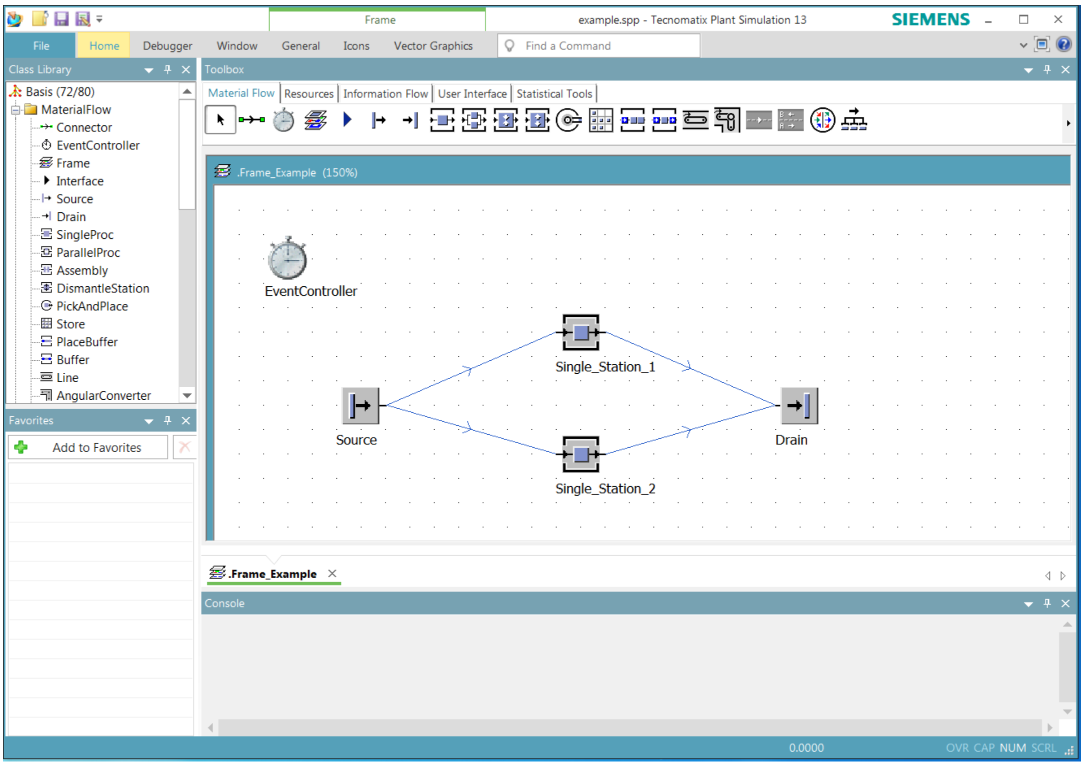


Figure 12: User Interface of Tecnomatix Plant Simulation Ver.13

The major portion of the simulation is managed and shown in the main window. Almost all functions can be selected here. The user can customize the library or use a default adjustment.

On the left hand side all necessary elements are listed in the class library. A customized folder, as a short cut to individual icons or duplicate elements as well as networks, is also listed in this class-library.

Above the window is the Toolbar. This can also be used for faster access of the elements duplicated out of the library.

Below this is the Framework. Here is where the user can place selected elements by Drag & Drop. It is not possible to run the simulation during the construction of the production line. All elements such as for example source, workplace and drain has to be linked with a connector otherwise the tool will show an error.

Below the window is the console. In this window, important information is given. For example, errors that occur in the progress of the simulation.

The event controller is shown as a stop watch. By double clicking on the icon, a window appears, as it is shown in Figure 13.

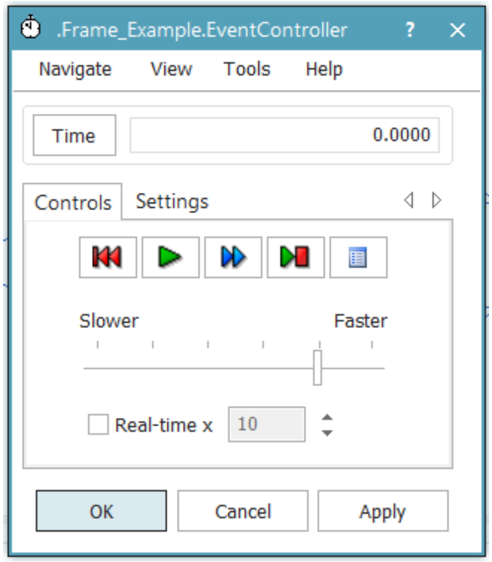


Figure 13: Event Controller

The user can run, stop or manipulate the simulation time through accelerating or decelerating it. By starting the simulation, the material flow is simulated in the framework. In Plant Simulation those parts are mentioned as moving parts and cannot include other parts. This tool permits the simulation of a production in a much shorter time than it would take in reality. Furthermore, other options allow real-time or step by step observation.

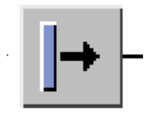
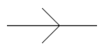
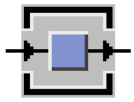
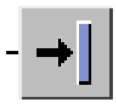
The reset button offsets the simulation into the default mode. However, the user has to consider that some tables have to be cleared as well.

All properties of the elements which are shown in the framework can be viewed and adjusted by double clicking on it.

4.4 Relevant Elements for the example

The following Table 5gives an overview about the utilized elements in the simulation example. Furthermore, the table describes their function and shows their symbol.

Table 5: Template of applied symbols

Name	Function	Symbol
Source	The user can choose between different entities and their interval of production. The parts appear immediately and the capacity is one.	
Connector	The connector links the elements. The arrow shows the direction of the product flow.	
Single station	A single station processes a part. After the set-up time and the machining time the part is delivered to the following station. Its material flow is limited to one part per time.	
Drain	The drain is the last station in every simulation model. The parts disappear after reaching this station. This station could be a distribution centre or the customer in general.	
Method	Method is an information flow element to control other objects in the simulation. The source code is SimTalk. This element can e.g. control the specified behaviour of stations.	

4.5 Description to implement Industry 4.0 with Tecnomatix Plant Simulation

To implement Industry 4.0 countless effects, have to be considered. Because of high implementation cost and significant time consumption in the future, the simulation tool will be even more necessary. Due to the fact that Industry 4.0 has a huge range of topics, the focus of the simulation is to realise machine to machine communication by using a method element. This is required for the source code to develop an algorithm. An autonomous optimization in process flow with use of RFID tags enables to determine the properties of machines and products.

The following Figure 14 shows a screen shot of an example in which a product is processed at four stations. At each station is a working place for an operator. During the unused time when the operator is not acting at the machine, he/she has to go back over the food bath to the worker pool and wait there for the next part.

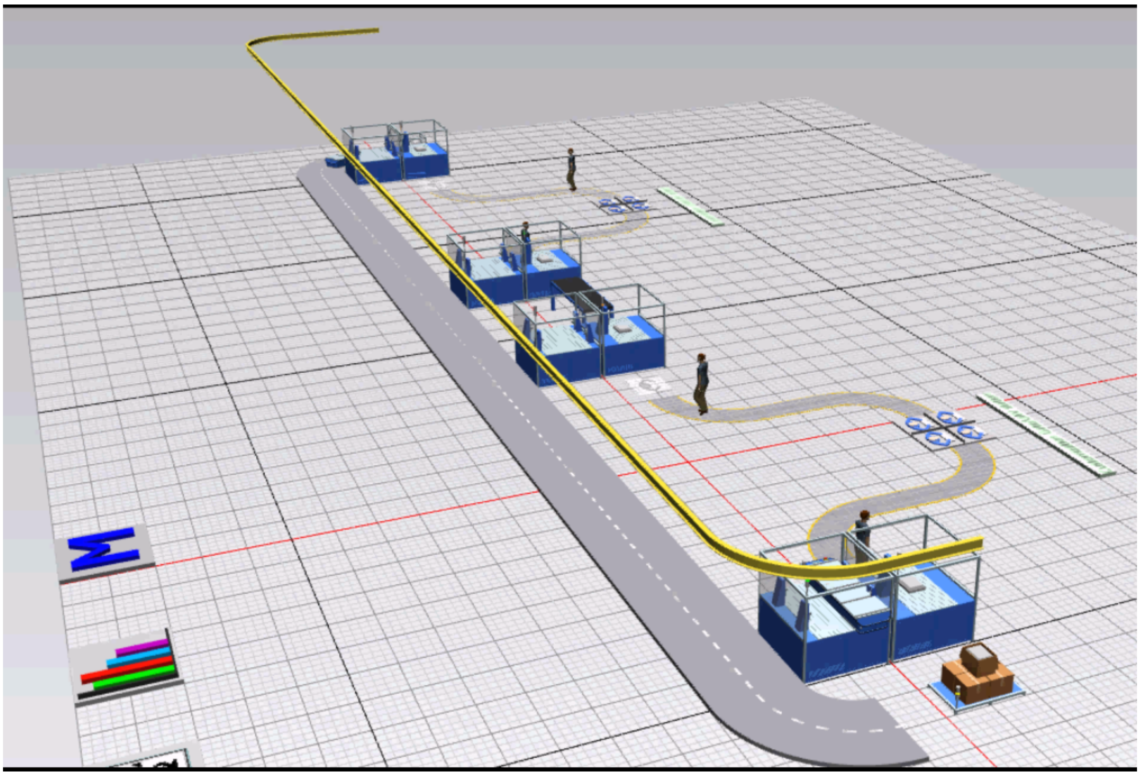


Figure 14: Simulation

The product starts at the sink and is edited at every station until it reaches the drain. To simulate the reality in the best possible manner, each operator and station has a failure rate. The following chart shows a failure at station 1 and based on this a waiting time at all following stations is determined. If the following stations know the performance of every station in real time, specific stations could skip the machining process and be sent to stations with waiting time. However, the following station must have the same configurations or chose specific procedures.

The simulation tool Tecnomatix Plant Simulation is visualizing the performance of the selected stations in a chart, as it is shown in Figure 15. This chart shows that the SingleProc has a small amount of failure and also a blocked time. The failure of a machine brings a chain reaction of waiting time to all following machines.

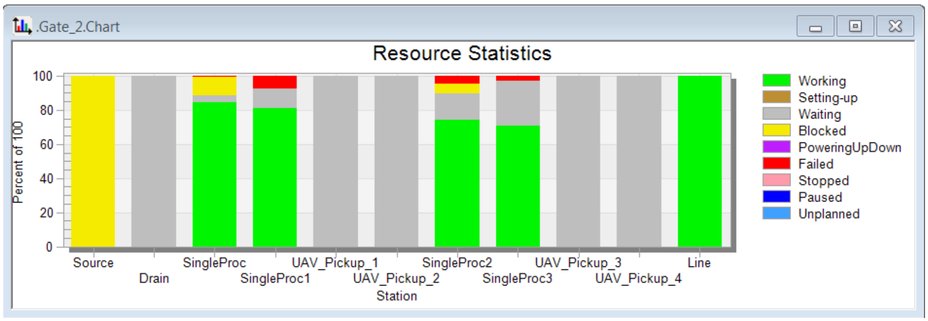


Figure 15: Performance statistic overview

Contemporary technology enables the possibility to communicate and track machines and products in real-time by using a RFID tag. With this technique each machine is able to check the degree of capacity from all other machines. The following block diagram visualize how the machine to machine communication can improve the process flow time. For example, machine 2 is telling machine 3 that it will have a delay. Therefore, the next part will be skipped and the product is further moved along the production lane and onto the next machine. Based on this dynamic change in the production plan, the waiting time can be decreased. As already mentioned earlier in this chapter, this is only possible, if the following machines have at least the same degree of performance.

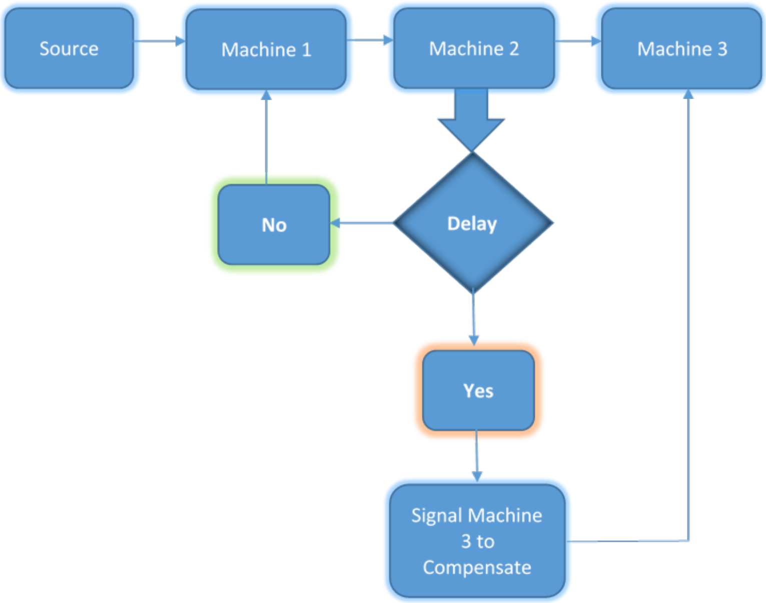


Figure 16: schemata of machine to machine communication

4.6 Challenges of Industry 4.0

This chapter looks at the challenges of Industry 4.0 from a company's point of view. What are the most challenging situations according to implementing Industry 4.0? What would framing a condition in the environment of Industry 4.0 entail? These are questions that concern almost every company, planning to become Industry 4.0 ready. For a better overview, the selected challenges are categorized into two types: technological and organisational challenges. The technological challenges describing difficulties, related to the IT or data analysis. The organisational challenges on the other hand, focus on general regulations such as aspects of law, sustainability and standardisation.

4.6.1 Technological Challenges

The first important challenge of Industry 4.0 is the *communication and interaction* between machines as well as between the workers and the machines. The Hardware makes real time communication possible. It is only the software, which has to be linked perfectly into the technique. For example, the human nervous system is controlled by the brain. The action to raise the hand, is performed in milliseconds. Even if the instruction is changed the body reacts in real time. This is the goal of communication. To be as fast as nature.

Another point that is becoming more and more necessary is *Big Data*. The company Mieschke Hofmann and Partner has shown in a study that 58% of 254 respondents believe that understanding customers could be useful for Big Data scenarios. Furthermore 46% believe in the value of product improvement or more specifically improving their properties. Also uncertainty in the market and preparing internal processes to the demands of customers is highly seen as a chance by 48 %. These days, storage is cheap and not the problem it once was. Furthermore, the systems and components in a company have to be able to use a larger amount of data without a reduction in processing speed. However, in the future customer satisfaction will remain the biggest focus.

The most under estimated challenge is Data or *Cyber Security*. If companies cannot provide for the safe exchange of sensitive data, Industry 4.0 will remain science fiction. There are already companies, which are not implementing Industry 4.0 because of the circumstances of data safety are still unclear.

4.6.2 Organisational Challenges

Essential for Industry 4.0 is *standardisation*. To interact with other companies, especially from all over the world, standards and norms are necessary. A general commitment will help the collaboration as defined in chapter 3.3.2, vertical and horizontal integration.

However, if standards are defined too specifically, the implementation will consume a lot of time and matching the requirements will be quite difficult. The Industrial Internet Consortium proposed in practice, applies the use of “de-facto Standards”. This outlines the minimisation of the expenditure of time. General standards must be followed and its implementation, guaranteed.

Great importance is also attached to *sustainability* in Industry 4.0. To implement something new, the damage of the environment is no greater than what it was before, but it is even better if it is less damaging. By using intelligent logistics pollution will be minimized. When it comes to Industry 4.0 sustainability should be on the agenda as well.

The next challenge affects *the role of the worker* in a future industrial environment. Therefore, a willingness for further training will be a basic requirement. Workers will be surrounded by machines or even work hand in hand with them. Technical, robotic, information and automation are the core skills needed. However, this does not mean the worker of the future has to know everything in detail. For example, jobs that require the use of techniques supported by Augmented Reality (AR).

Due to the fact, that Industry 4.0 is based on an exchange of data, the last challenge listed is the *legal aspect*. The exchange of data can be between companies or internal. In case of a data breach the responsibility has to be identified clearly. Therefore, new laws have to be defined in a shorter amount of time. The challenge will be to find the balance between using personal information naturally and still giving the society a feeling of safety by doing this. [39]

4.7 Interim conclusion

The simulation with Tecnomatix Plant Simulation has shown a production example. The user interface is well structured and easy to customise. However, as mentioned in chapter 4.6, there are a few technological and organisational challenges with Industry 4.0. These challenges can be seen even in the simulation tool. The implementation of Industry 4.0 is not possible yet. The program does not allow machine to machine communication. With SimTalk it is only possible to program simple algorithms. There is no kind of intelligence. Industry 4.0 already has been announced in 2013. It falls short of providing a tool with the possibility to test recently developed trends. The concept of Industry 4.0 should be integrated as soon as possible to become a standard. If companies are given the chance of using such a tool to simulate, the trend would become reality much faster.

5 Potentials of using UAVs in the intralogistics

5.1 Terminology and Historical Background

A drone or better known as unmanned aerial vehicle (UAV), is an aircraft without a pilot on board. A pilot at the ground can control the UVA over remote. On the other hand, the UAV can fly autonomously based on pre-programmed flight plans or even more complex dynamic automation systems. [40]

The United States first used the UAVs as reconnaissance drones in 1960 to spy on Cuba, Vietnam, China and North Korea. Also from 1955 until 1975 the US-military utilised UAVs in the Vietnam War, to locate surface-to-air missiles. In 1990, the German military continued the use of drones by inventing Canadair CL-289 which was able to deliver videos in real time. During the Kosovo War in 1998 UAVs tagged F16-fighter jets laser-assisted as a target. For the next 15 years, a lot more military uses of drones has followed. [41]

Also since August 2014, the US aeronautical authority Federal Aviation Administration (FAA) has allowed the use of UAVs for farming.

Until 2020 EasyJet is planning to reduce the failure rate to zero by using UAVs. [42]

Based on the fact that UAVs first were used in the military, it is not easy to give a general overview of UAVs including civil UAVs. They differ greatly in weight, altitude, endurance and range. All civil UAVs belong to the category "Micro" as shown in Table 6.

The following Table 6 gives an overview of the different type of UAVs used in the military.

Table 6: Classification of UAVs by range and endurance [43]

Category	Weight (kg)	Altitude (ft)	Endurance (hr)	Range (km)
Micro	< 1	300	1	< 5
Mini	< 25	< 10.000	1-6	< 25
Close range	< 200	< 15.000	4-8	< 75
Small range	< 750	< 25.000	8-24	< 200
Male	> 1.000	< 30.000	> 24	> 1.000
Male +	> 3.000	> 30.000	> 24	> 1.000
Hale	> 3.000	> 45.000	> 24	> 1.000

Another way to define a category of UAVs is by the maximum take-off weight (MTOW), as it is shown in the Table 7. Here civil UAVs will be allocated only in the “Class 0” category. However, the UAVs for the non-military use will be in the Class 0 only.

Table 7: Classification of UAVs under consideration of the MTOW [43]

UAV Class	MTOW (kg)	Range category	Typical-radius (NMI)	Typical-max Altitude (ft)
Class 0	< 25	Close	< 10	1.000
Class 1	25-500	Short	10-100	15.000
Class 2	500-2.000	Medium	100-500	30.000
Class 3	> 2.000	Long	> 500	> 30.000

5.2 Potentials of using UAVs

Unmanned aerial vehicles are a relatively newer invention. Their introduction has paved way to newer possibilities and has pioneered automated air transport. The current scenario in industries is rather primitive. Companies resort to manual methods and commission a huge workforce, it is both inefficient and wasteful. The use of UAVs has changed the strain imposed on industries in more than one way. Financially UAVs are considered as a long term investment. For example, the cost of a single device is around three thousand euros. This is approximately equivalent to a month’s salary for an operator. It is also worth mentioning that there are plenty of parallel benefits with UAVs. Taking into account a factory’s generic high ceiling build, the UAV hugely maximizes the use of air space. This in turn allows higher labour mobility rate on ground. The transport of material and products overhead permits limited storage traffic on site, the use of heavier vehicles such as trams can be eliminated. The UAV may be regarded as a contemporary intelligent design for intralogistics. It can be upgraded with state of the art technology such as high resolution camcorders and lasers sensors. UAVs open doors to an assortment of opportunities. The following few descriptions exhibit how an industrial production line can be altered for progress, by means of introducing UAVs.

Increased ground mobility and faster transportation: Aerial fly zones

One of the key advantages of this schematic is the ability to increase speed of transport. Common workplace ethics involves movement of workers and machinery on ground, comparing the two, and the difference in movement speed is evident. This causes obstructions and the manufacturing process is often delayed. Employees are required to compensate technical delay and are subject to inconvenient working conditions. This kind of fault in the process of production can be completely negated by employing UAVs. UAVs are programmed to function above the altitude of human interaction in designated 'aerial fly zones'. They profit from the high rise infrastructures that provide sufficient air space for travel and transportation of intralogistics. The inherent light weight property allows for greater movement speed and the dynamic range of the propeller can alternate between directions within seconds. By default, the device is programmed to find the shortest flight distance; the most apparent choice being, linear. However, restricted no fly zones may be incorporated into design, under these circumstances the route may cease to be linear. A sensor coupled UAV can even halt or rotate to best suit proficiency. The UAV is able to quickly revert positions along the radius of its central axis. Therefore, as an entity the UAV significantly increases transport time and reduces delay of delivery.

Inspection of inaccessible areas

Regular maintenance checks and risk assessments are woven into the very fabric of a successfully industry. It secures the safety aspects and functions of the workplace environment. It is mandatory that these safety checks inspect all areas irrespective of the nature of function. Not all regions of an industry are structurally similar, these variations can mean few regions remain inaccessible. For example, a human worker may be too large in frame to have full, unrestricted access to the junction between two parallel conveyor belts. At these instances UAVs provide the fastest and most effective means of performing an inspection. Furthermore, UAVs give an aerial perspective (bird's eye view), can take images or even record videos. This kind of data in memory allows for review and detailed risk assessment. It is customary, that a sector during survey is shut down to prevent hazards. Eventually the industry is made to compromise for the loss in terms of productivity. UAVs may replace/eliminate this practice and provide real-time, overhead surveillance.

Maintenance assistance

Heavy-duty machinery frequently undergo maintenance due to constant operation. Similarly, industrial plumbing, exhaust and electrical systems have sizable wiring/pipelines that must submit to obligatory maintenance checks. These routine processes make use of multiple hardware and tools. These tools are most often industrious and cumbersome to be carried to and fro between sites to station. This is yet another field in which the application of UAVs has high regards. UAVs can withstand or hold, up to 5000 grams in total weight. This gives industries ample leeway for transportation of tools. Providing a list of reserved material for various operations. The operator is assisted by a UAV that brings a requested tool or spare part. He/she can inspect the area/situation without having to carry unnecessary equipment then choose to call for a tool afterward. A second worker then loads the requested tool onto the UAV which then traces its way back by means of a paired sensor device. UAVs are also quite efficient during the time of emergencies. They are able to rapidly transport first aid boxes to remote regions. A torch coupled UAV can help light dark pathways as in the case of mining industries.

Real-time alteration of product during production

UAVs are capable of providing unique features of customization. It allows the customer to participate and personalize their product. UAVs stationed at every sector of the production process respond to changes in the custom content. At any given time, the customer is able to alter or replace the components of the product. There has been an exponential increase in the rate of product replacement due to the rapid progress in technology. The life-cycle of an item has severely been reduced, for example a mobile phone released this month is quickly replaced by its upgraded version. Should this rate continue to increase the same way, industries will eventually have to resort to changes made even as the product is being manufactured. The customer will be able to track the product whilst viewing and visualizing his/her idea before production. Apps and various forms of augmented reality make for the most customizable experience.

5.3 Transportation

Goods that are produced, have to be transported. In 1970, robots were used in storage systems. These robots were responsible for inward and outward movement of pallets or good containers. However, these types of machines are limited in terms of capacity and alternative storage systems were needed. For this reason, over the past ten years, the usage of smaller and more mobile robots is reasonable. [44]

For a few years, automatically-guided vehicles (AGVs) have been used for internal transport. This was only possible, under the consideration of fixed and pre-programmed routes. Through CPS, in combination with smart sensors and vision technology, a better generation of AGVs is emerging.

Of course, the type of UAV as presented in chapter 2, is not designed for the indoor transportation of goods. The usual weight of objects should be less than 5000 g. Therefore, another scale of UVAs is needed.

Many companies have already realized the trend and are trying to benefit from this grand new market. Amazon, DHL, Hermes and Daimler Inc. will be using UAVs to deliver packages outdoor (for example from the vehicle, to the customer's door) by 2018. On the other hand, companies, such as Audi Inc., started a pilot program to transport goods indoor during manufacture. The "Frauenhofer-Institut for the flow of material and logistic IML" has a unique idea of the future transportation of goods in the intra-logistics.

The idea is simple: Whenever it is possible the transportation system rolls. If there is an obstacle that impedes its movement, it takes off and continues the delivery through the air. This concept is energy efficient. At the same time, the frame (the surrounding in the form of a ball) secures people and enables an integrated human to machine environment. On the other hand, the sensitive components such as rotors are safe at the same time. Due to this concept, more than one Bin: Go UAV can work together with more than one person simultaneously.

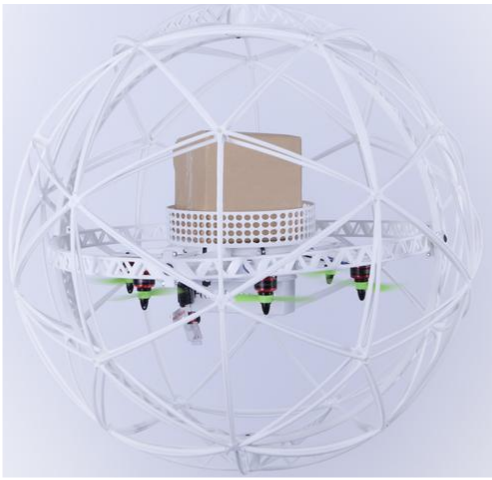


Figure 17: Bin: Go transportation UAV by "Frauenhofer Institut"

The UAV, as it is shown in Figure 17, weighs about 1500 grams. It is designed for the in-house transportation of small goods with a weight up to 700 grams. Upon call for a transfer order, the UAV is loaded with the package and the destination data is entered. The UAV is able to find its own way autonomously. For the most part the UAV is locomotive on the ground. To overcome differences in altitude, obstacles or reach high racks the UAV can fly. For downwards movements the UAV is rolling on rails using gravity. Therefore, this technology is more flexible and scalable than previous solutions such as pneumatic delivery or comparable transportation systems. Furthermore, the UAV has a low-maintenance and the process cycle in more reliable. [45]

5.4 Monitoring and maintenance

Industrial welfare often revolves around the robustness of the infrastructure, a factory that is ill-built gives way to high risks, some that may result in fatalities. As a measure of prevention, industries employ regular monitoring methods and safety checks. In collaboration with ongoing doctoral research conducted by Tran Hiep Dinh, the following idea involving the use of UAVs is presented. The project is demarcated into two distinct modules. The first, to collect data by means of a laser scanner and an RGB-D camera, the latter, to run the acquired data through a series of image processing techniques.

The algorithm in use converts the obtained RGB image to a greyscale image. This banalization of the captured surface under review, provides ease of discerning intensity peaks on close inspection of the image histogram. Global and adaptive thresh holding methods are applied to distinguish the foreground and background information from each other. They are then segregated for further examination. A Hessian filter superimposed onto the resultant image can remove noise and segment three-dimensional line like features. These features are synonymous to cracks that are present on the surface of the structure. Additionally, region growing algorithm is used to enhance the whole process of segmentation.

The following Figure 18 visualise the change from a picture taken by a digital camera on the left side and converted into a binaries picture on the right side.

Figure 18: Test picture for crack detection

The crack detection result is shown on the left part of the figure. Two cracks are distinctly visualized. However, the properties of the crack in the middle of the picture are not as clear as the crack in the bottom right side. For a better solution a further research about the locally adaptive thresholding method has to be done as described in source [46].

5.5 Customization

The global market for customisation of goods and services has seen a rapid growth. Industries are required to cater to individual product customisation to maximise their revenue. The competition to better customer satisfaction puts customisation at the forefront. The higher the degree of customisation the greater the profit. The ability to tweak and personalise an object greatly increases its value and demand. For this very reason, the introduction of UAVs in unison with industry 4.0 could be profoundly advantageous. The customer is given superfluous control over the amount of installable custom content. The future of smart industries allows the customer to purchase the product and participate in its production.

The following Figure 19 shows an example drone manufacturing process that involves the use of UAVs.

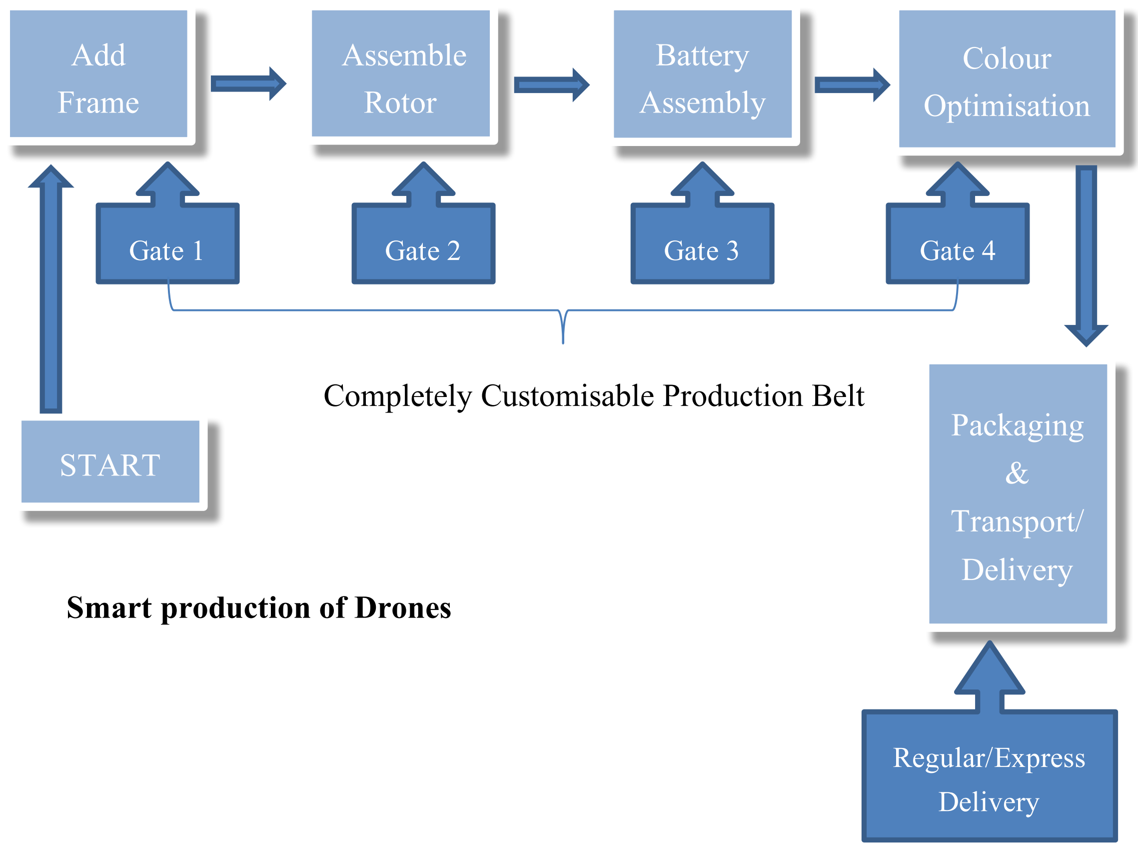


Figure 19: Degree of Customization

The production line is a series of machinery that carry out specific tasks with the help of UAVs that pilot the surrounding area. The industry even has the capacity to customise the use of the UAVs based on their level of investments or allocation of finances. This example of drone production shows different factory equipment working on the product's various components.

Each stage has its own significant gate. These gates work as a portal for customisation of the drone at its respective position. The production belt has the following assembly line: frame, rotor, battery and console colour optimisation. At every gate of this process, the elements of the drone can be altered by the customer by means of the UAV via the internet. It is possible to station the UAV in multiple ways. For example, a single UAV can be stationed and called to make adjustments or transport products from designated area or multiple UAVs can be stationed at every gate, performing specified tasks.

The customer is given command over the entity as a whole. This implies he/she is fully aware of the location and aesthetic of the product with respect to its stage in production and is able to make changes, should the outcome be less than preferred.

At the end of the production line is the package and transport to delivery platform. Even at this stage the customer is given the option of selecting the kind of packaging and the method of delivery. This method of customisation is more suited for industries willing to provide express delivery methods.

6 Occupational health and safety

Due to the introduction of Industry 4.0, processes will be automated continuously by utilizing robots, machines and UAVs. However, humans most likely will always be present and assume an important role during the production process. The "Verband Deutscher Maschinen-und Anlagenbau (VDMA)" or English "Mechanical Engineering Industry Association" published a paper in March 2014 about the robot density to measure the degree of automation. In 2012, 10.000 employees and 273 robots have been counted. Regarding to the study, Germany was at this time the third most automated country behind Japan and Korea. [47]

Therefore, the collaboration between humans and machines is indispensable. The focus in this chapter is to define the risks for human machine interaction in which the human safety is of the highest priority.

6.1 Ranking risks based on a Survey of field specialist

To define the risks and their impact, an investigation with the Benefit Analysis is realized. 12 PhD students have been interviewed on what they believe are the most significant risks regarding the safety of humans. All subjects currently pursue research in different fields of employing UAVs.

The Benefit Analysis is called Cost Benefit Analysis (CBA) in consumption to cost decreasing. For this research, as it is a nonmonetary analysis, the wording value benefit analysis is more appropriate.

Value benefit analysis is a method to rank criteria's. The result can be diverse, depending on the subjective input of the participants. The criteria is listed on the basis of methods to reach the target value. First, a paired comparison as is shown in Figure 20 rates each criteria from one (less important) to ten (very important). Once all criteria are related to each other, a weight is added.

Paired comparison for risks regarding UAV													
For each cell: If the horizontal (left) Criteria is more important than the vertical (top) a "+" is given, else a "-".													
No.	Type	Criteria name	Comparison to 'type'									Sum der "+"	Factor g_i="+"/Σ"+"
			1	2	3	4	5	6	7	8	9		
1.	HR	Injury of the operator		+	+	+	+	+	+	+	+	8	0.222
2.	HR	Complexity of changes	-		-	-	-	+	-	-	+	2	0.056
3.	FR	Government regulations	-	+		-	-	-	-	-	-	1	0.028
4.	HR	Operator overstrained due to environment	-	+	+		-	+	-	+	-	4	0.111
5.	HR	Replacement of the opperator by the UAV	-	+	+	+		+	-	+	-	5	0.139
6.	HR	Noise pollution	-	-	+	-	-		-	+	-	2	0.056
7.	FR	Investment	-	+	+	+	+	+		+	-	6	0.167
8.	FR	Insurance	-	+	+	-	-	-	-		-	2	0.056
9.	HR	Cyber security	-	-	+	+	+	+	+	+		6	0.167
												Σg_i =	1.000

Figure 20: Paired comparison for risks regarding UAVs

The results of the table show that the safety of the operator is more than 22% the most important criteria. Followed by investment and cyber security. What's interesting is the fact that all participants think, human risks (HR) are as important as or even more important than financial risk (FR).

The following Figure 21 compares the UAV and the AVG in the manner of risk. Based on the previous weightage the risk can be quantified for each criterial. The degree of importance is variable from one (very important) to five (least important) and the cumulative summation depends on subjective point of views. In this case, the 12 PhD students, which have been also interviewed for Figure 20, responded that the injury is in both concepts highly important. However, for AGVs, Cyber security is less important than for UAVs.

Overall, both concepts are around 3, 3 as a total number of risk quantification. The improvement in cyber security would decrease the risk and the make UAVs more suitable. This is further discussed in the discussion in chapter 7.

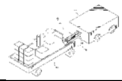
		Concpt 1				Concpt 2			
Compareison UAV and AGV		Using UAV 				Using AGV 			
No.	Criterial for Benefit Analysis	Degree of importance	Ranking	Weightage	Risk quantifier	Degree of importance	Ranking	Weightage	Risk quantifier
1.	Injury of the operator	1	5	0.22	1.11	1	5	0.22	1.11
2.	Complexity of changes	4	2	0.06	0.11	3	3	0.06	0.17
3.	Government regulations	3	3	0.03	0.08	4	2	0.03	0.06
4.	Operator overstrained due to environment	5	1	0.11	0.11	3	3	0.11	0.33
5.	Replacement of the opperator	3	3	0.14	0.42	4	2	0.14	0.28
6.	Noise pollution	3	3	0.06	0.17	2	4	0.06	0.22
7.	Investment	4	2	0.17	0.33	2	4	0.17	0.67
8.	Insurance	3	3	0.06	0.17	4	2	0.06	0.11
9.	Cyber security	1	5	0.17	0.83	4	2	0.17	0.33
Cumulative Sum. Σ			3.00	1.00	3.33		3.00	1.00	3.28

Figure 21: Risk comparison of UAV and AGV

6.2 Risks by using UAVs

The commitment of UAVs will bring many risks for operators. The three most important dangers have been chosen from the survey which are:

R1. Operators get injured by UAVs

R2. Cyber security manners

R3. Operator's preliminary work is replaced by the UAVs

The first named risk is obviously the most dramatic scenario. The operator has to be secured under any circumstances. This could occur, when the UAVs power system switch off. Also a part of the UAV or the transported good can hit an operator on the ground. Even if the UAV's performance is impeccable, operators could cross their way and cause an accident.

The second listed risk describes cyber-attacks. Due to the fact that a greater amount of data and more gateways are needed, the danger increases. Customers are gaining access and they are able to view and visualize their product in the factory environment. On the other hand, the future of data collection will be managed with cloud computing. All information will be stored in the internet or intranet and hacking attacks become the greatest security threat for personnel data.

The third risk explains a process flow, in which the operator only assume a supporting role and the actions depend on the UAV. The production process is planed towards utilizing technology and without the possibility of technology the process flow breaks down.

6.3 Solutions for a safe application of UAVs

The following examples provide ideas to solve the risks, before they take effect. The following solutions concern the risks mentioned in Chapter 7.2.1 and are defined as:

S1. Integrate sensitive sensors to prevent collision

S2. Higher security systems

S3. Collaboration between humans and UAVs are clearly defined in working instructions

Basically, the changes by implementing UAVs brings different type of risks which cannot be known by now. However a general reorganization of the plant layout would prevent this risk of high cost for adapting a process flow towards a specific technology, as shown previously in this chapter. Since production is a continuous improvement process, new technology has been brought into an exciting concept. The fourth industrial revolution could change this dramatically. This imply placing of all objects which are necessary in the production process as reverse planning by focusing on UAVs.

The future factory will be loaded with integrated sensitive sensors. The UAV has to avoid obstacles and decrease in case of an accident the impact of the damage to a minimum. Fly paths should cross food path only if unpreventable. The surrounding of the UAV should not have sharp edges and the used material must be able to withstand the force of an impact. The surrounding or frame also isolates the UAV and secures the operators from releasing parts such as lose propeller.

Another essential reason that challenges the implementation of UAVs is cyber-crime. For a safety of employees recorded operators face should be unrecognizable. A sign has to rout the areas of observation. There has to be a process optimizable reason and not a control function. The online shared data has to be secured with an end to end coded key and furthermore signed with a digital signature.

To guarantee the future role of operators in the manufacture the final decision have to be approved by a control button. At any time, the operator has to be able to cancel the running process over remote. All operations should also be managed without using the UAV.

7 Discussion and conclusion

7.1 Discussion

Data security

With Industry 4.0 companies are becoming more connected worldwide. Machines are built locally where it is most beneficial to customers in their planed environment. The adjustment time is reduced significantly and the machines stay connected with the mechanics so that they have the knowhow. In case of problems, remote diagnostics can be made by reading data and analysing them. A wrong use of the machine can be detected by viewing the data history. [48]

However, many companies are trying to resist these changes. As it is mentioned in chapter 0, many companies have been attacked by cybercrime. For a functioning concept of Industry 4.0 sensitive data have to be exchanged over the internet. If this data gets published, the company can go into bankruptcy. For example, parameters for the machine adjustment, construction plans or strategic views of mandatory removal of employees. This would bring fear to stakeholders. This would remove their capital and the injured company will be bankrupt soon.

Digital signature

One way to increase the security of delivering data is the digital signature. This cryptic coding of massages or data can be distinct in symmetrical and asymmetrical coding. With symmetrical coding the transmitter and receiver are using the same encoding and decoding key. Therefore, the medium for the exchange has to be equal. Since both participants are using the same key, it is not possible to detect which user misbehaves.

For the asymmetrical coding, every participant is coding two keys. One is public and the other one secret. The unknown key cannot be decoded in real time. To implement the digital signature, the reverse of asymmetric coding is used. The key to review a signature is public. However, the key for the signature has to kept secret.

Many companies are about to or have already have invented the digital signature for higher security in transmitting data.

7.2 Conclusion

The purpose of this project was to design a concept of 'smart' utility and a framework of algorithms to effectively implement Industry 4.0. An algorithm will be developed and used to introduce the use of Unmanned Ariel Vehicles to perform transportation and handling of intralogistics. Simulation is pending to prove that the concept is more cost-effective and time efficient than other forms of design to structure a smart factory.

To convey an overview of the current situation, a literature review has been realized. The literature review suggests that many companies are not practically applying Industry 4.0. Furthermore, the use of UAVs in the intralogistics is still in its infancy and not implemented yet. A minority of industrial companies are researching in the field of utilizing the UAV.

The simulation example with Tecnomatix Plant Simulation has shown that the program is not ready yet to apply the ideas of Industry 4.0. The machine to machine communication cannot be coded. Even if there is a possibility to code with SimTalk, the machine is unable to request the status of other objects in the process environment.

An alternative to implement Industry 4.0 is the use of UAVs combined with communication technology such as RFID. A plant layout has been created to visualize how the shared environment with humans and UAVs could appear. Different fields of application have been discussed. Customization of products is one of them. The idea is for it to enable the customers need to change, view and track (visualized) during the production process. A concept was presented to insert gates to define different stages of the process.

To identify the risks by utilizing UAVs in the intralogistics together with operators, a survey with 12 PhD students has been accomplished. Based on a paired comparison, the results show that the protection of humans is most important followed by cyber security and investment. Additionally, a comparison to Automatically Guided Vehicles has confirmed that in total the estimated risk is not significantly higher.

These advantages will create a more functional method to mass production and assist companies to transition into a smart factory. Utilizing UAVs can reduce cost and time for companies who want to be smart factories. Currently, companies are spending 10 to 20 percent excessive in logistic costs and 20 to 30 percent excessive in maintenance cost [49].

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Appendix

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Erklärung zur selbstständigen Bearbeitung einer Abschlussarbeit

Gemäß der Allgemeinen Prüfungs- und Studienordnung ist zusammen mit der Abschlussarbeit eine schriftliche Erklärung abzugeben, in der der Studierende bestätigt, dass die Abschlussarbeit „– bei einer Gruppenarbeit die entsprechend gekennzeichneten Teile der Arbeit [(§ 18 Abs. 1 APSO-TI-BM bzw. § 21 Abs. 1 APSO-INGI)] – ohne fremde Hilfe selbständig verfasst und nur die angegebenen Quellen und Hilfsmittel benutzt wurden. Wörtlich oder dem Sinn nach aus anderen Werken entnommene Stellen sind unter Angabe der Quellen kenntlich zu machen.“

Quelle: § 16 Abs. 5 APSO-TI-BM bzw. § 15 Abs. 6 APSO-INGI

Dieses Blatt, mit der folgenden Erklärung, ist nach Fertigstellung der Abschlussarbeit durch den Studierenden auszufüllen und jeweils mit Originalunterschrift als letztes Blatt in das Prüfungsexemplar der Abschlussarbeit einzubinden.
Eine unrichtig abgegebene Erklärung kann -auch nachträglich- zur Ungültigkeit des Studienabschlusses führen.

Erklärung zur selbstständigen Bearbeitung der Arbeit

Hiermit versichere ich,

Name: Emad

Vorname: Bardia

dass ich die vorliegende Masterarbeit – bzw. bei einer Gruppenarbeit die entsprechend gekennzeichneten Teile der Arbeit – mit dem Thema:

Operational scenarios that implement Industry 4.0 by utilizing UAVs

ohne fremde Hilfe selbständig verfasst und nur die angegebenen Quellen und Hilfsmittel benutzt habe. Wörtlich oder dem Sinn nach aus anderen Werken entnommene Stellen sind unter Angabe der Quellen kenntlich gemacht.

- die folgende Aussage ist bei Gruppenarbeiten auszufüllen und entfällt bei Einzelarbeiten -

Die Kennzeichnung der von mir erstellten und verantworteten Teile der Masterarbeit ist erfolgt durch:

Hamburg	25.09.2017	
Ort	Datum	Unterschrift im Original