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Designing Smart Information Services in Automotive Production

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AUDI HUNGARIA Zrt.

Audi Hungaria

AFFIDAVIT

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ABSTRACT

In cooperation with Audi Hungaria in Györ an information service has been designed, implement and evaluated within a Proof of Concept. Audi Hungaria approached the Technical University of Graz with the target to identify the most promising use cases, areas of applications and technologies that lead to an improvement of their business processes in production. Based on a research on existing use case and technologies and guided by the Use Case Technology Mapping Framework (Vorraber et al., 2014) the most promising use cases were identified, described and visualized by applying Value Proposition Design. After that, the use case "Maintenance Assistance" was selected and requirements were specified. Based on the specified requirements and defined criteria the respective technology was selected by applying a Value Benefit Analysis. Finally, a prototype for the Proof of Concept was implemented and evaluated within an experiment conducted at Audi Hungaria in Györ together with several maintenance engineers of Audi Hungaria. The theoretical part of the thesis describes the applied frameworks such as Service Design, the Use Case Technology Mapping Framework, Value Proposition Design and the approach of Value Sensitive Design.

KURZFASSUNG

In Kooperation mit Audi Hungaria in Györ wurde ein Informationsdienst entworfen, implementiert und im Rahmen eines Proof of Concept evaluiert. Audi Hungaria ist an die TU Graz herangetreten, mit dem Ziel die vielversprechendsten Anwendungsfälle und Anwendungsgebiete zu identifizieren, die zu einer Verbesserung ihrer Geschäftsprozesse im Bereich der Produktion führen. Basierend auf einer Recherche von Anwendungsfällen und Technologien und geleitet vom Use Case Technology Mapping Framework (Vorraber et al., 2014) wurden die vielversprechendsten Anwendungsfälle identifiziert, beschrieben und unter Anwendung von Value Proposition Design zusammengefasst und visualisiert. Anschließend wurde der Anwendungsfall „Maintenance Assistance“ ausgewählt und die entsprechenden Anforderungen spezifiziert. Basierend auf diesen Anforderungen und zusätzlichen Kriterien wurde mit Hilfe der Nutzwertanalyse die entsprechende Technologie ausgewählt. Schlussendlich wurde ein Prototyp für das Proof of Concept implementiert und im Rahmen eines Experimentes, das bei Audi Hungaria gemeinsam mit Wartungstechnikern durchgeführt wurde, evaluiert. Der theoretische Teil der Arbeit umfasst die angewandten Frameworks, wie Service Design, Use Case Technology Mapping Framework, Value Proposition Design und Value Sensitive Design.

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Köszönöm!

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ABREVIATIONS

AG	Aktiengesellschaft
Zrt.	Zártkörűen működő részvénytársaság (geschlossen AG)
AH.	Audi Hungaria
VW	Volkswagen
VPD	Value Proposition Design
VPC	Value Proposition Canvas
VSD	Value Sensitive Design
ICT	Information and Communication Technologies
IT	Information Technologies
SDLC	Systems Development Life Cycle
AR	Augmented Reality
HMD	Head-Mounted Display
ERM	Entity Relationship Model
UML	Unified Modelling Language
CIO	Chief Information Officer
POC	Proof of Concept
OEE	Overall Equipment Effectiveness

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1 Introduction

As this thesis was conducted in close cooperation with Audi Hungaria, a short introduction to the company is given. Furthermore it is explained why Audi Hungaria approached the TU Graz to support them in identifying and designing information services to improve their business processes in the area of engine production.

1.1 Company Description

Audi Hungaria is located in Györ, Hungary. It is the biggest engine factory in the world. In 2015 more than two million engines have been produced. Varying from four cylinder up to even twelve cylinder engines. Their customers are companies belonging to the Audi or Volkswagen group, such as Volkswagen AG in Wolfsburg (Germany), SEAT,S.A. in Martorell (Spain), Dr. Ing. h.c. F. Porsche AG in Stuttgart (Germany) and SKODA AUTO a.s. in Mlada Boleslav (Czech Republic). Besides that, also various models of cars such as the Audi TT and the Audi S3 are produced at the Györ site. Soon also the series production for the Audi Q3 will start. In 2016 the one-millionth car had been produced at Audi Hungaria.
In total more than 11000 people are employed by Audi Hungaria. It all started in 1993 by signing the agreement for purchasing the industrial site in Györ. Already in 1994 the first engines were produced. In 1998 the assembly of the Audi TT Coupe started. Since that the company is continuously growing and expanding its portfolio.(AUDI AG, 2017)

The main partner of this project at Audi Hungaria was the IT department "IT Motor (G/FP-3)". This department is responsible for supporting the process of engine production by providing and managing IT solutions and services.

1.2 Problem and Motivation

In general, the entire automotive industry is undergoing a substantial change and companies have high pressure in being innovative to stay competitive. Many ideas for improving processes exist in the heads of various employees of various departments. The problem is that it is difficult to try out and evaluate ideas, to find out what is best or most promising, besides the daily work due to a lack of time and resources. Therefore, the idea was to conduct an innovation project in cooperation with TU Graz to let students evaluate ideas and find out what could improve their business processes significantly.

1.3 Objectives

The first task was to contribute to a research of use cases and technologies, that was already started by colleague Johannes Viktor Gasser, to get a comprehensive overview of existing ideas and solutions. Based on that and guided by the UCTM Framework throughout the whole project the most promising use case should be selected for the implementation of a prototype and the evaluation in a Proof of Concept by also applying the approaches of Service Design and Value Sensitive Design. All used frameworks and tools should be documented for reusing them in further innovation projects conducted by Audi Hungaria.

2 Frameworks

This chapter describes the characteristics of Service Design. Selected tools and methods that have been applied within the project, to support the Service Design approach, are described in more details. There are many other tools and methods available in this area, which will also be listed but not described in further details.

2.1 Service Design

Before going into the details a short introduction about Service Design is given. Later the five principles of Service Design and the underlying process is described including a list of tools that can help to apply Service Design in practice.

2.1.1 What is Service Design

First of all the term “Service Design” consists of the noun “Service” and the verb “Design”. In an economic environment, a “Service” is defined as transaction of immaterial goods from provider to customer (Gabler Wirtschaftslexikon, 2017).
In the past, everything was focused on the moment of sale, where a physical product is sold to a customer. The “Service” has been seen as something that comes after sales. A product and a service were clearly distinguishable. This is the so-called Goods-Dominant Logic where the value is in the exchange. (Mager, 2008)

The new thinking is focusing on the End-to-End experience of the customer. For the customer it does not matter if it is a product or a service. In a Service-Dominant Logic, the focus is on value in use and value co-creation.(Stickdorn et al., 2011)

One example for that is the Rolls Royce Turbine “Power-by-the-hour”, where a complete engine including maintenance was offered as a service by paying a certain amount of money per hour in use, instead of selling the engine to customer and offering each maintenance service on demand.(Rolls-Royce, 2012)

“Design” can be seen as process of designing something. In former ways, it was seen as an isolated discipline besides marketing, IT or sales. The focus was on making a product look good. Within “Service Design”, it becomes inter-disciplinary. The role of the designer changes from a person in an isolated environment, to person that becomes a facilitator, who needs to encounter all touch points and channels with the service to achieve a great customer experience along the whole customer journey with a seamless experience on all channels. If the experience matches or even over exceed the expectations of the customers, they will be satisfied.(Stickdorn et al., 2011)

There are several definitions on “Service Design” existing. As Service Design is more seen as new way of thinking, than as a discipline on its own. A unique definition of it is not really required and therefore has not yet been agreed on. Most of existing definitions have a few things in common. As already mentioned before it is often defined as a new way of thinking that is interdisciplinary. Therefore, it is crucial to agree on a common language between the different involved people from various disciplines or especially in companies of various departments, which all tend to have their own language focused and specialized on their field of expertise. According to existing definitions, Service Design focuses on the benefit to the end-user experience. The user needs have to be the leading element by creating a service that shall be perceived as useful, usable and desirable by the end-user. It should create value in society by helping to innovate new or improve existing services. Finally, if two comparable services are offered it shall make the difference why the one is preferred to the other by the customer.(Stickdorn et al., 2011, p.28ff)

2.1.2 The 5 Basic Principles of Service Design

From the previously described “definition” of Service Design, the following five principles that Service Design is built on, have been derived.

Service Design is (Stickdorn et al., 2011):

- **User centred**
  The customer is in the centre of the process and understanding the customer is crucial to the success.

- **Co-creative**
  All different stakeholders shall be considered and involved in creating the service. To identify all service propositions and to gather all different ideas from various people, it is crucial to create a safe space, where people feel secure to open their mind to others.

- **Sequencing**
  The process of the service is deconstructed into touch points, which represents interaction with the service. It is distinguished between pre-, actual- and post-service. Not only front stage processes, also processes that are running backstage have to be considered.

- **Evidencing**
  Especially for services that run in the background and are intangible, a physical evidence or an artefact can help to improve the customer experience. They can act as an excellent anchor point for storytelling if customers can use them e.g. a bottle opener as a gift when leaving the airplane.

- **Holistic**
  Always try to keep the big picture by considering a wider range of service aspects. Do not miss any of the stakeholders and think outside given boundaries, as those

boundaries might not exist any longer in the future. Try to really understand touch points with senses, by also taking the customer culture into account.

2.1.3 The Iterative Service Design Process

The method applied in Service Design is an iterative process that consists of following 4 phases (Stickdorn et al., 2011):

- **Exploration**
  The goal of this phase is to understand the customer and his/her situation.

- **Creation**
  This phase focuses on exploring as many mistakes as possible before starting prototyping.

- **Reflection (Quick prototyping)**
  In the "Reflection" phase, prototypes that are close to reality shall help to get reliable feedback from customers on their experience of the service.

- **Implementation**
  Finally, in the last phase the new or improved service shall come to operational use, which usually requires a process change.

Iterations through the different phases, depending on the aspect of the service that is currently worked on, can happen within days, hours or even minutes. One underlying concept is "Trial and error". Figure 1 illustrates that this is not always a straightforward approach.

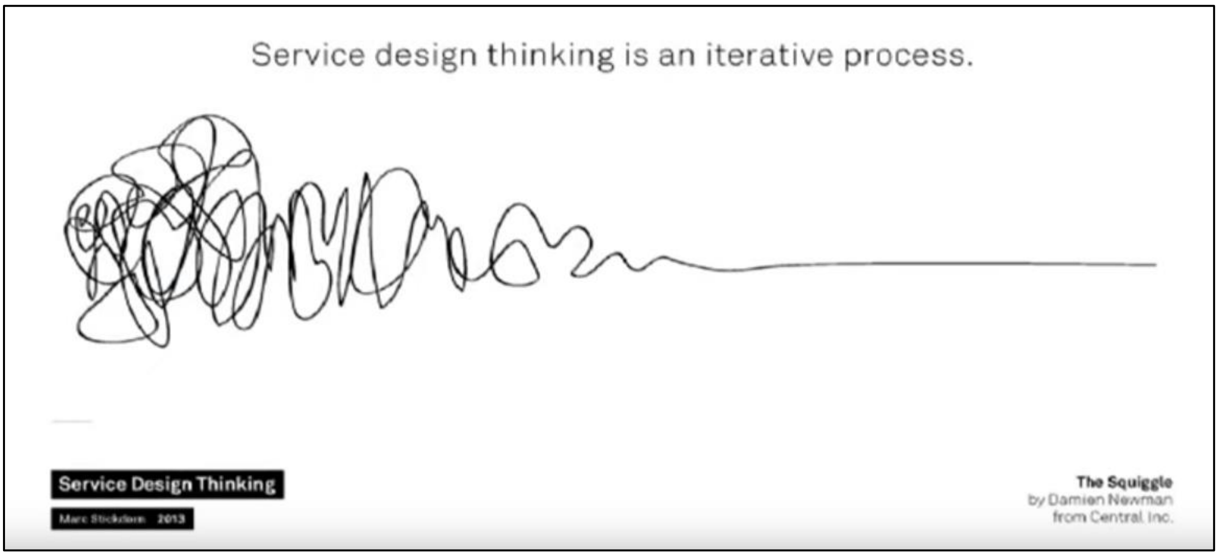


Figure 1: Service design thinking is an iterative process (Stickdorn et al., 2011)

2.1.4 Tools Related to the Process Phase

Following tools can be used to achieve the goals of each phase. Not all of them have to be applied. It is suggested to try them out to get an better idea of how they can be applied and for a specific project select the tools that fit best to the team and environment the project is conducted in (Stickdorn et al., 2011):

Exploration

- Stakeholder Maps
- Service Safaris
- Shadowing
- Customer Journey Maps
- Self-exploration - try out the service
- Observation
- Contextual interviews (in the context of the service interaction)
- The five whys
- Cultural probes
- Mobile ethnography
  - e.g. diary on phone or application “ExperienceFellow” (More than Metrics GmbH, 2017)
- A day in the life
- Expectation maps
- Personas (ad hoc, data driven) describes a concrete person

Creation/Reflection

- Idea generation
- What if…
- Design scenarios
- Storyboards
- Desktop walkthrough
- Service prototypes (“Quick and dirty” e.g. blueprint + Lego)
- Service staging
- Agile development
- Co-creation

Implementation

- Storytelling
- Service Blueprints
- Service Role-play
- Customer Lifecycle maps
- Business Model Canvas

2.2 Applied Tools and Methods within the Project

The following tools and methods have been applied within the project. The theoretical background is described in the following chapters. Whereas the results gathered with those tools are described in chapter 4.

2.2.1 The UCTM Framework

The whole project was guided by UCTM Framework (Vorraber et al., 2014, p.1268) shown in Figure 2. By following the three-step approach of the UCTM Framework first, a research on existing use cases in industrial environments was conducted. In the second step, those use cases where abstracted, classified, and documented in a structured way to be able to compare them and extract the relevant information. As third step technologies, including concrete products, where mapped to the use cases to find out what are the related technologies and products to the identified use cases.

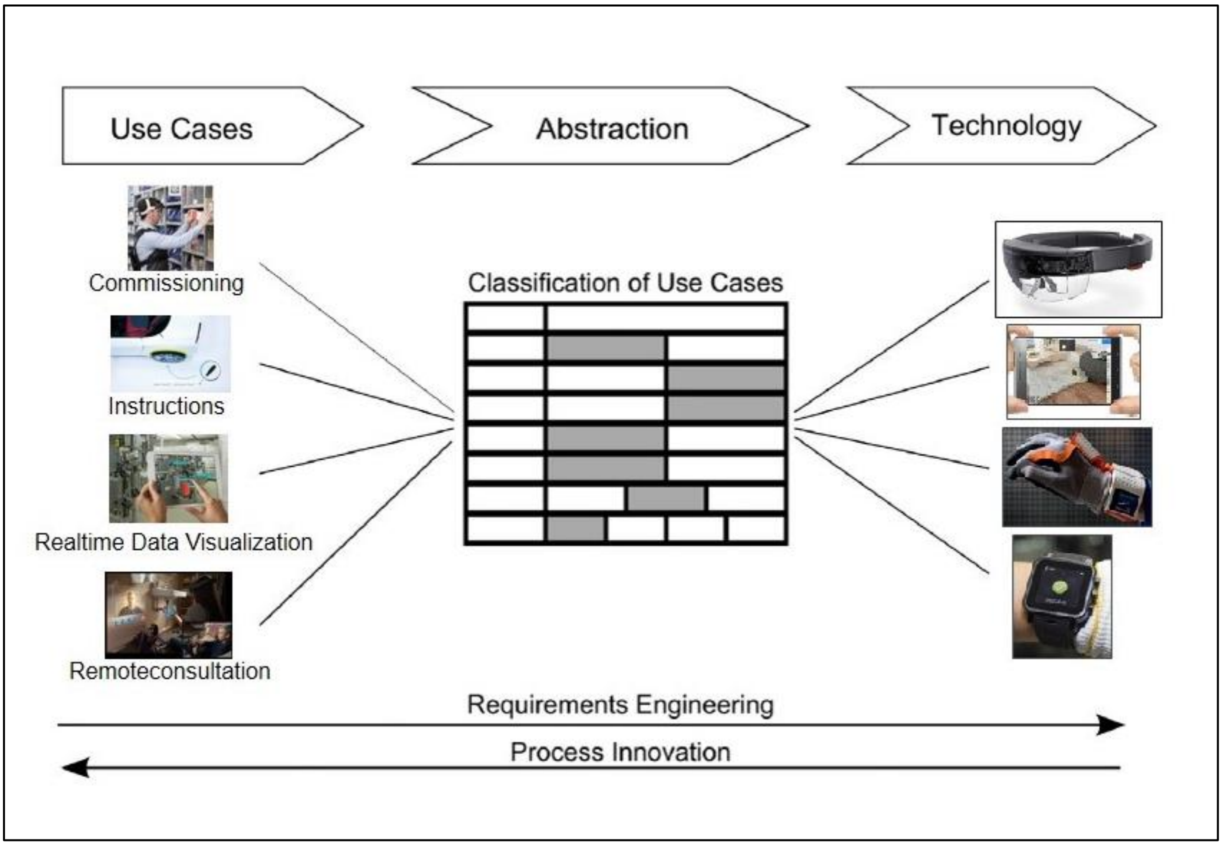


Figure 2: Use Case Technology Mapping Framework (Vorraber et al., 2014, p.1268)

The result was a big table of information. The next step was to identify the underlying value propositions and structure them in a comprehensive way to be able make a decision on which area the focus should be put. For this purpose, the tool Value Proposition Design was selected which is described in the next chapter.

2.2.2 Value Proposition Design

Value Proposition Design is a tool that shall help to design, test and provide products that customers really want and need. It focuses on the customer. That means the focus is on the creation of value for the customer instead of focusing on products and their features. This shall help to avoid product developments that nobody wants or needs. Additionally, applying this concept helps to generate a common understanding, between supplier and customer and in general between all stakeholders of a project, of good value proposition.(Osterwalder, Pigneur, Bernarda, & Smith, 2014)

To achieve this, two areas of the Business Model Canvas, see Figure 3, are extracted and described in more details. Those two areas are the “Value Propositions” and the “Customer Segments”, which are shown in Figure 4.

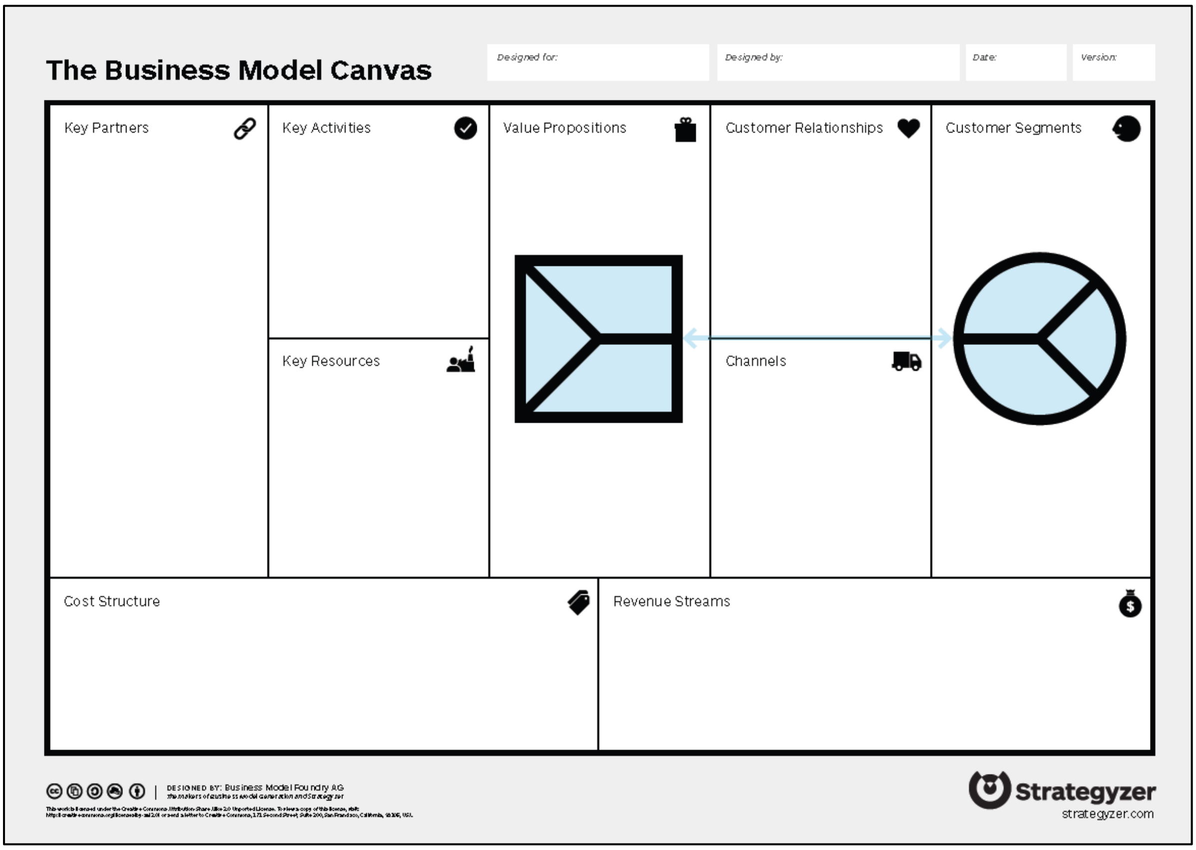


Figure 3: Business Model Canvas (Osterwalder et al., 2014)

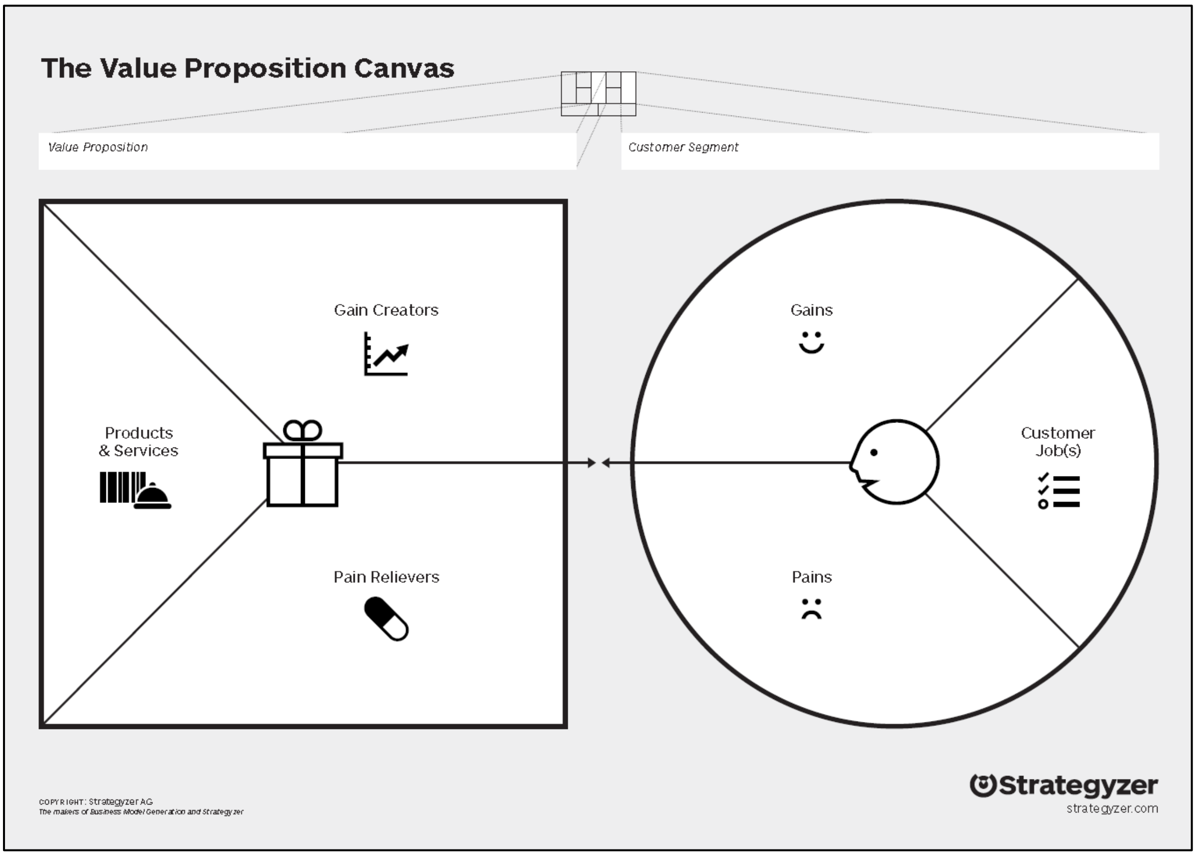


Figure 4: The Value Proposition Canvas (Osterwalder et al., 2014)

The segment “Value Proposition” consists of following three aspects (Osterwalder et al., 2014):

- **Products and Services**
  Includes all products and services that are required to provide the described pain relievers and gain creators. Products and services can be rated according their relevance to the value proposition.

- **Gain Creators**
  Gain creators shall describe how exactly the outcomes and benefits for the customers are created by the products and services. A rating by relevance can be done according to how relevant the produced outcomes and benefits are.

- **Pain Relievers**
  Here it is described in detail how the listed products and services address specific customer pains. They might be rated by relevance according to the value they provide for the customer.

The “Customer Segment” consists of following three aspects (Osterwalder et al., 2014):

- **Customer Job(s)**
  Describes the jobs, tasks and activities of a customer. Things he or she wants or needs to get done. It is crucial to describe this from the customer’s perspective or even better

ask the customer to describe it. Additionally, if different jobs, tasks or activities are described it is also possible to rate them by importance, to be able to focus on the important ones.

- **Gains**
  Describes benefits and outcomes. Some of them are required, some are expected and some might be expected. Can also include gains that are not expected. Gains might be rated by relevance, to ensure if the most relevant gains are addressed.

- **Pains**
  Within this section, annoying things for the customer are described. Things that prevent a customer to get his job done or undesired outcomes. Pains can be rated by severity, to later see if the ones with higher severity are addressed or not.

As a next step, a mapping between the two segments has to be conducted. The mapping shall indicate how many of the gains and pains are addressed by the value proposition's gain creators and pain relievers. A high match indicates the product or service that shall be developed tends to result in a product or service that the customer wants and needs.(Osterwalder et al., 2014)

Within the project the VPC was used to sum up the use cases and technologies as value propositions and map them with different customer jobs of different main departments.
Details about that are described in chapter 4.1 of the case study.

2.2.3 V² Value Network Notation

The V² Value Network Notation, which is partly based on (Biem & Caswell, 2008),
is used to visualize actors, their value exchanges, their motivation, and influences (Vorraber & Voessner, 2011). Additionally, it also covers various forms of non-functional requirements to facilitate planning and design and to cover ethical aspects (Vorraber, 2016). Figure 5 gives an overview of how actors are described according to the V² Value Network Notation.

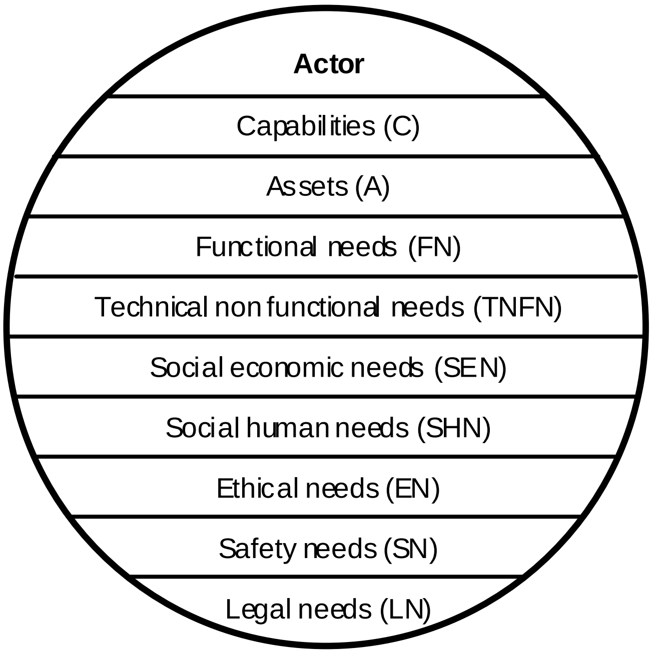


Figure 5: Representation of an actor in the V² Value Network Notation (Vorraber, 2016)

Following aspects can be described for an actor of the V² Value Network Notation (Biem & Caswell, 2008), (Vorraber, 2016):

- **Capabilites**
  Specific activities or processes of the actor can be described here.
- **Assets**
  This describes anything that is in possession of the actor, such a goods, knowledge, or budget.

In addition to capabilities and assets the aspects of various needs can be described (Vorraber, 2016):

- **Functional needs**
  Describes any functionality that is required to fulfil a certain task.
- **Non-functional needs**
  This part describes human needs and can be used to model values as described in Value Sensitive Design in chapter 3. Non-functional needs are further distinguished into following groups to represent the different aspects of human needs.

    - Technical non-functional needs
    - Social economic needs
    - Social human needs
    - Ethical needs
    - Safety needs
    - Legal needs

The practical application of the Value Network Analysis is part of the Case Study and is shown in chapter 4.5.

Why paying attention to non-functional requirements and especially ethical aspects is important and crucial for the successful implementation and operation of a new system is described in the following chapter.

3 Value Sensitive Design

VSD states to have as an overall target, the creation of technology that helps us to be better human beings. It is a theoretical approach of how to design technology, systems or products to achieve the previously mentioned target and was introduced in the field of ICT, which is still its main area.(Friedman, Kahn Jr, Borning, & Huldtgren, 2013)

Ethics itself has changed a lot in the past, beginning in the 20th century. In parallel, a similar development can be observed in the field of ICT. In the sixties and seventies, not much attention was put on the social and organizational context of where ICT applications have been deployed. The technology was new and fascinating. That was enough to justify its usage. Later, in the eighties and nineties, after a lot of projects failed, it was realized that there are users, human beings, who interact with those applications and their requirements should be considered in the development of applications. Nowadays, the needs of humans, values of people, groups or even society are starting to drive research and development.(Van den Hoven, 2007, p.71f)

Just to outline how important the consideration of values can be for a successful design of a system and how close the relation between IT and moral values can be, following example is given. The project covered a real time audio and video link system for firefighters to directly get support by emergency medicine experts. From a technical and functional perspective, everything worked perfect. During the design of the system the different roles of firefighters and emergency medicine experts, in particular their different responsibilities, priorities and value systems were not considered, which led to conflicting views of what had to be done by the firefighters. The result was disagreement and confusion instead of support for the firefighters. (Van den Hoven, 2007, p.69)

Following chapters are going to describe the eight fundamental features of VSD, how IT innovation is driven by values, how those values can be defined and how those values can be integrated in the design process of products and systems. Finally, a short introduction to RRI, an even broader approach compared to VSD, is given.

3.1 Eight Features of VSD

VSD combines many targets and methods concerning values and design of systems of related disciplines such as computer ethics or social informatics to just name a few. In addition to that, it brings up eight features that are unique in this constellation (Friedman et al., 2013, p.12ff):

- Be proactive and influence design from the beginning until the end of the design process
- Apply an holistic approach including all areas where the technology could be applied in future

- It describes a methodology that includes conceptual, empirical and technical investigations (see chapter 3.4.2)
- Its scope considers all values of humans
- It clearly distinguishes between usability (functional) and human values (ethical import)
- It distinguishes between direct and indirect stakeholders, which also considers all other parties that might be affected by the technology now or in the future
- It is an interactional theory. Features and properties either support or hinder certain values. How the technology is actually used depends on the targets of the people who use it.
- It is built on the proposition that some values are universally held, but their importance depends on culture at a certain point in time (Ethical pluralism).

3.2 IT Innovation Driven by Values

IT innovation driven by values shall support growth and welfare of people. Therefore, a switch from function centred to human centred thinking is required. Values such as privacy, security, trust, transparency, attention-sensitivity, objectivity, accessibility, reliability, autonomy, or property have to become the leading elements in the process. To achieve this functionality alone is not enough. A great success example is the company Apple, which considered aesthetics as an important human value and is today still belonging to most successful IT companies in the world. Not achieving this target through IT innovation is often related to poor design, too little testing, too little documentation and the lack of stakeholder involvement. Another critical aspect in IT innovation are IT hypes. The recommendation is to do not rush without questioning.(Spiekermann, 2015)

“Envision the sustainable value that you want to create with the new technology. Do not invest unless you see this value. Only go to market with a fully tested, trustworthy and mature technical product.”(Spiekermann, 2015)

This way is in the long term the less cost intensive and relaxed strategy. Summing up IT innovation driven by values shall lead to value creation through IT and to the protection of values, that today are undermined by bad IT. As an example, following human values could be supported through IT innovation and the resulting systems: Better health, better duties/functions, more calmness, more courtesy, more autonomy, more privacy, more control.(Spiekermann, 2015)

How values can be identified and defined is described in the next chapter.

3.3 What Are “Values”?

Someone could simply think of the economic worth of an object as a value. A holistic approach would be to consider everything as a value what humans consider important in life.(Friedman et al., 2013, p.2)

The underlying question is *“What is desirable, good or worthwhile in life?”*(Spiekermann, 2015)

Today many values are affected by new IT devices and services. There are positive examples such as improved learning and health, help to consider ethical conduct in our life, support our convenience and negative aspects such as surveillance, big data analysis, spying, or privacy concerns. First, it is crucial to clearly distinguish between functionality and value. In philosophy values are split in intrinsic and extrinsic values. Value can be defined as degree of worthiness. Its origin is in Latin “valere” which means “to be strong”, “to be worth”. It is not “the absolute good”. It implies a threshold value, which depends on culture of group and society at a specific time. E.g., today we have a capitalist society that defines itself by economic success. So values such as competition, pride, or autonomy are stronger than other values such as charity, humility, or obedience. Some values have been considered as very important and became even rights in the legal system or even in international conventions such as the right to a private life in the European convention of Human rights. An intrinsic value is valuable in itself. There is no need for a reason e.g. Happiness. Whereas extrinsic values are always related to something that is good or enable it. E.g., the extrinsic value “Support of convenience” increases the intrinsic value “Happiness”.(Spiekermann, 2015)

Considering intrinsic values, following three approaches exist (Spiekermann, 2015):

- Ethical relativism – there are no universally valid norms and values
- Ethical absolutism – universally valid norms exist for everyone at all time
- Ethical pluralism – some of the values are universal, but their importance differs by culture and society at a specific time

Values can be further distinguished by non-moral and moral values. Non-moral values, such as happiness, are considered as good or desirable in our society. They frame our life and give identity to it. They do not force us to act in a certain way. Moral values instead clearly imply how people should behave e.g. honesty, responsibility.(Spiekermann, 2015)

Table 1 gives an overview of 18 intrinsic values where both views, the philosophical and the psychological, are considered.

Human Values Discussed in Philosophy (Frankena, W. 1973. Ethics. 2nd ed. Upper Saddle River, NJ: Prentice-Hall.)	**Human Values Identified and Measured in Psychology**
Life, consciousness, and activity	Comfortable life (prosperous life)
Health and strength	N/A
Pleasures and satisfactions	Pleasure (an enjoyable, leisurely life)
Happiness, beatitude, contentment	Happiness (contentedness)
Truth	N/A
Knowledge and true opinion of various kinds, understanding, wisdom	Wisdom (mature understanding of life)

Mutual affection, love, friendship, cooperation	True friendship (close companionship); mature love (sexual and spiritual intimacy)
Harmony and proportion, in one's life	Inner harmony (freedom from inner conflict)
Power and experiences of achievement	Self-respect (self-esteem)
Self-expression	A sense of accomplishment (lasting contribution)
Freedom	Freedom (independence, free choice)
Peace, security	National security (protection from attack); family security (taking care of loved ones); a world at peace (free of war)
Adventure and novelty	Exciting life (a stimulating active life)
Good reputation, honor, esteem	Social recognition (respect, admiration)
Beauty, harmony, proportion of objects contemplated; aesthetic experience	A world of beauty (beauty of nature and the arts)
Morally good dispositions or virtues	N/A
Just distribution of goods and evils	Equality (brotherhood, equal opportunity for all)
N/A	Salvation (belief in God, eternal life)

Table 1: Summary of intrinsic values in Philosophy and Psychology (Krobath, 2009), (Spiekermann, 2015)

Based on Maslow's work those 18 intrinsic values have been reduced/mapped to seven values/needs as shown in Figure 5.

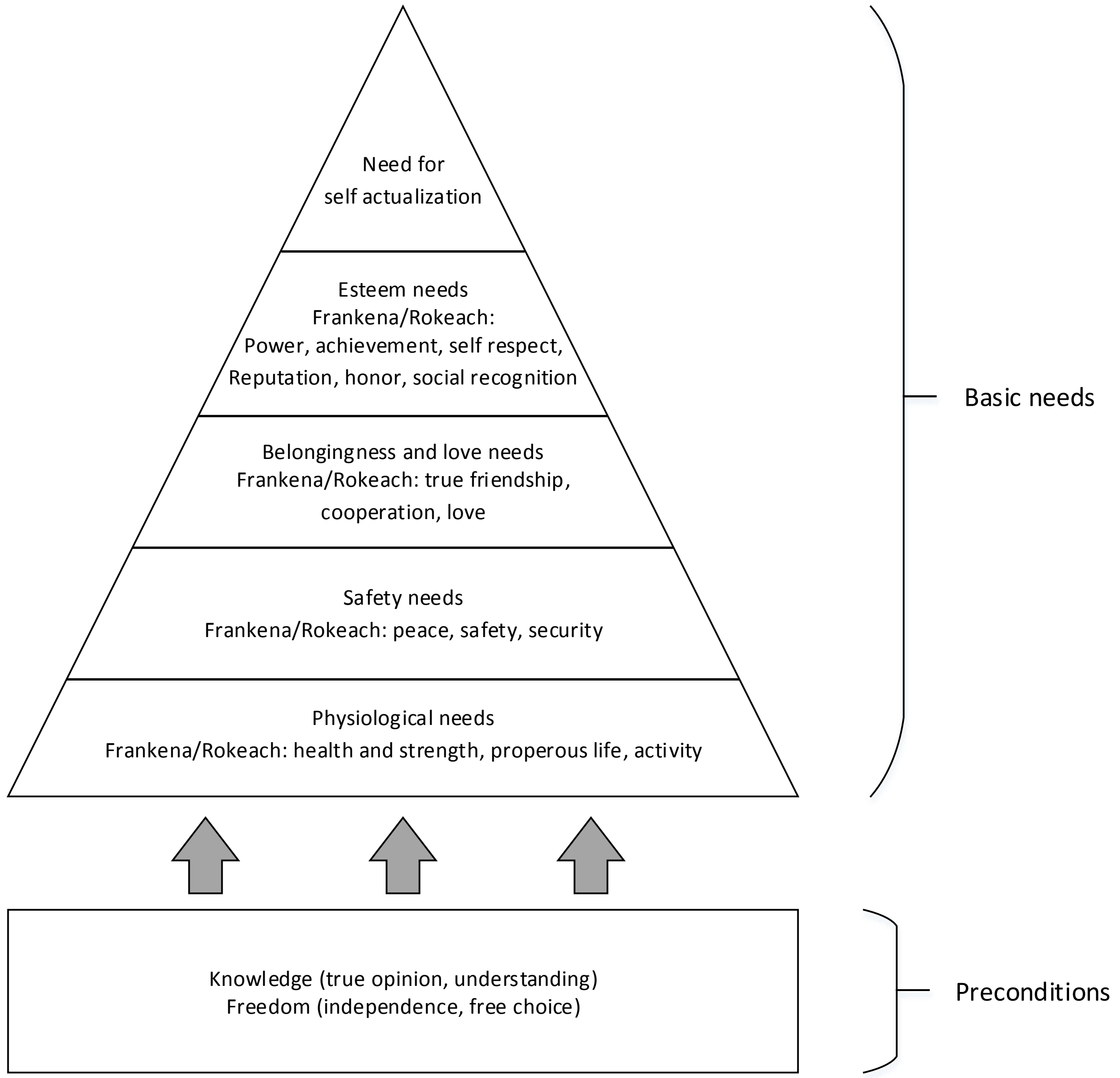


Figure 6: Frankena's and Rokeach's list of values combined with Maslow's hierarchy of motivation and flourishing (Spiekermann, 2015.p 45)

3.4 Design Approach

This chapter shall give an overview of how ethical aspects can be considered in the design of new systems. First, it is shown how the VSD Framework can be applied to standard processes by having a closer look at those processes and see how ethical aspects can be considered. Next, some more details on VSD and its tripartite methodology are given. Finally, suggestions for applying VSD in practice are given.

3.4.1 Standard Processes Extended with Ethical Design

For following processes in innovation, system and software development it is going to be described how they can be extended by Value Sensitive Design:

- Stage-Gate Process
- Waterfall Model
- Spiral Model
- Agile Models

Today many innovation projects are managed according to the Stage-Gate process by Robert Cooper. The Stage-Gate process consists of six phases and five stages separated by gates (go or no go decisions) as shown in Figure 7.This process represents the management view of new product development.(Cooper, 2017)

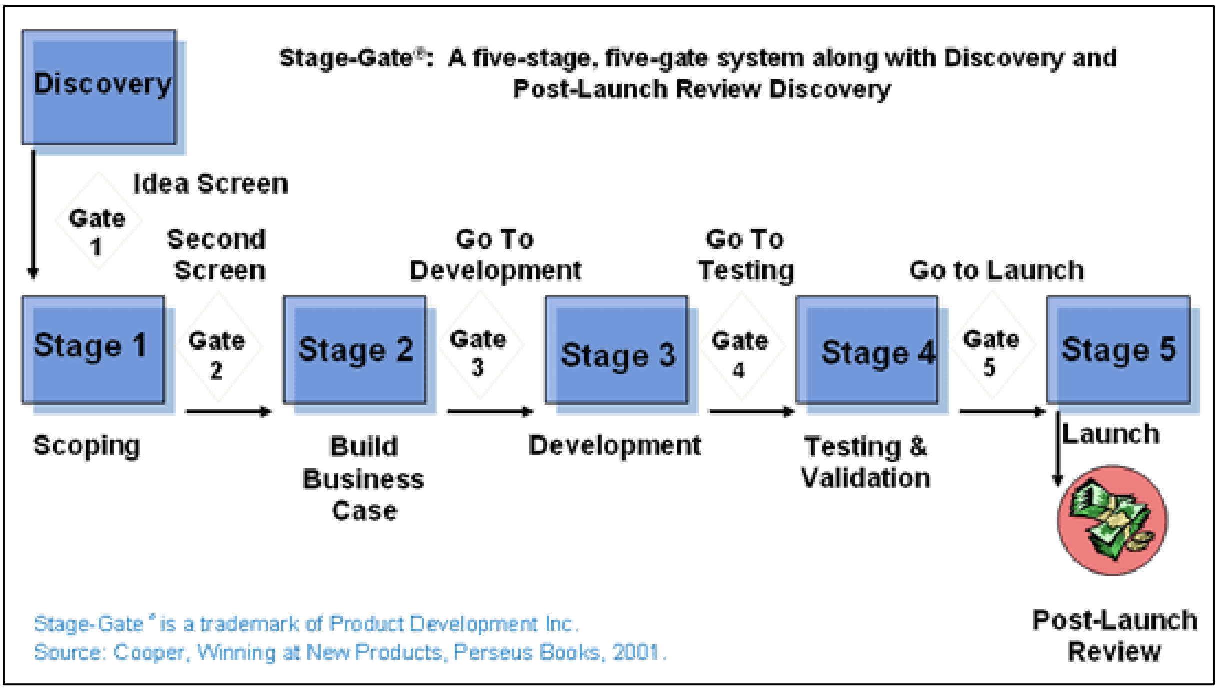


Figure 7: Stage-Gate Process (Cooper, 2017)

Following this process, gate 1 is already crucial in regards to ethical design. The question at gate 1 is “Does it match companies’ success criteria?” Here it is important to also ask if ethical criteria are considered. What is about social values? What about the costs? Usually non-functional ethical requirements are often not considered at that point and could lead to wrong decisions.(Spiekermann, 2015)

It is also important to distinguish between system engineer and software engineer in terms of roles and responsibilities throughout the whole project. A system engineer is responsible for all technical dimensions including software engineering, whereas a software engineer focuses only on software.(Spiekermann, 2015)

Switching to the engineering view of IT product development the Waterfall Model shown in Figure 8 is commonly used model. Based on this model, which is used for describing the system development lifecycle (SDLC), it is described how ethics can be part of the process of system design. For each phase ethical aspects are mentioned and how those aspects can be applied in the respective phase.(Spiekermann, 2015)

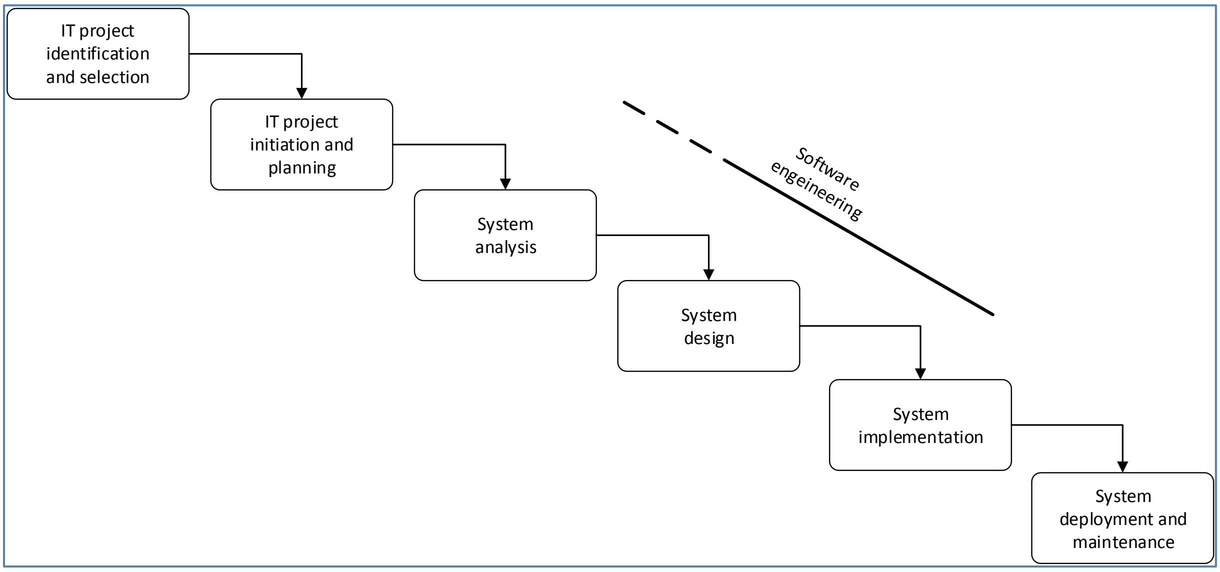


Figure 8: The Waterfall Model for IT system design (Spiekermann, 2015)

IT project identification and selection

The suggestion is to put more focus on values that should be created or protected. Is the project ethically compatible with social or organizational goals? Should a process really be automated or should the process still be handled by employees? What are the benefits or harms to customers if the technology is applied?(Spiekermann, 2015)

- Formulate value priorities for later decision making in case of value conflicts
- Involve stakeholders in this phase, people who will be significantly affected

IT project initiation and planning

In this phase, it is crucial to understand the system requirements, to determine realistic total costs of ownership and to make a clear scoping. A pitfall in this phase is often that the value and viability are not challenged hard enough. Understanding the true boundaries and all non-functional requirements is often underestimated and therefore neglected. It is recommended to do a feasibility check on following dimensions of a project (Spiekermann, 2015):

- Economic
- Technical
- Operational
- Legal
- Political
- Ethical

Whereas ethical issues can have a high impact on all dimensions of a project. Conduct a value analysis to understand all dimensions of the values that are promoted or threatened by the system to be build. Understand all legal restrictions. Finally, if the conclusion is that, the organization or society is not yet ready for it; do not hesitate to stop the project for now.(Spiekermann, 2015)

System analysis

Now the definition of concrete system requirements takes place. In general, system requirements shall correspond to the physical, technical, organizational and sociocultural context in which the system operates. So, conducting a detailed context and user analysis is required. It is also important to take care when trying to reuse off the shelf software components, which is usually cheaper and faster than developing everything from scratch. Those software components should not be treated as given or simply as black boxes. Always question them and analyse them in respect to identified values that should be promoted or protected. E.g. A prefab component might fulfil all functional requirements but might include too little security and privacy. Do not forget about the final users, when agreeing on technical compromises, as they might frustrate them. Use UML diagrams also to visualize and model value flows (ethical enablers) and value dams (ethical barriers) that shall be part of the system.(Spiekermann, 2015)

Typically, UML does not directly specify how to model human values. Nevertheless, the methodology can also be used to model human values instead of data values for example. Behaviour diagrams such as information flow diagrams or activity diagrams could be used for that. Another tool is the V² Value Network Notation that actually considers exactly the human values (non-functional requirements) and models them as already described in chapter 2.2.3.(uml-diagrams.org, 2017)

System design, implementation, and software engineering

System requirements are now converted into logical and physical system specifications, which are then implemented by either following a spiral, see Figure 9, or nowadays quite often an agile model.(Spiekermann, 2015)

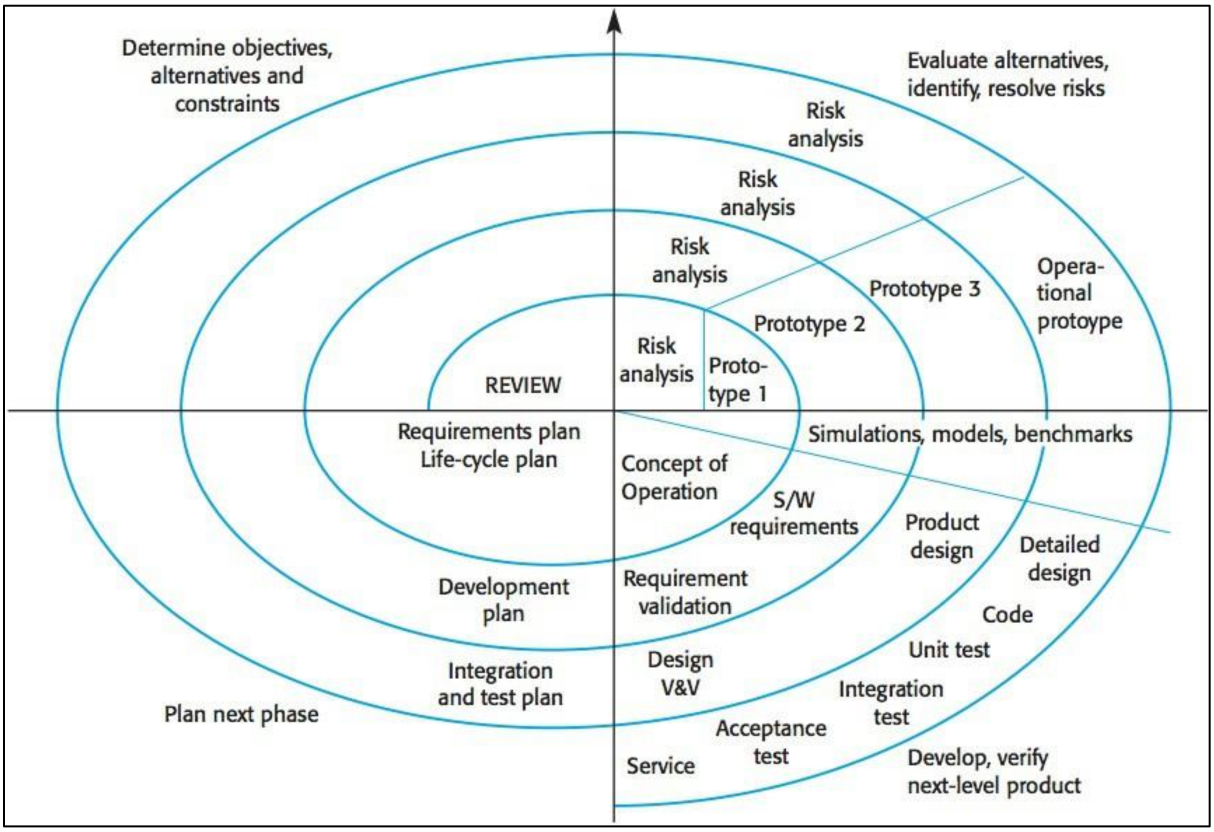


Figure 9: Spiral Model (Sommerville, 2017)

Historically the focus was put on project-related risks mainly. Which means staying in budget, meeting all deadlines and implementing all functionalities were highly considered, whereas social risks were hardly considered. It is highly recommended to also put focus on non-functional value impacts and ethical sustainability. Try to consider all holistic system risks, which have been collected earlier, and do not ignore them just because the project is running short on time or budget.(Spiekermann, 2015)

Prototyping is a well established methodology of early validation of certain aspects of a system. The drawback with prototyping is that managers tend to take them as close to final implementation and push project teams to release soon.(Spiekermann, 2015)

Agile software development processes, as mentioned already above, are nowadays getting more and more popular in companies. In terms of Value Sensitive Design, agile processes are seen critically for two reasons. When applying agile models a project team could be too focused on specific software applications and functionalities, due to the high expense of integrating a holistic view of an overall system, its boundaries, and all non-functional requirements. The holistic approach of considering all values and non-functional requirements of a system tends to be somehow a contradiction to release early and iteratively increase functionality of a system. Additionally it stresses that working software is more important than documentation. Which might lead to in practice that systems become opaque black boxes. The problem especially occurs if the code is not as good structured and written, as agile methods want it to be. It is important that earlier phases get requirements architecture right. So both models, spiral and agile, can be used within ethical system design and implementation.(Spiekermann, 2015)

System operation and maintenance

If everything was done right before this should be an easy phase. In reality, this phase is the most cost intensive. It takes approximately two third of overall costs. In respect to ethical design, it is highly recommended to invest more in ethical requirements engineering up front. Also, consider that small services can easily become global very quickly and therefore minor rated aspects or non-functional requirements rated with low priority can become very critical on a global scale.(Spiekermann, 2015)

Figure 10 shows a mapping of previously mentioned processes for a better overview and understanding.

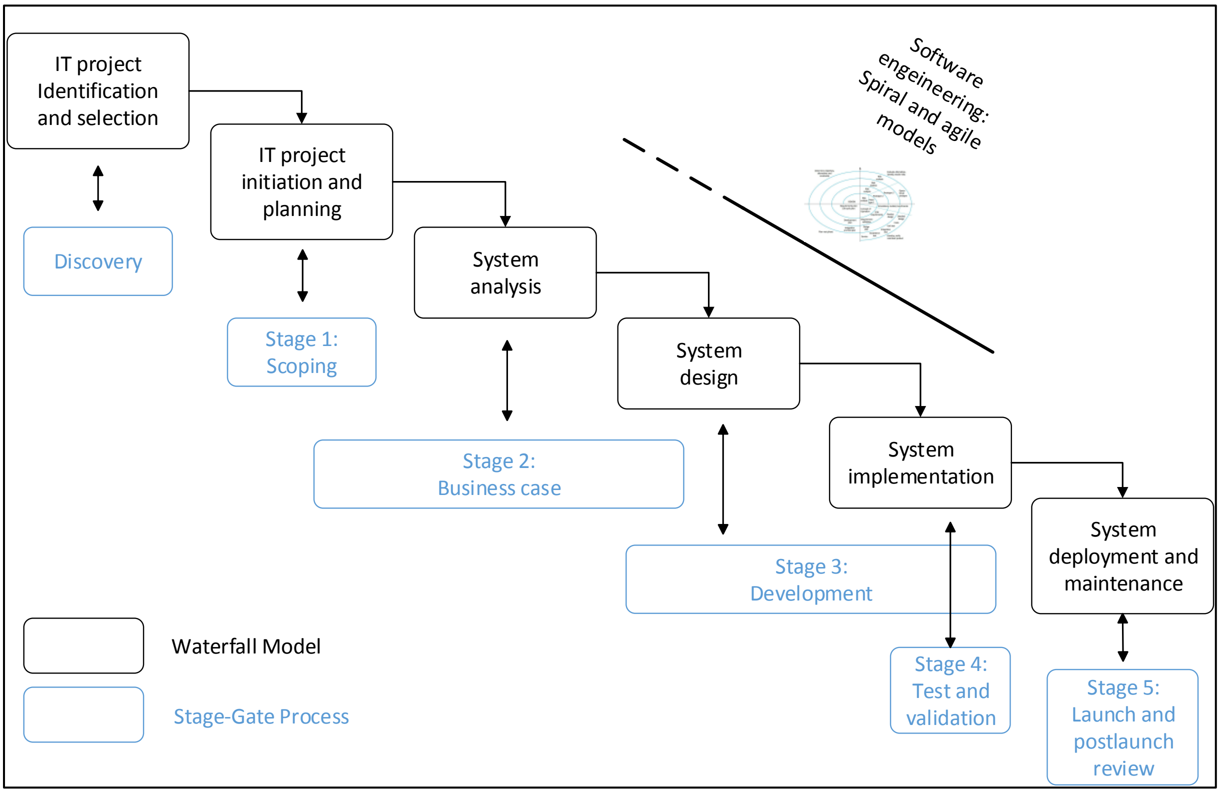


Figure 10: Stage-Gate Process, Waterfall Model and software engineering models aligned (Spiekermann, 2015)

Combining above standard processes together with the VSD framework by (Friedman et al., 2013) the process of system/product innovation and development could look like shown in Figure 11.

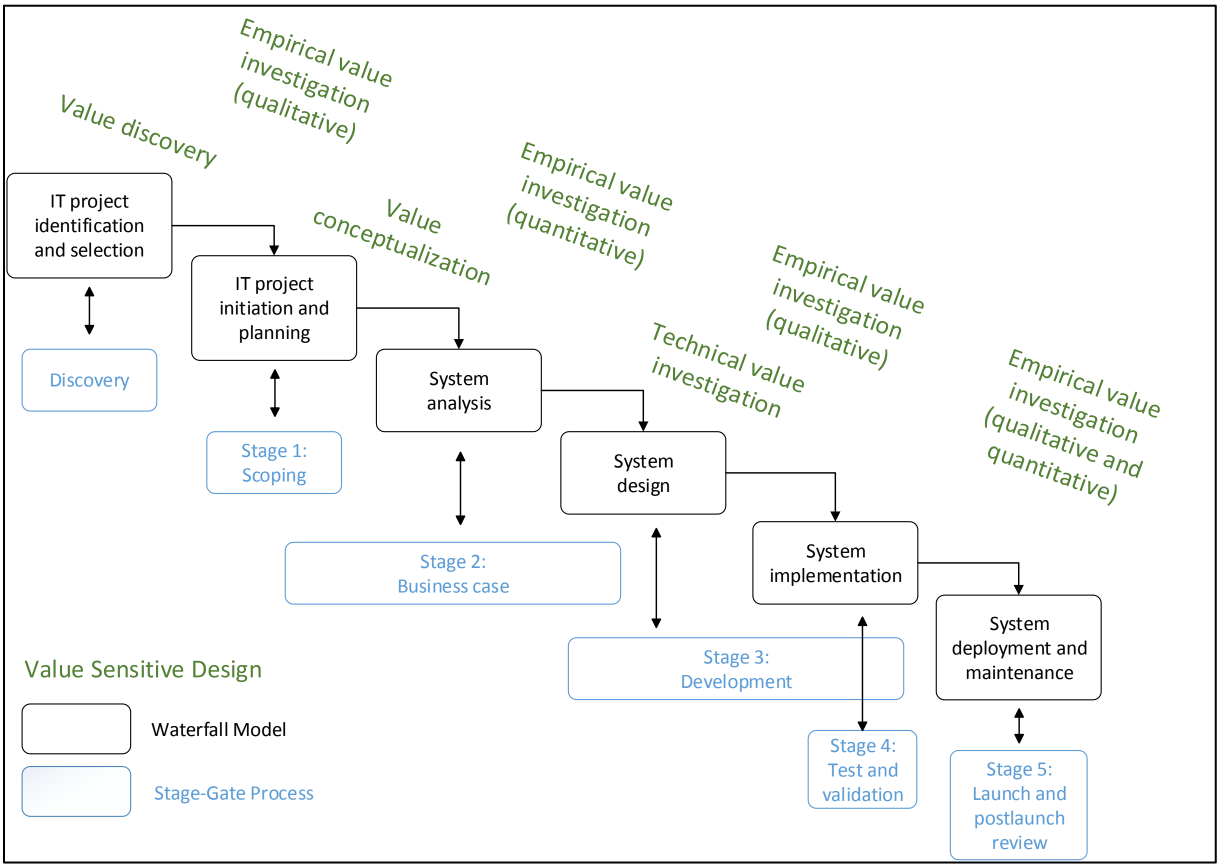


Figure 11: Standard processes combined with VSD (Spiekermann, 2015)

VSD is based on the paradigm that a machine or system can be designed and shaped in a way to support and protect human values and moral norms actively.
As shown in Figure 11 following related activities are required:

- Value discovery - Discover and prioritize value threats and benefits created through a system
- Value conceptualization
- Empirical value investigation
- Technical value investigation

The following chapter explains more details on VSD and its specific methodology.

3.4.2 Tripartite Methodology

According to (Friedman et al., 2013, p. 3f) VSD is built on three investigations that are iteratively applied throughout the design process.

Conceptual Investigations

Identify direct and indirect stakeholders and how they are affected by the system. Identify the values that are implicated. Clarify how it is planned to deal with competing values throughout the whole process of design, implementation, and operation of the system. Also think about how values shall be prioritized e.g. if moral values in general have a higher weight than non-moral ones. At the beginning, it is highly recommended to carefully conceptualize specific values. By doing this, a common understanding about the identified values is generated among the whole project team and helps to clarify fundamental issues.(Friedman et al., 2013)

Empirical Investigations

Those investigations try to go beyond the concepts by investigating the human context in which the system or product is supposed to be applied. This also can be used for example for validating a specific design. In general, it can be applied to any human activity that can be observed or measured. Any method from social science research, quantitative and qualitative, can be applied here.(Friedman et al., 2013)

Technical investigations

Whereas empirical investigations focus on people or groups that are affected by the technology, technical investigations focus on the technology itself. On the one hand, the focus is put on investigating how technological properties create or protect values. On the other hand, technical investigations support the proactive design of systems to create the earlier identified values.(Friedman et al., 2013)

3.4.3 Recommendations for Applying VSD in Practice

Especially for those who would like to try out above mentioned design approaches immediately the questions arises: “How can all of this be applied in a practice?”
The following suggestions should help designers to apply VSD in their projects (Friedman et al., 2013):

- Start with one of the following core aspects, Value, Technology, or Context of Use. Select the aspect that is the most relevant to project.

- Identify all stakeholders. Direct and indirect ones. Identify subgroups and consider that individuals might be a member of more than one group. Also consider the organizational structure where stakeholders might be embedded.

- For each identified stakeholder group list benefits and harms. Priority should be given to strongly affected indirect stakeholders. Also consider competency issues e.g. by considering that children or elderly people might have a lower cognitive abilities. As a tool Personas can be very powerful, as already mentioned in 2.1.4, to identify and document the benefits and harms of concrete people identified as stakeholders.

- Benefits and harms should be mapped onto the corresponding values. In the following Case Study the approach of Value Proposition Design, see also chapter 2.2.2, has been used. Results of the practical implementation can be found in chapter 4.1.3.

- Identified key values shall be conceptually investigated. For doing this, philosophical ontological literature can be very helpful to formulate definitions of values and how to asses them.

- Potential conflicts of values have to be identified and should be considered as constraints for the design. Examples for value conflicts are accountability vs. privacy, trust vs. security, environmental sustainability vs. economic development, privacy vs. security, and hierarchical control vs. democratization.

- Integrate values into the organizational structure. One way of how this can be done is by creating a value network map as shown in chapter 4.5.
  When interviewing stakeholders, the method of a semi-structured interview is recommended as in comparison to a structured interview. It inherits the chance to get more unexpected insights. Also, try to find out the reasons of the stakeholders' judgments by simply asking: “Why?” Moreover, try to ask also indirectly about values not only directly.

- Regarding technical investigations try make it explicit, how design trade-offs due to technical reasons affect stakeholders and map onto value conflicts.

3.5 RRI - Responsible Research and Innovation

An even broader approach, which considers values of the society as an essential part of research and innovation, to ensure that results and impacts of research and innovation benefit society, is called RRI – Responsible Research and Innovation.
“Responsible development” and “Responsible research” have its origin in the USA in the beginning of the 21st century. Back then integrity, ethical, legal and social impacts of research and innovation were discussed. It inherits the vision that scientists of different fields collaborate to address RRI aspects early on and that the public engagement in science and technology is increased. RRI has gained more and more EU policy relevance in the last years, especially in the European Commission.(Owen, Macnaghten, & Stilgoe, 2012)

Compared to VSD, RRI even approaches the way of how fundamental research and innovation is conducted on a governmental level. Following features are the base of RRI (Owen et al., 2012):

Features of RRI

- Science for society: Democratic governance of purpose of research and innovation.
- Science with society: Responsiveness and use of established approaches of anticipation, reflection and deliberation.
- Framing of responsibility in research and innovation

First, the two following examples show how the approach of RRI can lead to a successful implementation and therefore a benefit for society in a whole, whereas the other two examples show how innovation can fail if not considering important values of the society.

Practical examples where the approach of RRI has or is been applied:

- Fairphone
  This is an example from the mobile phone industry. The initial intention of the project was to increase awareness on poor working conditions of mine and factory workers in that industry, by pretending to produce a “fair” smartphone and involving the publicity in the design process. Finally, the whole thing turned into a real production of a smartphone and the foundation of the company Fairphone with the target to increase social welfare. (Akemu & Whiteman, 2014)

- Vision Zero
  This example describes the philosophy that nobody will be killed or seriously injured on the road. As there are potential conflicts considering the values safety and mobility it is clearly stated that the value safety has higher priority. This long-term strategy inherits also that the responsibility for safety has to be shared between the designer and the user. (Tingvall & Haworth, 2000)

Following examples show how projects can fail due to not considering values that are seen as important by the society. In those particular cases the value “Privacy” was not considered highly enough in the design of the system:

- Smart meter
  In the Netherlands all seven million households where supposed to have a smart meter as proposed by the Dutch government. The mandatory rollout had to be stopped after a short period as privacy concerns were raised. Finally, it had to be decided that the rollout is only voluntary instead of mandatory. (Cuijpers & Koops, 2013)

- Electronic patient records
  After introduction of electronic patient records several security breaches, that allowed for example unauthorised people to access confidential health information, are undermining the privacy of patients. Not considering the privacy of patients highly enough during the design led to severe loss of confidentiality of patients in such a system. (Ozair, Jamshed, Sharma, & Aggarwal, 2015)

4 Case Study

The following case study shall demonstrate how previously described theory including the respective tools has been applied in a large-scale automotive production environment at Audi Hungaria in Györ.

4.1 Technology and Use Case Screening

The initial phase of the project consisting of a technology and use case screening has been conducted, in collaboration with Johannes Viktor Gasser, a colleague who was working on a similar project at that time. The goal of the screening was to create a base for the proceeding steps of the project. Furthermore, this overview shall also be extended by future projects conducted at Audi Hungaria in Györ. The UCTM Framework described in chapter 2.2.1 was applied.

As a result, a table containing 33 products including their specifications and 44 use cases has been created.

4.1.1 Categorization of Technologies and Products

The main categorization of the products was done according to following main types:

- Mobile Devices
- Network
- Remote or stationary sensors
- Wearables

Within this case study, in alignment with Audi Hungaria, the focus was put on “Wearables” as the first screening showed many very promising use cases and products in this area.

The main type “Wearables” was further described by following subcategories:

- AR HMD (active)
- AR HMD (passive)
- AR - Mobile Projectors
- VR HMD
- Smartwatches (with camera)
- Smartwatches (without camera)
- Smart Gloves
- Smart Bands
- Smart Rings

Further information that was collected for each technology was:

- Technology lifecycle state [emergence, growth, maturity, degeneration] (Schuh & Klappert, 2011)

Gartner Hype Cycle (Gartner, 2017)

- Hype cycle phase [technology trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, plateau of productivity]
- Duration in years until plateau state [0, <2, 2-5, 5-10, >10, obsolete before plateau state]

- Mounting location [head, arm, hand, shoulder, wall, floor, ceiling]

4.1.2 Categorization of Use Cases

For the screening of use cases the focus was put on industrial use cases. Researched use case were documented by describing them according to following categories. The selection of categories were in alignment with Service Design and Value Proposition Design. The categorization was defined in collaboration with colleague Johannes Viktor Gasser, who focused on academic use cases.

- Company department[R&D, assembly, maintenance, logistics, quality control, training, all]
- Task
- User role
- Value proposition
- General function [gamification, training, assistance, communication, documentation, monitoring, simulation]
- Way of information provision[text, audio, visual, graphs, spread sheets, vibration]
- Use case – subject
- Use case – description

Finally, the use cases were mapped with the applied technology by adding the information for each use case what kind of technology was used.

4.1.3 Summary of Results in VPCs

As next step, the collected information was summarized and presented in a Value Proposition Canvas to be able to decide in which field of operation at Audi Hungaria the focus should be put. Therefore, VPCs for following fields of operation have been created. Before putting the information together in the VPC the data was collected in excel spreadsheets. One for the customer profile and one for the value proposition. For presenting the results to Audi the VPCs were printed and placed on the walls in the meeting room, which made it very easy for the stakeholders at Audi to discuss about the results and next steps in the project. Having those VPCs in printed form made it very easy throughout the whole project to explain also to other people at Audi, who were interested in the project, what the project is about and was has been done so far.

The information for the customer profiles were collected by interviewing respective stakeholders from the fields of operation as well stakeholders from the IT department that is responsible for IT applications in the area of engine production. The number in brackets, that is written next each pain and gain in following tables, indicates by how many use cases this pain or gain is addressed. In the VPC this information is represented by green checkmarks at each pain and gain.

The information shown for the value proposition was extracted from the information that was collected in the use case and technology screening. In section “Products & Services” the information, which kind of technology and in how many of the identified use cases the listed pain relievers and gain creators were created, is shown. It is also described which additional technology was used in combination e.g. especially AR-HMDs were quite often used in combination with other technologies.

VPC for Assembly

This part of the case study was not created by the author, but by his colleague Johannes Viktor Gasser. Table 2 and Table 3 are showing the customer profile and the value proposition for the field of operation “Assembly” of the engine production at Audi Hungaria. Figure 12 shows the filled out VPC.

Customer Profile for "Assembly"		
Customer Job(s)	**Pains**	**Gains**
Tasks:	defects (5)	inventory reduction (3)
Training	over-production	hands free operation (8)
Manual assembly	waiting (10)	PR (5)
Assembly coordination and task assignment	transporting	motivation (11)
Documentation	movement (9)	satisfaction (11)
Validate tasks	inappropriate processing (13)	less fluctuation and sickness (3)
Analyse product, error or process data		
Scan barcode of part or tool to identify and document it		
Report errors		
Roles:		
Assembly worker		
Expert (e.g.: R&D engineer)		
Team leader		
Trainer		
Process owner		
	(#) of use cases that addresses this pain or gain	

Table 2: Customer Profile for “Assembly” (Created by colleague Johannes Viktor Gasser)

Value Proposition for "Assembly"		
Pain relievers	**Gain creators**	**Products & Services**
Provide task instructions	**Provide virtual training environment**	**26 Use cases**
Context-based	Reduce physical training materials	**13 AR HMD:**
In place and in time		+ Tablet PCs
Hands free operation and documentation	**Gamification of assembly task**	+ Smart Phone
	Better user engagement	+ Smart Watch
Provide remote consultation capabilities		+ RFID System
Ad hoc expert support	**Improve ergonomics of the work environment**	+ Mobile Sensor
As being on site (no travelling for expert)		+ Smart Glove
No waiting until arrival of expert	**Reduce mental workload**	+ Other Stationary Sensor
Better utilisation of expert resources		
		2 VR-HMD
Workflow optimisation		
		3 Stationary Sensors:
Efficient Documentation		+ Projection System
		+ Display
Warning if wrong component picked		+ Motion Tracking
		1 Smart Band:
		+ Tablet PC
		1 Tablet PC
		1 Smart Gloves
		1 Smart Watch
		1 AR Mobile Projector
		1 other Wearable

Table 3: Value Proposition for “Assembly” (Created by colleague Johannes Viktor Gasser)

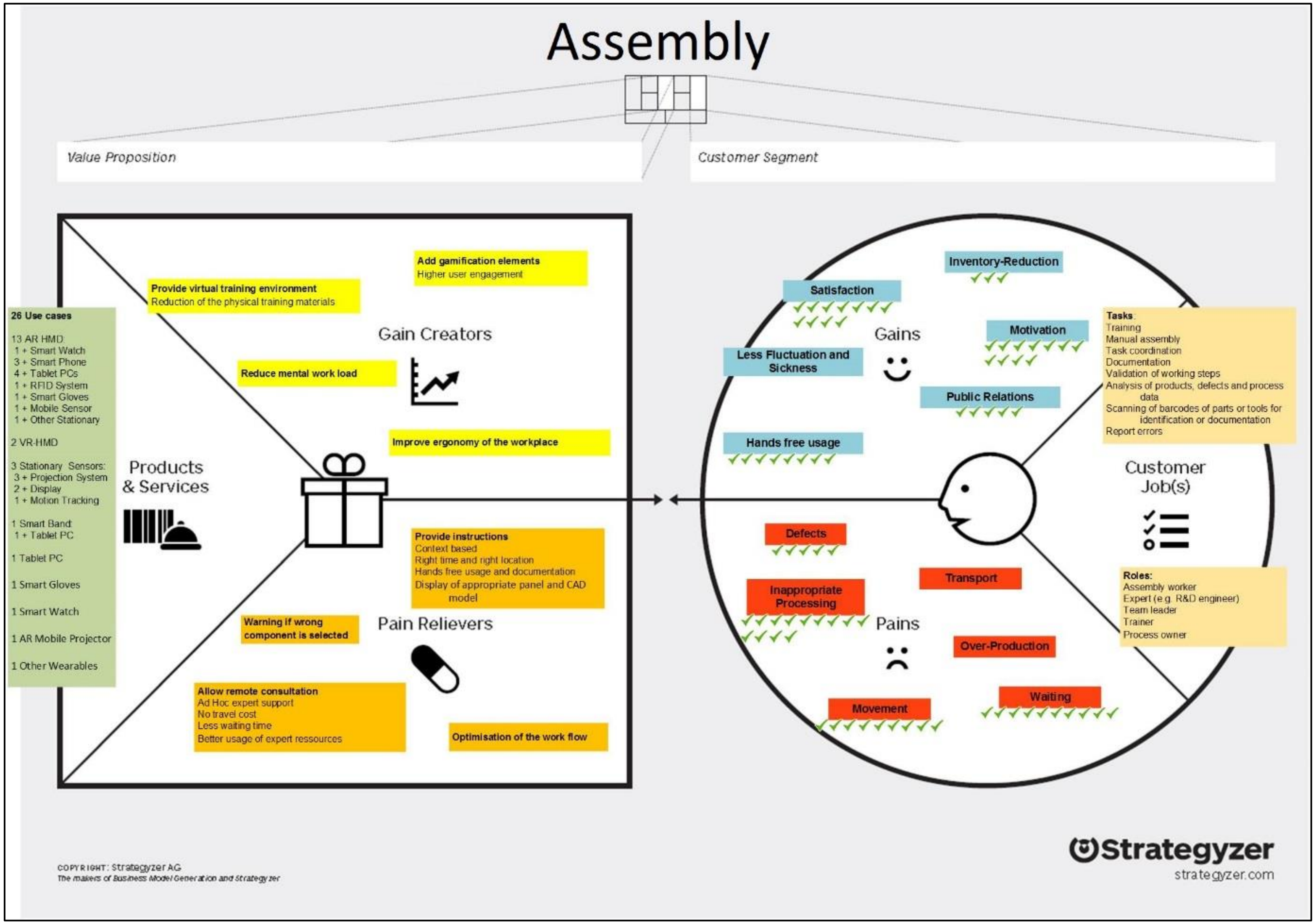


Figure 12: Value Proposition Canvas for “Assembly” (Created by colleague Johannes Viktor Gasser)

VPC for Maintenance

Table 4 and Table 5 are showing the customer profile and the value proposition for the field of operation “Maintenance” of the engine production at Audi Hungaria. Figure 13 shows the filled out VPC.

Customer Profile for "Maintenance"		
Customer Job(s)	**Pains**	**Gains**
Tasks:	defects (2)	inventory reduction (1)
Maintenance (corrective/preventive)	over-production	hands-free operation (4)
Documentation	waiting (10)	public relations (5)
Spare part ordering	transporting	motivation (4)
Central task-coordination	movement (7)	satisfaction (4)
On-the-job training	inappropriate processing (7)	less fluctuation and sickness
Roles:		
Maintenance worker		
Expert (e.g.: R&D engineer)		
Team leader		
Process owner		
Operator		
	(#) of use cases that addresses this pain or gain	

Table 4: Customer Profile for "Maintenance"

Value Proposition for "Maintenance"		
Pain relievers	**Gain creators**	**Products & Services**
Provide task instructions	**Provide virtual training environment**	**18 Use cases**
Context-based	Reduce physical training materials	**12 AR HMD:**
In place and in time		+ Smart Watch
Hands free operation and documentation	**Gamification of maintenance task**	+ Smart Phone
	Better user engagement	+ Tablet PCs
Provide remote consultation capabilities		
Ad hoc expert support	**Live diagnosis using AR**	**1 VR-HMD**
As being on site (no travelling for expert)		
No waiting until arrival of expert		**1 Stationary Sensors:**
Better utilisation of expert resources		+ Projection System
		+ Display
		1 Camera:
		+ Display
		3 Tablet PCs

Table 5: Value Proposition for “Maintenance”

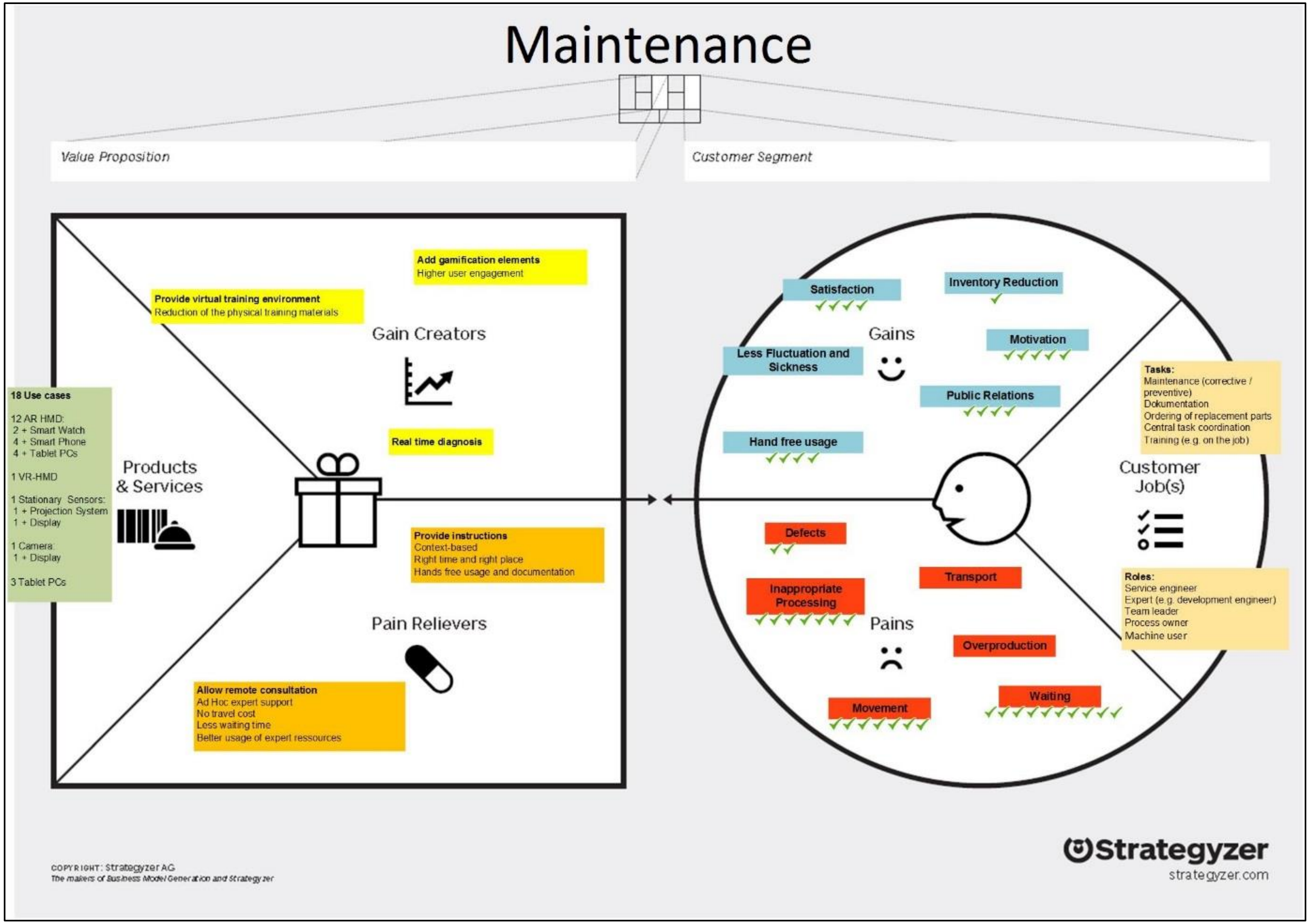


Figure 13: Value Proposition Canvas for “Maintenance”

VPC for Logistics

Table 6 and Table 7 are showing the customer profile and the value proposition for the field of operation “Logistics” of the engine production at Audi Hungaria. Figure 14 shows the filled out VPC.

Customer Profile for "Logistics"		
Customer Job(s)	**Pains**	**Gains**
Tasks:	defects (5)	inventory reduction (1)
Commissioning in logistics	over-production	hands free operation (7)
Central task-coordination	waiting (8)	public relations (4)
Scan barcode of part or tool to identify and document it	transporting	motivation (5)
Find correct parts	movement (10)	satisfaction (4)
Conduct training	inappropriate processing (7)	less fluctuation and sickness
Report errors		
Roles:		
Logistics worker		
Expert (e.g.: R&D engineer)		
Team leader		
Process owner		
	(#) of use cases that addresses this pain or gain	

Table 6: Customer Profile for “Logistics”

Value Proposition for "Logistics"		
Pain relievers	**Gain creators**	**Products & Services**
Zero fault and paperless commissioning	**Provide virtual training environment**	**13 Use cases**
by using smart wearables	Reduce physical training materials	**10 AR HMD:**
		+ Tablet PCs
Provide task instructions	**Hands free barcode scanning**	+ Smart Phone
Context-based		+ Smart Watch
In place and in time		+ RFID System
Hands free operation and documentation		+ Smart Bands
Pick by Vision		
Smart Picking Solutions		
Warning if wrong parts picked		
		1 VR-HMD
Provide remote consultation capabilities		
Ad hoc expert support		**1 Smart Gloves**
As being on site (no travelling for expert)		
No waiting until arrival of expert		**1 Stationary Sensors:**
Better utilisation of expert resources		+ Projection System
		+ Display

Table 7: Value Proposition for “Logistics”

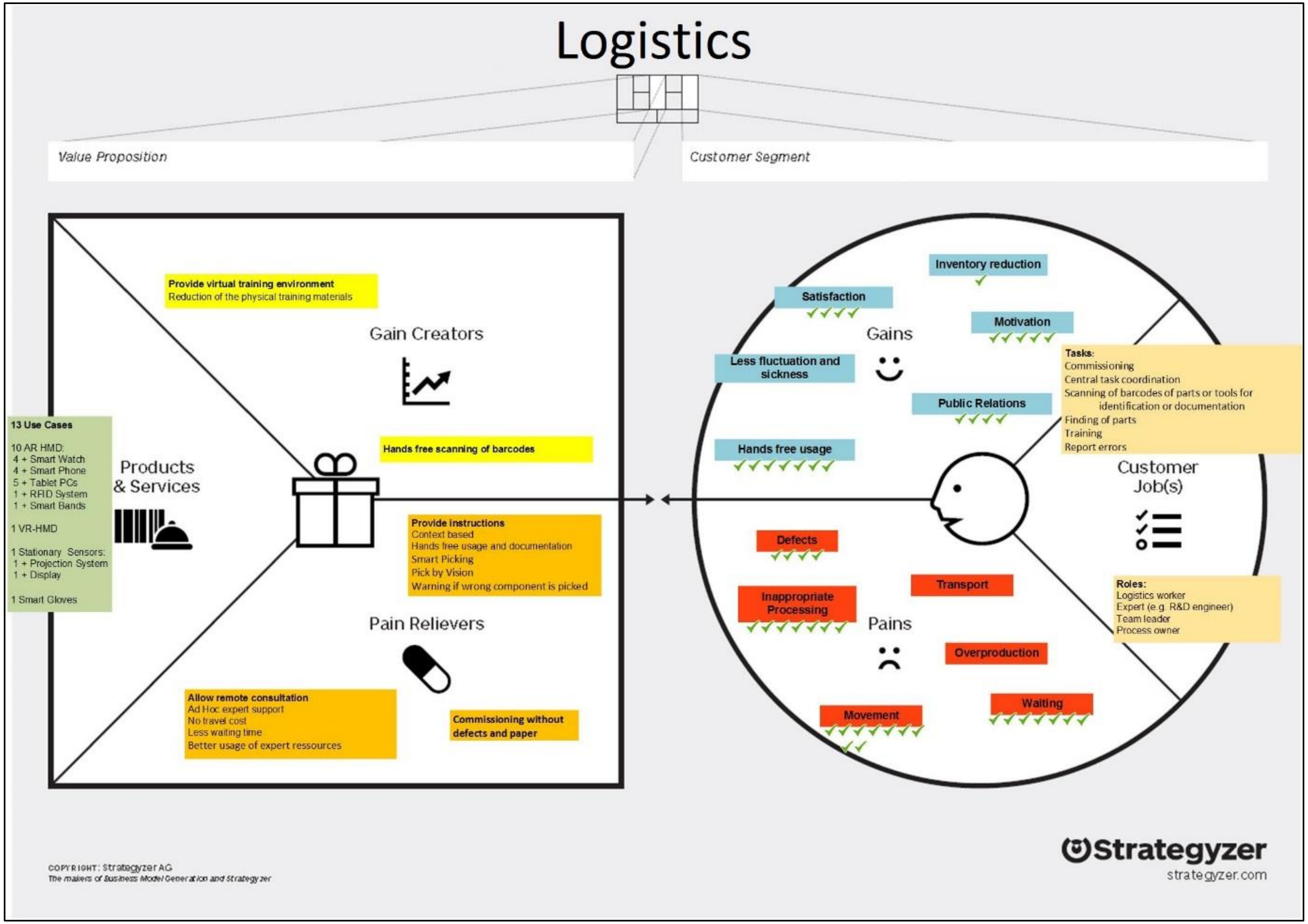


Figure 14: Value Proposition Canvas for “Logistics”

4.1.4 Result of VPCs

Evaluating the VPCs showed a promising fit in all three fields of operation. Augmented reality was the most prominent technology. It is also remarkable that AR-HMDs were very often used in combination with other technologies such as Tablet PCs and Smart Watches.

The VPCs made it easy to present and explain the results to various stakeholders at Audi Hungaria. Very positive feedback was received from management regarding the way of presentation and its comprehensibility.

As a next step, it was required to select a field of operation and a use case based on the previously collected information for further investigations.

4.2 Use Case Selection

After presentation and discussion of the results to stakeholders from all fields of operation, finally the use case of an assistance system in the field of operation “Maintenance” was selected. Criteria for the decision were the availability of resources for further investigations, the generic nature of the use case that would make it easy to apply its result in other fields of operation, and the expected long-term synergy with other ongoing projects at Audi Hungaria in the area of maintenance.

Involved stakeholders for the decision:

- G/FP3 department (Project owner, IT department for engine production)
- CIO
- Logistics leader
- Series production leader
- Pre-series production manager
- Process owner for Maintenance

To proceed and define further details for the use case a workshop with following stakeholders was conducted**:**

- G/FP3 department (Project owner, IT department for engine production)
- Process owner for Maintenance
- 360World (Application development partner)

Following topics were addressed in this workshop:

- Status presentation of project
- Selection of maintenance task and initial description of use cases for Proof of Concept
- Collaboration with 360 world for Proof of Concept

Following potential tasks in the area of maintenance have been identified in the workshop:

- Planning and scheduling of maintenance tasks (currently on paper)
- Conduct preventive maintenance
- Conduct corrective maintenance
- Status check e.g. oil level check

Following further details of the use case and the scope of the Proof of Concept have be defined:

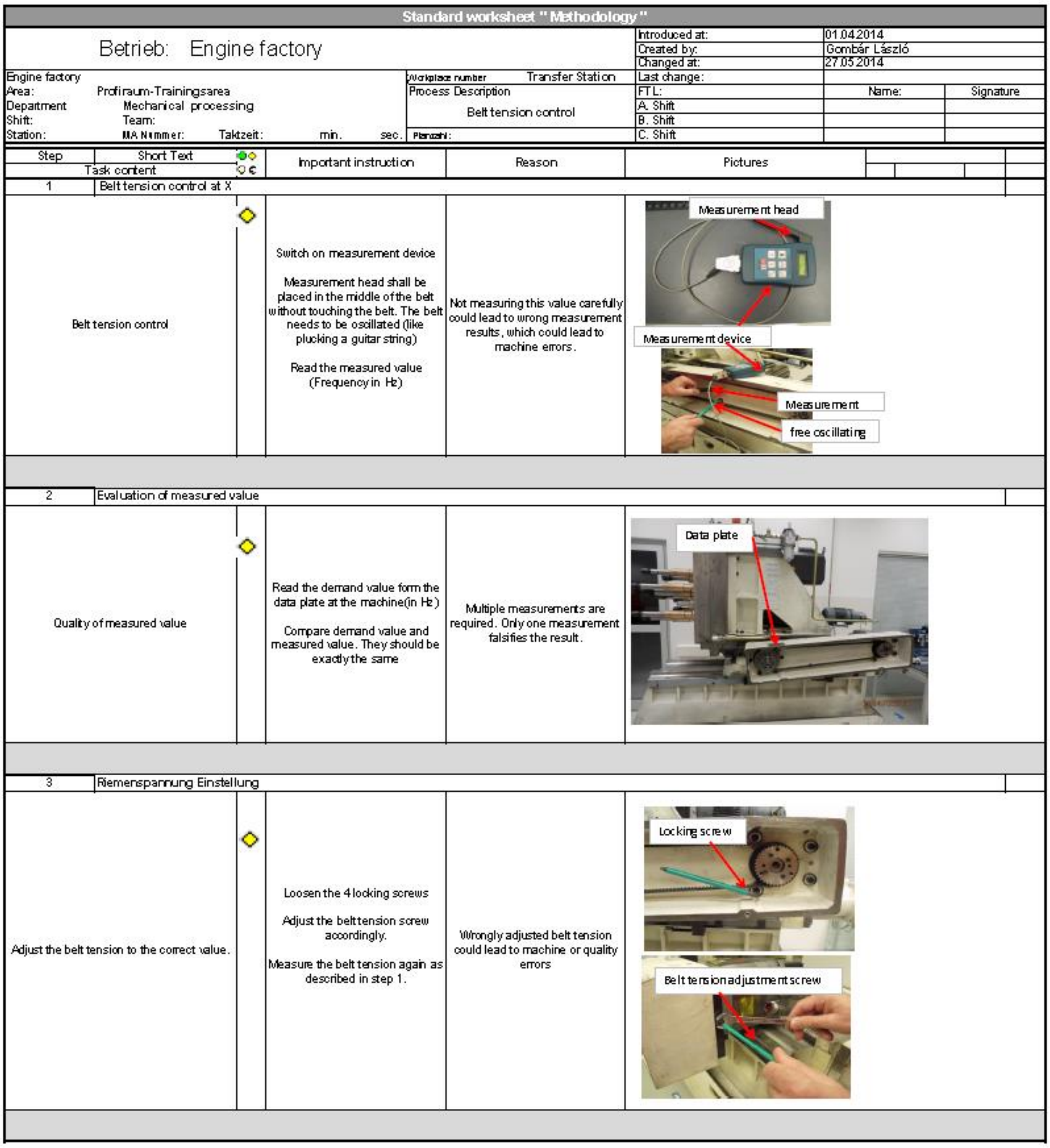
- Use case “Maintenance Assistance” for conducting a preventive maintenance task by a maintenance engineer
- Precondition: Info about which task has to be accomplished at which machine is digitally available: For demonstration purpose, this info will be "hardcoded" in the Proof of Concept
- For one machine following features shall be demonstrated:
- Task list in factory
- X-ray Vision (Operational data monitoring, media flow charts)
  - Visualise sensor data that influences task
  - Visualise hazards (e.g. high temperature)
- Specific task instructions incl. documentation of each step
  - Confirm step completion
  - Take photos, videos
  - Record voice
- Automatic prefilling of "maintenance report"
  - Basic data (machine id, start time, end time, task, and engineer name) is transferred from the system into a report. Additional info needs to be entered via another system (e.g. Smartphone)

4.2.1 Selected Task Including Criteria for Selection

As next step, an appropriate preventive maintenance task had to be selected. Therefore, an additional meeting with the process owner for maintenance at Audi Hungaria was conducted. Finally, the task “Belt tension control and adjustment” as shown in Figure 15 was selected due to following criteria:

- Task is relevant for Audi Hungaria due to its high frequency
- Task is easy enough to create a realistic prototype for evaluation and validation in a short time
- Machine for testing and evaluation is easy accessible

The task consists only of a few steps and is well described in a maintenance documentation that was previously created by Audi Hungaria for training purpose.



Standard worksheet " Methodology "

Betrieb: Engine factory		Introduced at:	01.04.2014
		Created by:	Gombár László
		Changed at:	27.05.2014
Engine factory	Workplace number Transfer Station	Last change:	
Area: Profiraum-Trainingsarea	Process Description	FTL:	Name: / Signature
Department Mechanical processing	Belt tension control	A. Shift	
Shift: Team:		B. Shift	
Station: MA Nummer: Taktzeit: min. sec.	Planzahl:	C. Shift	

Step / Task content	Short Text	Important instruction	Reason	Pictures
1	Belt tension control at X			
Belt tension control		Switch on measurement device Measurement head shall be placed in the middle of the belt without touching the belt. The belt needs to be oscillated (like plucking a guitar string) Read the measured value (Frequency in Hz)	Not measuring this value carefully could lead to wrong measurement results, which could lead to machine errors.	Measurement head Measurement device Measurement free oscillating
2	Evaluation of measured value			
Quality of measured value		Read the demand value form the data plate at the machine(in Hz) Compare demand value and measured value. They should be exactly the same	Multiple measurements are required. Only one measurement falsifies the result.	Data plate
3	Riemenspannung Einstellung			
Adjust the belt tension to the correct value.		Loosen the 4 locking screws Adjust the belt tension screw accordingly. Measure the belt tension again as described in step 1.	Wrongly adjusted belt tension could lead to machine or quality errors	Locking screw Belt tension adjustment screw

Figure 15: Maintenance task “Belt tension control and adjustment”

4.2.2 VPC for Use Case “Maintenance Assistance”

After selection of the use case an additional Value Proposition Canvas, as shown in Figure 16 was created, one abstraction level lower than the previously created ones. The VPC was used as an overview and starting point for the use case specification and again to present the progress of the project to management at Audi Hungaria.

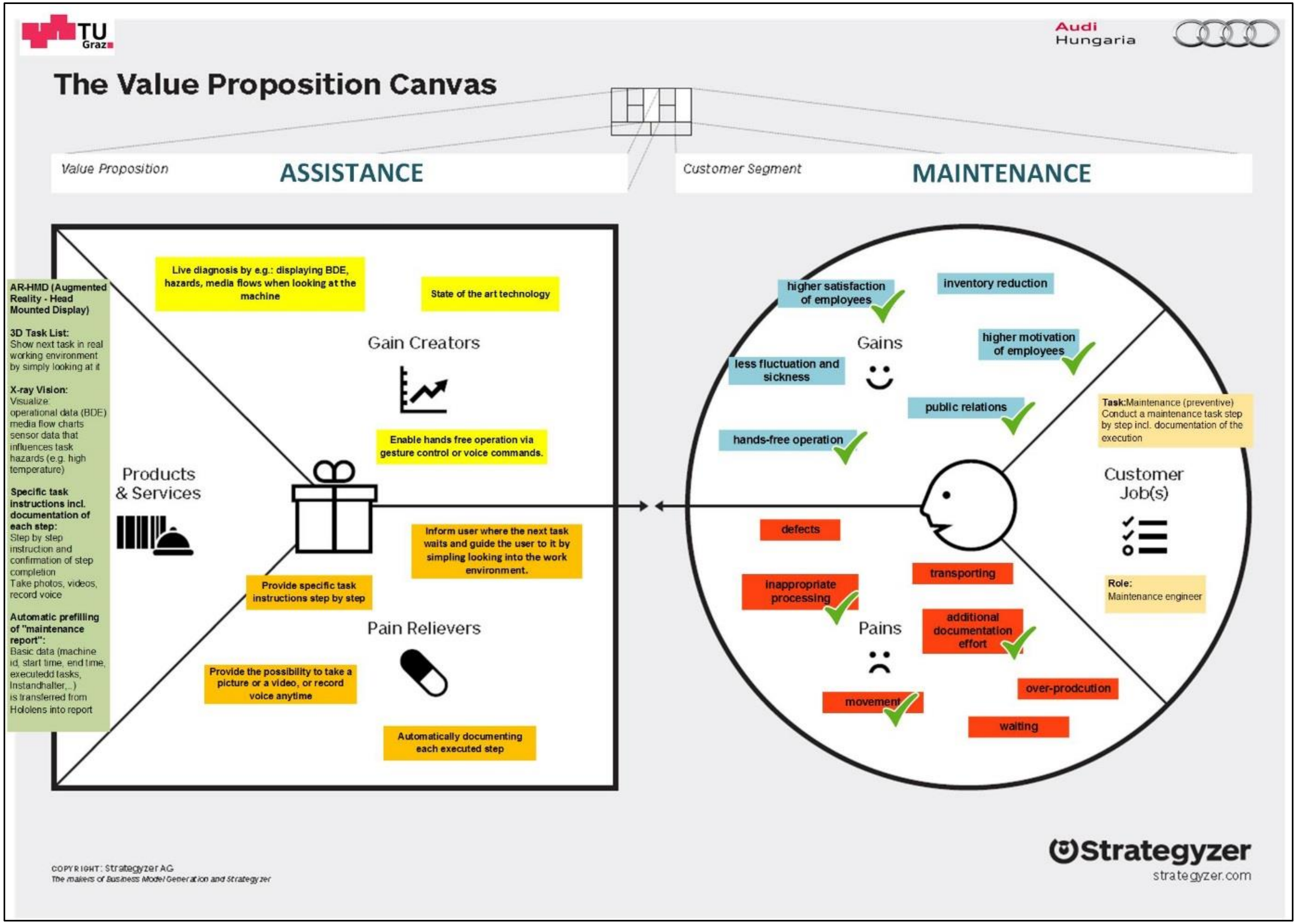


Figure 16: Value Proposition Canvas for “Maintenance Assistance”

4.3 Use Case Specification

Specifications that have been gathered in previously mentioned workshop and meetings were first put into following use case description. Based on that a storyboard was created to increase understanding of stakeholders how the application could be designed and look like.

4.3.1 Use Case Description

Table 8 describes the use case in a scheme according to (Sommerville, 2011).

Name	**Maintenance Assistance**
Short Description	The use case describes the process of conducting a preventive maintenance job at a machine in the production.
Actors	Maintenance engineer (ME)
Precondition	Info about which task has to be accomplished at which machine is digitally available. For demonstration purpose this info will be "hardcoded" in the POC. Augmented reality device (AR-HMD) is ready to use. In the first demo BDE data will be hardcoded, as a next step an interface to the BDE system shall be implemented. Following maintenance tasks has been selected for Feature 3: "Wechsel von Zahnriemen inkl. Einstellung" The POC will be demonstrated in the Training center "Profiraum".
Trigger	Maintenance engineer decides to continue with next maintenance task.
Typical Process	ME puts on and starts the AR-HMD. **[Feature 1] 3D Task List - Show next task in real working environment by simply looking into the environment** ME walks to the production area and looks at the different production lines. The next maintenance task for the ME is indicated by the AR-HMD by simply looking into the environment. The ME walks to the machine that is indicated by the AR-HMD. **[Feature 2] Task and machine overview - visualize operational data (BDE), media flow charts,** **sensor data that influences task, hazards (e.g. high temperature)** The ME confirms the arrival and that he/she is ready to start the task. BDE data is visualized (e.g. state of machine, operating hours, last maintenance task and date & time, ...) **[Feature 3] Specific task instructions incl. documentation of each step - Step by step instruction and confirmation of step completion and Take photos, videos, record voice** Each step of the task is displayed in the environment of the ME. The ME is able to decide where the instructions appear. Each completion of a step is confirmed by the ME and is stored for later documentation purpose. The ME can take a picture or video or voice record at anytime. The data is stored with timestamp and current step. **[Feature 4] Automatic prefilling of "maintenance report" -** **Basic data (machine id, start time, end time, executed tasks, maintenance engineer,...) is transferred from HoloLens into report, Additional info needs to be entered via another system (e.g.:**

	Smartphone) After completion of all steps the collected data is transferred to a server for automatic report creation. The ME continues with the next task.
Additional Constraints	It shall be visible for others if video or voice recording is active or if a picture is taken.

Table 8: Use case description “Maintenance Assistance”

4.3.2 Visualization of Use Case with a Storyboard

For additional visualization of the requirements a Storyboard was created as shown in Figure 17. Each previously defined feature is described by one scene. That shall already give, in an early stage of the project, a better idea of how the application could finally look like.

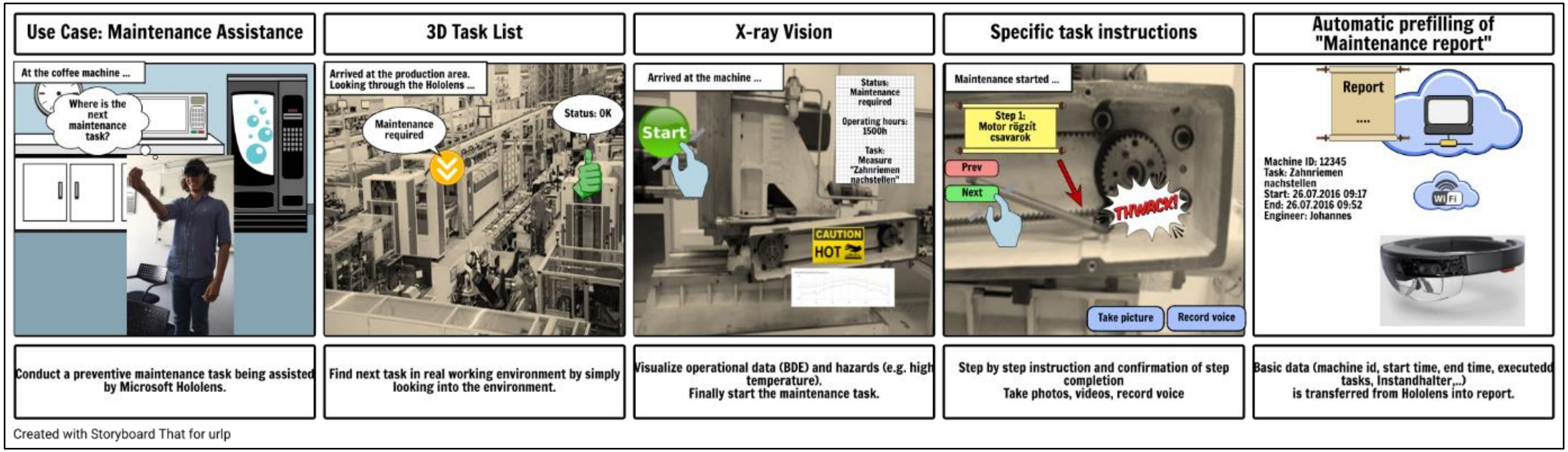


Figure 17: Storyboard “Maintenance Assistance”

Table 9 shows additional requirements for the use case that have been collected by interviewing stakeholders who were directly affected by the use case. The additional requirements, that also contain several non-functional requirements, where defined in collaboration with colleague Johannes Viktor Gasser, as he was working on a similar use case at that time. The list was finalized after iteration and alignment with stakeholders from IT department G/FP-3 and the process owner for maintenance at Audi Hungaria.

Category	**Requirements**	**Definition**
Technology	Long Availability (Connectivity)	Constant and long availability of technology due to multiple connection capabilities
	Ergonomically long usable	Uninterrupted long use is ergonomically possible
	Hands-free operation	Allows hands to be focused on work
	Small and light	User effort for carrying
	Useable with gloves	Can be operated with gloves, does not interrupt work flow
	Low maintenance effort	E.g. load battery, calibrate, clean
	Robustness	Against physical influences
	Long battery duration	Usage time of technology before charging is required
	Visualisation capabilities	2D or 3D, texts, graphics, holograms
	Control capabilities	Offers easy and intuitive control possibilities
	Recording capabilities	Speech, pictures, videos
	Audio quality	Quality of the audio output capabilities
Process	Start-up effort	The required to start the product before every usage
Organisation	User acceptance	User will most likely accept technology
	Privacy	Respects the privacy of the user
	IT infrastructure compatibility	Integration in Microsoft Platform
	Workplace security standards	Effort to fulfil workplace security standards
	IT security standards	Fulfils existing IT security standards
	PR Potential	Influences public relations in a positive way
Start up	Development effort	Initial one time programming, calibration, configuration
	User Training	Effort for training and learning

Table 9: Additional requirements for use case “Maintenance Assistance”

4.4 Technology Selection

Now as the requirements had been defined it was time to select the appropriate technology and product. For this purpose, the tool “Value Benefit Analysis” had been selected. Following steps were conducted. The term criterion is used instead of requirement in the following tables.(Schuh & Klappert, 2011)

The first step was to assess the priority of the requirements. For this purpose the requirements where transferred in an assessment matrix as shown in Table 10. To assess the requirements the process owner for maintenance was interviewed and asked to assess each requirement according its relative importance to each other requirement. The result of the assessment in shown in Figure 18.

	Assessment: 0=less important than other criterion 0,5=equally important as other criterion 1=more important than other criterion	Technology												Proce	Organisation						Start			
		Long Availability (Connectivity)	Ergonomically long usable	Hands-free operation	Small and light	Useable with gloves	Low maintenance effort	Robustness	Long battery duration	Visualisation capabilities	Control capabilities	Recording capabilities	Audio quality	Startup effort	User acceptance	Privacy	IT infrastructure compatibility	Workplace security standards	IT security standards	PR Potential	Development effort	User Training	Summe Punkte	Gewichtung [%]
Technology	Long Availability (Connectivity)		0,5	1	0,5	1	0	1	0	1	1	1	0,5	1	1	0	0,5	1	1	0	0,5	0,5	13	6,2
	Ergonomically long usable	0,5		1	0,5	0,5	0,5	0,5	0,5	1	1	1	0	1	0,5	0,5	0,5	0,5	0,5	0	0,5	0,5	12	5,5
	Hands-free operation	0	0		0	0	0	0,5	0	0,5	0,5	0	0,5	0,5	0,5	0,5	0	0,5	1	0,5	0	0,5	6	2,9
	Small and light	0,5	0,5	1		0	0,5	0,5	0,5	1	1	0,5	1	1	1	0,5	1	1	1	1	1	1	16	7,4
	Useable with gloves	0	0,5	1	1		0,5	0	0	0,5	0,5	0,5	0,5	0,5	0,5	1	0,5	0,5	0,5	0,5	0,5	0,5	10	4,8
	Low maintenance effort	1	0,5	1	0,5	0,5		1	0,5	1	1	1	0,5	0,5	1	1	0,5	1	1	1	0,5	0,5	16	7,4
	Robustness	0	0,5	0,5	0,5	1	0		0,5	0,5	0,5	0,5	0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	9	4,3
	Long battery duration	1	0,5	1	0,5	1	0,5	0,5		1	1	0,5	1	1	1	1	1	1	1	1	0,5	1	17	8,1
	Visualisation capabilities	0	0	0,5	0	0,5	0	0,5	0		0,5	0,5	0,5	0,5	0,5	0,5	0	0,5	0,5	0,5	0,5	0,5	7	3,3
	Control capabilities	0	0	0,5	0	0,5	0	0,5	0	0,5		0,5	0,5	0,5	0,5	0,5	0	0,5	0,5	0,5	0,5	0,5	7	3,3
	Recording capabilities	0	0	1	0,5	0,5	0	0,5	0,5	0,5	0,5		0,5	0,5	0,5	0,5	0	0,5	0,5	0,5	0,5	0,5	8,5	4,0
	Audio quality	0,5	1	0,5	0	0,5	0,5	1	0	0,5	0,5	0,5		1	0,5	0,5	0	0,5	0,5	0,5	0,5	0,5	10	4,8
Proce	Startup effort	0	0	0,5	0	0,5	0,5	0,5	0	0,5	0,5	0,5	0		0,5	0,5	0,5	0,5	0,5	0	0	0,5	6,5	3,1
Organisation	User acceptance	0	0,5	0,5	0	0,5	0	0,5	0	0,5	0,5	0,5	0,5	0,5		0,5	0	0,5	0	0,5	0	0,5	6,5	3,1
	Privacy	1	0,5	0,5	0,5	0	0	0,5	0	0,5	1	0,5	0,5	0,5	0,5		0,5	1	0,5	0,5	0,5	1	11	5,0
	IT infrastructure compatibility	0,5	0,5	1	0	0,5	0,5	0,5	0	1	0,5	1	1	0,5	1	0,5		1	0,5	1	0,5	1	13	6,2
	Workplace security standards	0	0,5	0,5	0	0,5	0	0,5	0	0,5	0,5	0,5	0,5	0,5	0,5	0	0		0	0	0	0	5	2,4
	IT security standards	0	0,5	0	0	0,5	0	0,5	0	0,5	0,5	0,5	0,5	0,5	1	0,5	0,5	1		0,5	0,5	0,5	8,5	4,0
	PR Potential	1	1	0,5	0	0,5	0	0,5	0	0,5	0,5	0,5	0,5	1	0,5	0,5	0	1	0,5		0,5	1	11	5,0
Start	Development effort	0,5	0,5	1	0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1	1	0,5	0,5	1	0,5	0,5		0,5	12	5,5
	User Training	0,5	0,5	0,5	0	0,5	0,5	0,5	0	0,5	0,5	0,5	0,5	0,5	0,5	0	0	1	0,5	0	0,5		8	3,8
																							210	100,0

Table 10: Assessment matrix (Value Benefit Analysis)

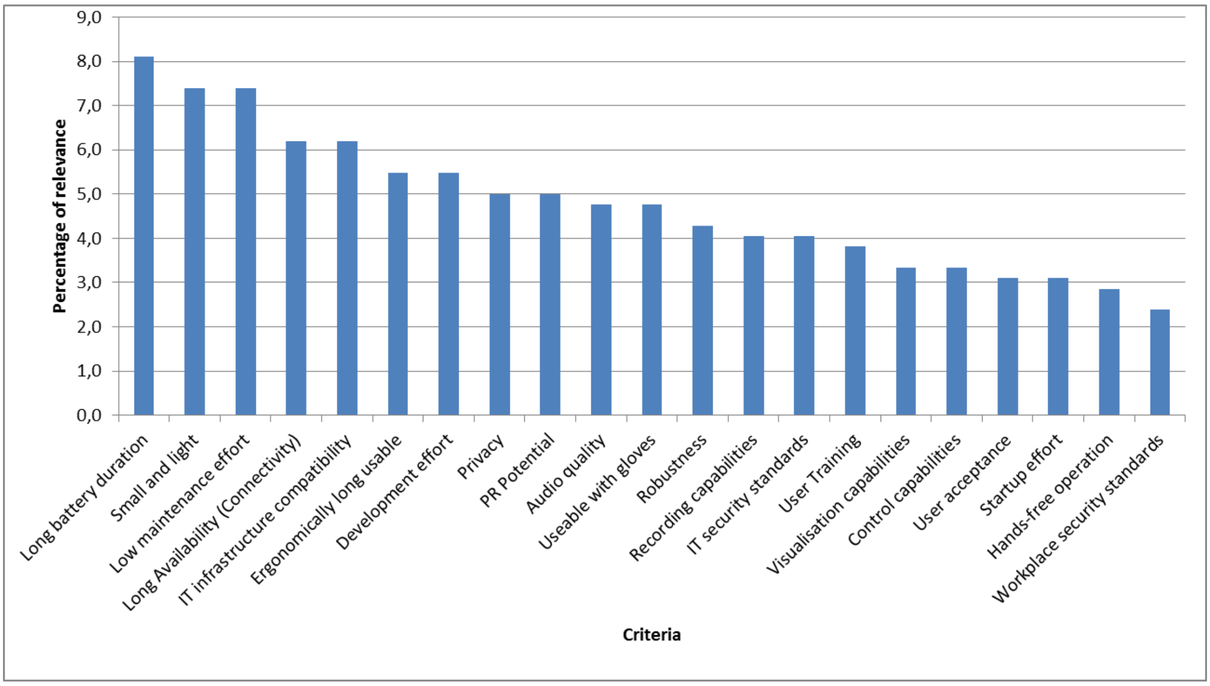


Figure 18: Sorted criteria according to assessment (Value Benefit Analysis)

The next step was to create the decision matrix. The decision matrix, shown in Table 11 consists of the requirements on the one hand and their assessed importance represented by the weighting and several product candidates. The product candidates where preselected based on the technology screening and the nature of the use case in alignment with department IT Motor G/FP-3. For each product, it was required to assess the fulfilment of each requirement. Therefore an auxiliary value table, shown in Table 12, was created and filled out based on the information that was collected during the technology screening. Finally, for every product an overall value was calculated as shown in Table 11. The result is shown in Figure 19.

0 Unsatisfactory 1 Barely acceptable 2 Satisfactory 3 Good 4 Very good		AR-HMD (active)						AR-HMD (passive)			Smartphone			Tablet PC		
		Microsoft Hololens			ODG-R7			Google Glass			Apple iPhone			Dell Venue 10		
Decisioncriteria	Weighting [%]	Assessment	weighted	Comment	Assessment	weighted	Comment	Assessment	weighted	Comment	Assessment	weighted	Comment	Assessment	weighted	Comment
Long Availability (Connectivity) and long availability of technology due to multiple connection c	6,2	3	0,186	WiFi, Bluetooth, USB	2	0,124	WiFi, Bluetooth	3	0,186	WiFi, Bluetooth, USB	4	0,248	WiFi, Bluetooth, 3G/LTE, USB	3	0,186	WiFi, Bluetooth, 3G/LTE, USB
Ergonomically long usable Uninterrupted long use is ergonomically possible	5,5	2	0,110		2	0,110		3	0,164		2	0,110		2	0,110	
Hands-free operation Allows hands to be focused on work	2,9	4	0,114	Voice, Gestures	2	0,057	finger controller	3	0,086	Touch, Gestures	1	0,029	hold in one hand, operate with other hand	1	0,029	hold in one hand, operate with other hand
Small and light User effort for carrying	7,4	2	0,148	579g	3	0,221	125g	3	0,221	36g	3	0,221	129g	2	0,148	597g
Useable with gloves Can be operated with gloves, does not interrupt work flow	4,8	4	0,190	Voice, Gestures	3	0,143	problems with glasses	1	0,048	problems with gloves	1	0,048	problems with gloves	1	0,048	problems with gloves
Low maintenance effort e.g. load battery, calibrate, clean	7,4	2	0,148	daily	2	0,148	daily	2	0,148	daily	3	0,221	every 2 days	3	0,221	every 2 days
Robustness against physical influences	4,3	2	0,086		2	0,086		2	0,086		3	0,129		3	0,129	
Long battery duration Usage time of technology before charging is required	8,1	1	0,081	2-3h	1	0,081	4h	3	0,243	~1day	3	0,243	>=1day	3	0,243	
Visualisation capabilities 2D or 3D, texts, graphics, holograms, ...	3,3	4	0,133	3D Holograms	3	0,100	?	2	0,067		3	0,100		3	0,100	
Control capabilities offers easy and intuitive control possibilities	3,3	4	0,133		3	0,100	?	3	0,100		3	0,100		3	0,100	
Recording capabilities speech, pictures, videos, ...	4,0	4	0,162	audio and video	4	0,162	audio and video	4	0,162	audio and video	4	0,162	audio and video	4	0,162	audio and video
Audio quality Quality of the audio output capabilities	4,8	4	0,190	spatial sound	3	0,143		1	0,048	bone transduce	2	0,095		2	0,095	
Startup effort The required to start the product before every usage	3,1	3	0,093	1-5min	3	0,093	1-5min	3	0,093	1-5min	3	0,093	1-5min	3	0,093	1-5min
User acceptance User will most likely accept technology	3,1	2	0,062		2	0,062		2	0,062		2	0,062		4	0,124	
Privacy Respects the privacy of the user	5,0	4	0,200	Windows Platform	2	0,100	ReticleOS (Android based)	2	0,100	Android	2	0,100	iOS	2	0,100	Android
IT infrastructure compatibility Integration in Microsoft Platform	6,2	4	0,248	Windows Platform	2	0,124	ReticleOS (Android based)	2	0,124	Android	2	0,124	iOS	2	0,124	Android
Workplace security standards Effort to fulfil workplace security standards	2,4	2	0,048		2	0,048		2	0,048		2	0,048		4	0,095	
IT security standards Fulfils existing IT security standards	4,0	4	0,162	Windows Platform	2	0,081	ReticleOS (Android based)	2	0,081	Android	2	0,081	iOS	2	0,081	Android
PR Potential Influences public relations in a positive way	5,0	4	0,200		2	0,100		0	0,000		0	0,000		0	0,000	
Development effort Initial one time programming, calibration, configuration	5,5	0	0,000	external programming required	0	0,000	external programming required	0	0,000	external programming required	0	0,000	external programming required	0	0,000	external programming required
User Training Effort for training and learning	3,8	2	0,076		2	0,076		2	0,076		2	0,076		4	0,152	
	Sum	2,77			2,16			2,14			2,29			2,34		

Table 11: Decision matrix (Value Benefit Analysis)

Auxiliary Value Table

	0 Unsatisfactory	1 Barely acceptable	2 Satisfactory	3 Good	4 Very good
Long Availability (Connectivity)	no connections	1 connection (Wi-Fi or Bluetooth or 3G/LTE or USB	2 connections	3 connections	> 3 connections
Ergonomically long usable	less than 10 min	10 min < x < 1 h	1h - 4h	one work day	unlimited
Hands-free operation	no hand free	sometimes 1 hand free	1 hand always free	sometimes 2 hands free	always 2 hands free
Small and light	> 2kg	1 - 2 kg	0,5 - 1 kg and well balanced weight	up to 500 g and well balanced weight	no force effort
Useable with gloves	cannot be operated with gloves	problems with gloves	gloves possible	gloves possible + 1	3 possible (gloves, glasses, no cable)
Low maintenance effort	x	every hour	daily	every 2 days	weekly
Robustness	not usable long-term in production	quite sensitive	office standard	higher office standard	industrial standard (water, dust, oil)
Long battery duration	< 1 h	1 - 4h and no changeable battery	1 - 4h and battery is changeable	4 - 24h	>=1 day
Visualisation capabilities	no display	only pictograms / signals	only big text and symbols	lots of text readable	also details readable, e.g. 3D holograms or videos
Control capabilities	no	only through special device	1 (speech, or gestures or touch or keyboard)	2	3 or more
Recording capabilities	no	x	audio or video	x	audio and video
Audio quality	no audio	bone conduction transducer	mono	stereo	integrated spatial sound
Start-up effort	> 30 min	15 - 30 min	5 - 15 min	1 - 5 min	immediately ready
User acceptance	unlikely - new and hardly acceptable	x	likely - new but interesting	x	very likely - known and used to it
Privacy	users have no control about collected data	x	partially in control of the users	x	data is in full control of the users
IT infrastructure compatibility	incompatible with Microsoft platform	x	other than Windows Microsoft but compatible with effort	x	Microsoft Platform
Workplace security standards	not fulfilled product adaptations required	x	additional user training required	x	fulfilled no additional effort required
IT security standards	not fulfilled Cloud / external Server	x	partially fulfilled (additional integration effort required e.g. Android OS)	x	fulfils standard IT security policies (e.g. Microsoft platform)
PR Potential	no public interest	x	sellable	x	big publicity expected

Development effort	external programming	internal programming	external config + calibration only; no programming	internal config + calibration only; no programming	no effort
User Training	longer special training	x	only short in-house training required	x	no training required

Table 12: Auxiliary value table for decision matrix (Value Benefit Analysis)

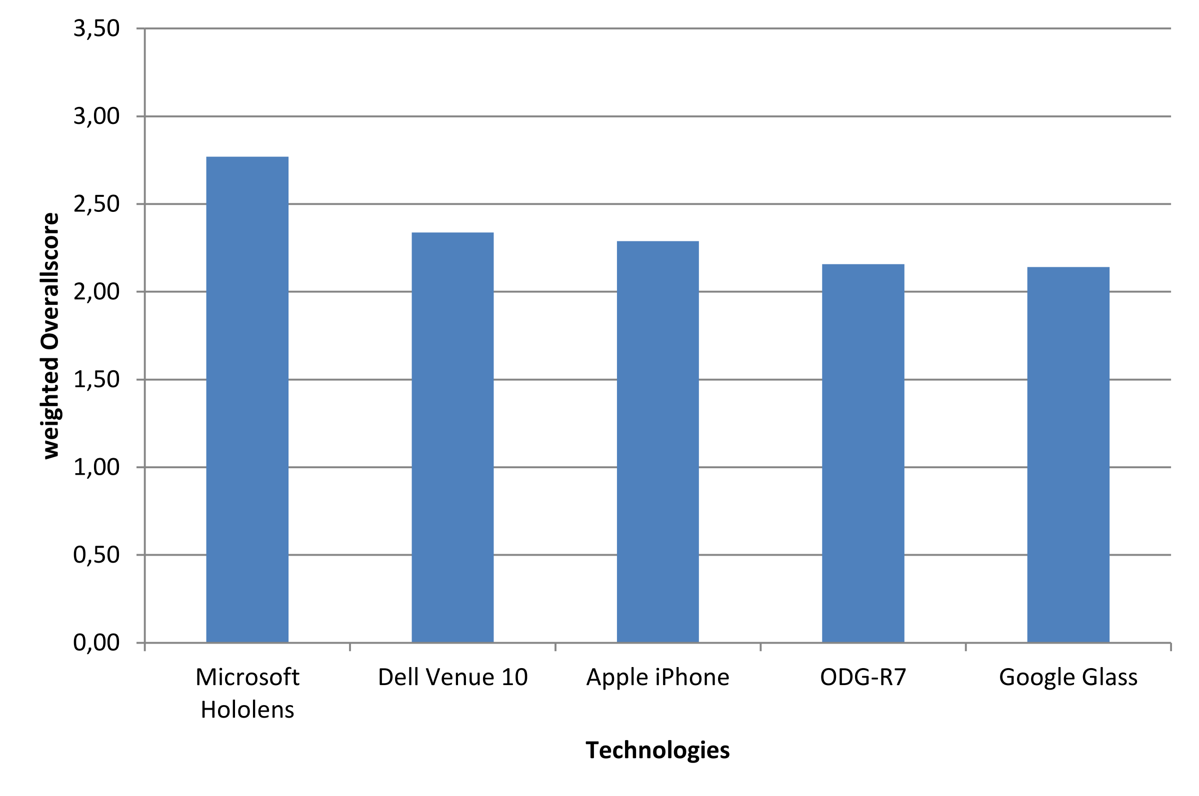


Figure 19: Result of Value Benefit Analysis

4.4.1 Selected Technology

Microsoft HoloLens was the selected product as it achieved the highest score in the Value Benefit Analysis. HoloLens is a headset that offers mixed reality features. That means it can connect holograms with the real environment, which is great feature for displaying information at the right place.(Microsoft, 2017)

Technical specification of Microsoft HoloLens (Rubino, 2016)**:**

Display:

- See-through holographic lenses (waveguides)
- 2x HD 16:9 light engines
- Automatic pupillary distance calibration
- 2.3M total light points holographic resolution, 2.5k light points per radian

Sensors

- Inertial Measurement Unit

- 4x environment understanding cameras
- Mixed reality capture
- 4x microphones
- Ambient light sensor

Processor

- Custom Microsoft Holographic Processing Unit HPU 1.0
- Intel 32-bit architecture

RAM

- 2GB

Storage

- 64GB

Weight

- 579g

Camera

- 2MP photos
- HD Video

Audio

- External speakers
- 3.5mm audio jack

Connectivity

- Wi-Fi 802.11ac
- Bluetooth 4.1 LE
- Micro-USB 2.0

Power

- 2-3 hour active use battery life
- 2 weeks standby
- Passive cooling

OS

- Windows 10 with Windows Store

Human Understanding

- Spatial sound
- Gaze tracking
- Gesture input
- Voice support

4.5 Value Network Analysis for “Maintenance”

Table 13 shows an overview of all identified actors and the related information as described in chapter 2.2.3. The table also contains the transfer objects from the perspective of each actor. During analysis of the transfer objects, it was realized that with the available information it would make sense to group some of the actors as they have common in port and out port transfer objects and common requirements, for a better overview (see also Vorraber, 2012). The resulting Value Network is shown in Figure 20.

The values network has been further used to ensure that all stakeholders are considered throughout the implementation and evaluation of the system. It also indicates the motivational level as “active” for the actor “Process Owner Maintenance” and aggregated actor “IT-Motor (G/FP)” as those actors have been perceived as highly motivated so far in the project. The motivational level for the aggregated actor “Maintenance” is modelled as “neutral” as it was sometimes difficult to get hold of stakeholders in this group, although they are the main users of the system, as they were very busy with their daily work.

Actors	Capabilities (C)	Assets (A)	Needs							In port - transfer object	Out port - transfer object
				Non functional needs							
			Functional Needs (FN)	Technical non functional needs (TNFN)	Social economic needs (SEN)	Social human needs (SHN)	Ethical needs (EN)	Safety needs (SN)	Legal needs (LN)		
VW Wolfsburg	Define global strategies and processes for complete VW group	Money, Knowledge about global innovation projects Contacts to different partners within and outside the VW Group	High OEE	-	-	-	-	-	-	Product (Engines produced by AH)	Monetary Value, Information (Knowledge, Strategy, Targets)
Audi Ingolstadt	Define global strategies and processes for Audi Group	Money, Knowledge about global innovation projects Contacts to different partners within and outside the Audi Group	High OEE	-	-	-	-	-	-	Product (Engines produced by AH)	Monetary Value Information (Knowledge, Strategy, Targets)
Audi Hungaria CEO	Hire and fire, defines and implements overall strategy for AH based on global strategy	Money, Production Facility, Detailed knowledge about strategy and overall targets	High OEE	High employee satisfaction	High PR potential	-	Transparancy Objectivity Reliability	-	All regulations that apply for a company	Monetary Value Information (OEE KPI)	Product (Engines) Brand Information (OEE KPI)
Process Owner Maintenance	Define processes Measure and report KPIs (OEE KPI) Link between top managment and operative management	Detailed knowledge about maintenance processes	Process activites are documented and measured to be able to further improve the process	High user acceptance	Low start-up effort Low training effort	-	Transparancy Objectivity Reliability	-	-	Monetary Value Detailed **information** about conducted maintenance process activities Service (Maintenance App)	Information Coordination
Productsegement (P3-P8, Mech. Bear., MoMo) Productline Manager	Responsible for maintenance of the whole production line	Overall knowledge about production line	High availibiltiy of machines Scheduling and reports about maintenance tasks conducted by his team Information on maintenance task in time in place (what, where and when) Hands-free operation	High robustness of Hardware	Gain flexibility in conducting different maintenance tasks	-	Privacy Accessibility Reliability	Ergonomically long usable	-	Service (Maintenance App) Information Coordination	Information
Technical Service Manager	Manages resources and organizational setup up of workshop	Workshop									
Workshop Manager	Manages resources for maintenance tasks (manpower, tools)	Workshop									
Productline (P3 -P8)IH Linie Inge	Decides who will execute the maintenance job (internal or external) and is fully responsibel for budget	Detailed knowledge about production line and related machines									
Productline (P3 -P8)IH engineer	Conducts moderate (level 2) maintenance tasks	Knows how specific maintenance tasks are conducted									
Productline (P3 -P8)Operator	Conducts simple (level 1) maintenance tasks	Knows how specific maintenance tasks are conducted									
WorkshopIH engineer	Conducts complex (level 3) maintenance tasks	Knows how complex maintenance tasks are conducted									
Occupational Safety	Explain occupational safety requirements and ensure that they are not violated. Participation in the decision regarding selected product for operational use	Detailed knowledge about occupational safety requirements	Documentation of conducted tasks (who, where, what and when)	-	-	-	Security	-	Fulfillment of all safety regulations	Information	Information
CIO	Go or no-go decisions for projects Can supply additional resources (manpower, money)	IT Budget, Detailed knowledge about long term IT strategy	Overall reports on usage of the service and the satisfaction of users Fulfillment of IT Hard- and Software regulations Documentation and reports on all IT security related activities, Central management of IT security policies	Application shall be easy to support and maintain IT infrastructure compatability Constant and long availability of technology	-	-	Security	Defined security rules have to be applied.	-	Information Intangible Value (Development Know-How) Service	Coordination Monetary Value Information Service (Maintenance App)
IT-Motor (FP3) Project Manager	IT Projectmanagement for new applications required by the production	Project management Know-How Knowledge about different stakeholders Know-How about operative processes									
Dept. IT Infrstructure (FP5)	Provide and support required IT infrastructure	Standard IT Hardware and Software									
Dept. IT Security (FP1)	Explain security requiremetns and ensure that they are not violated. Participation in the decision regarding selected product for operational use.	Detailed knowledge about IT security requirements									
360 world Hololens Dev. Partner	Development support for PoC	Software development engineers, with expericence in augemted reallity app develoment	-	-	Acceptance of software application by the user High PR potential	-	-	-	-	Monetary Value Intangible Value (Use Case Know How)	Intangible Value (Development Know How) Service
Microsoft	Support companies in realizing their ideas	Product Know-How, App Development Know-How	-	Feedback about real life applications of their product to further imrpove it	Increase of reputation as a valuable business partner in large scale production environments High PR potential	-	-	-	-	Information Monetary Value	Information Product (Microsoft HoloLens)

Table 13: Value Network Map for “Maintenance”

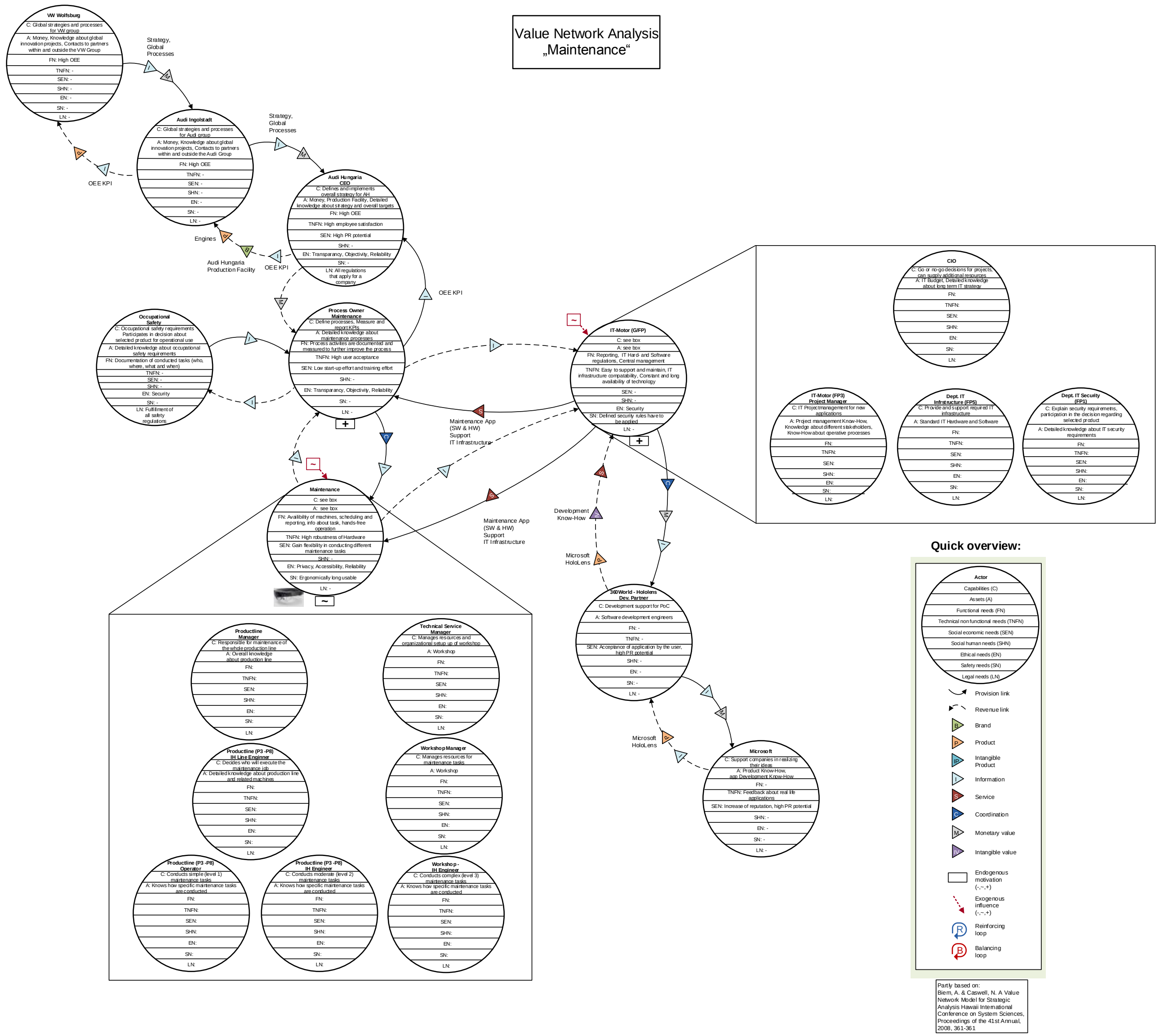


Figure 20: Value Network for “Maintenance”

4.6 Implementation

This chapter describes the implementation of the “Maintenance Assistance” application for the Proof of Concept. The programming itself was done by a third party company called 360World (360World, 2017), a Hungarian software development company located in Budapest. Due to lack of time for finishing the Proof of Concept and the availability of the required hardware, it was decided by Audi Hungaria to order the implementation for the Proof of Concept at 360World, as they already had experience in implementing mixed reality applications and as they could supply Audi Hungaria with a Microsoft HoloLens for the project.

A more detailed description of the implementation for the Proof of Concept was created in collaboration with 360World based on the use case description and the storyboard.

4.6.1 Proof of Concept for “Maintenance Assistance”

Following description was created together with 360World and used for the implementation of the “Maintenance Assistance” application:

Introduction
The goal of this Proof of Concept is to illustrate how Microsoft HoloLens can be used in a maintenance scenario.
The user of the app for the Proof of Concept is a Maintenance Engineer (ME). During the POC, ME will identify a machine that required maintenance, perform measurement and maintenance tasks on the machine, and record his work. For the purpose of the POC, the system will not be connected to an external data source, such as ODM (Operational Data Monitoring) system – all data will be “hard-coded”.
The task to be performed is verification of the tightness of a toothed belt, and any necessary adjustments.
The POC will include a “script” that showcases the features of the finished product, but does not necessarily implement everything to its full extent.

Preparation
During preparation, the operator identifies the positions of the different machines, and places the status indicators and other required objects in the room.

Steps
These are the steps the user will go through while experiencing the POC:

Step 1 – 3D Task List
Instead of a tabular list of tasks to be performed, the user will see a status indicator above every machine. The status indicator will be

- green for machines that don’t require maintenance,
- yellow for machines that require scheduled maintenance

- red for machines that need immediate attention

ME is instructed via the status indicators to visit a “yellow status” machine.

Step 2 – Task and machine overview

When the ME has arrived to the vicinity of the machine, he/she is shown an overview of the task that needs to be executed. The overview includes:

- A historical overview of the oil flow meter’s values. (e.g. a holographic graph).
- Name of the task – e.g. “Toothed belt tightness verification”
- Last verified date (which for the POC will always be today – 3 days)
- Oil level history (bar chart with min/max value lines)

There is a “Begin Maintenance” button the user can indicate that he/she is ready to start with maintenance. This will initiate Step 3.

Step 3 – Performing the measurement

“Hot” parts of the machine are indicated with a red outline of the dangerous objects.

The user is instructed to get the meter ready, and 3D holograms show where to place the sensor and how to resonate the belt.

The user can use voice command or a virtual keyboard to record the measurement. For example he/she can say “I measured 44”.

The correct value should be 46. If the value measured is 46, then we proceed to Step 5(if adjustment is made) or Step 6 (if NO adjustment has been made).

If the value measured is not 46, adjustment is required, and the user is taken to Step 4.

Step 4 – Adjustments

During adjustments, the “Hot” parts of the machine are still indicated with a red outline.

The user is shown the screws he/she has to loosen. After the user indicates he/she’s done (via a voice command or an air-tap), he/she is shown the screw that needs to be adjusted. Now, the app automatically indicates the right direction to adjust the screw in order to move it towards 46.

After adjustment, the user is taken back to Step 3 (via a voice command or air-tap).

Step 5 – Tighten the screws

Just like at the beginning of Step 4, the screws that need to be re-tightened are indicated.

Step 6 – Completion

The user is asked to hold up the measurement device with the value clearly readable in a virtual viewfinder, and take a photo to document the task well performed, and placed in the device’s standard image library.

Upon completion, a text file is created with the log of the performed steps and the measured values. The file starts with the device’s ID, task name (which is always the same for the POC), and an overall start time, end time, number of minutes taken, and the engineers name (which will be hard-coded). Every step will have a timestamp as well.

Other Features

During the entire process, the user can initiate taking a picture or recording a video with voice commands. Depending technical feasibility, the user will also be able to record an audio note. Any textual information can be moved by the user.

The application will be developed in English.

Information to be provided by Audi

- A video recording of the entire procedure
- All the text to be displayed
- Dimensions and photos of the machine and the tools
- Continuous feedback on the application as it is being developed

4.6.2 Screenshots of Actual Implementation

The following screenshots, that were taken from a video created at Audi Hungaria, shall illustrate how the use case description, the storyboard and the more detailed description for the Proof of Concept finally evolved in an application for maintenance assistance in a production environment.

Feature 1 - 3D Task List

Figure 21 shows the actual implementation of the “3D Task List”. The spheres above the machines indicate their state. “Green” stands for everything ok, “Yellow” for a scheduled maintenance task and “Red” means that the machine requires immediate attention by a maintenance engineer.

Figure 21: Screenshot of feature “3D Task List”

Feature 2 - Task and machine overview

Figure 22 shows a scene of the application that appears as soon as the maintenance engineer approaches a machine that has a yellow status indicator. On the left side, a holographic window is shown that gives an overview of the machine itself e.g. operational data or error messages. On the right, side a window appeared on the wall next to the machine. This window shows textual information about the task that has to be conducted. Both windows can be repositioned by the maintenance engineer via gestures.

Figure 22: Screenshot of feature “Task and machine overview”

Feature 3 - Specific task instructions incl. documentation of each step

As soon as the maintenance procedure is started by the maintenance engineer via a gesture specific task instructions are displayed step by step as shown in Figure 23

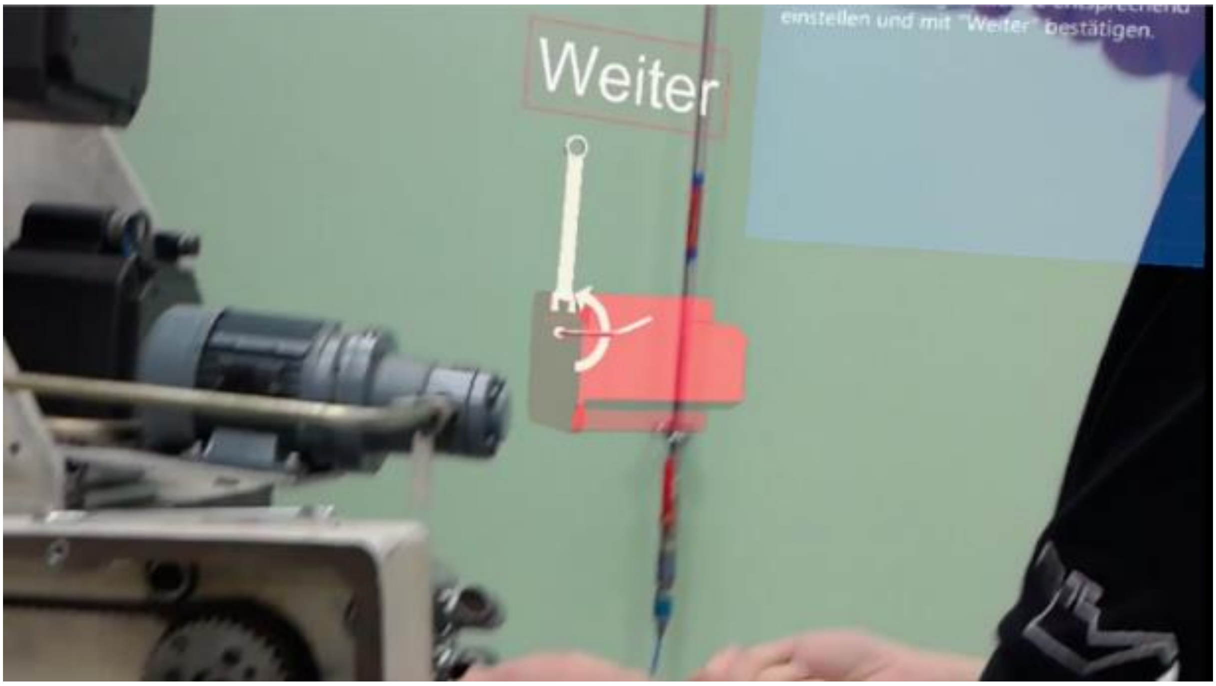


Figure 23: Screenshot of feature “Specific task instructions incl. documentation of each step”

Feature 4 - Automatic prefilling of "maintenance report"

After finishing the task data that is relevant for the maintenance report, like who conducted the task or when it was conducted, is automatically stored. The final report is shown in Figure 24.

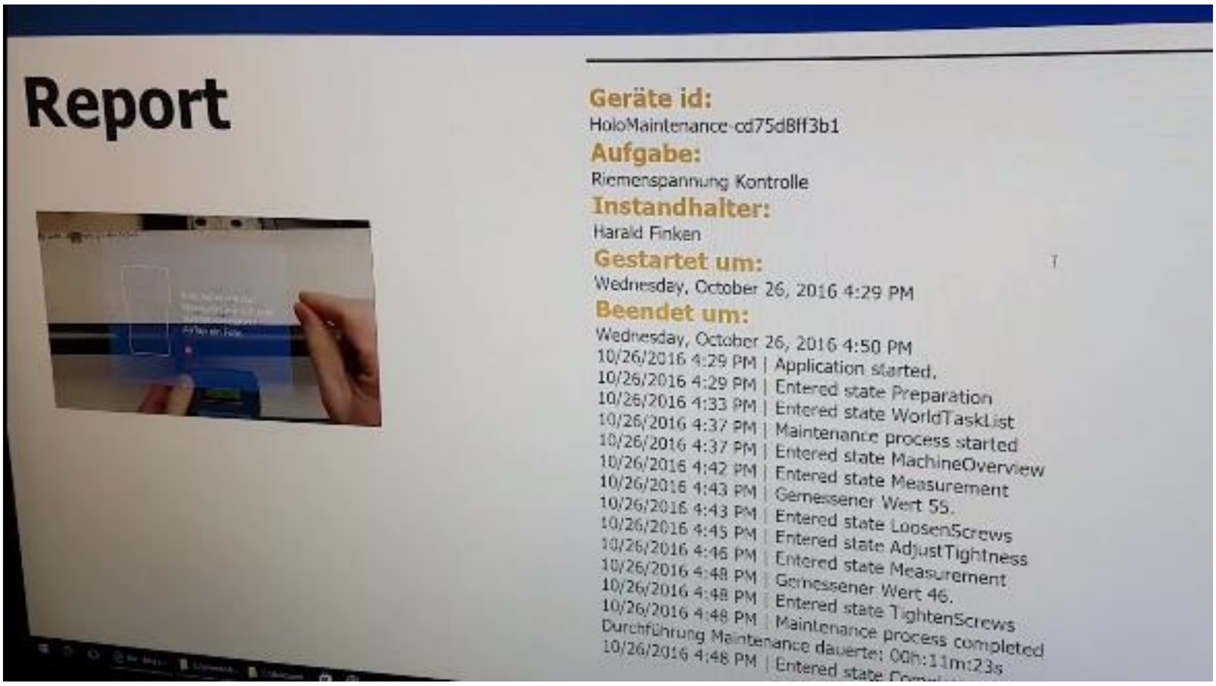


Figure 24: Screenshot of feature “Automatic prefilling of maintenance report"

4.7 Evaluation

The evaluation of the maintenance assistance system was done in an experiment with the following setup.

4.7.1 Evaluation Setup

Following targets had been defined for the conduction of the experiment:

- Encounter and distinguish between phenomena that are inherent to the use of the Microsoft HoloLens
- Encounter and distinguish between phenomena that are inherent to the use case and the tasks being performed
- Comparison of tasks with and without Microsoft HoloLens

The main technical device that was evaluated was the Microsoft HoloLens
The experiment was conducted at the “Profiraum” at Audi Hungaria. This room is usually used for training of employees.

The full experiment was recorded with a mobile camera that was operated by a cameraman. For tests with HoloLens, additionally the first person view including audio was directly recorded with the HoloLens. For tests without HoloLens a wireless headset was used to record the voice of the user for the “Thinking Aloud Test”.

Each participant went through following procedure:

- HoloLens introduction via application “Learn Gestures“
- Conduction of Maintenance Task 1 “Belt tension control and adjustment” with HoloLens
- Conduction of Maintenance Task 2 “Check oil level and refill” without Hololens
- Finally, each participant was interviewed including audio recording

Six maintenance engineers from the technical service department at Audi Hungaria participated in the experiment as test persons.

4.7.2 Evaluation Results

As first results, the conducted interviews have been evaluated. A summary of the result is shown below. More detailed results are going to be published in a separate paper after the collected audio and video material has been fully analysed and evaluated. The summary of the result is split in pros and cons regarding the implemented use case and the selected product.

Pros:

- Very helpful when conducting unknown or complex tasks

- Shows the relevant information
- Very good for documenting
- Status indicators are helpful for finding the machine
- No concerns about privacy

Cons:

- Uncomfortable
- Could be problematic in case of less space
- Hardware is still a prototype and doesn’t fulfil industrial requirements yet
- Field of view for holograms is too small
- Some uncertainty in the operation of the HoloLens

5 Conclusion

The conclusion includes a summary of the results of the whole project as well its limitations.

5.1 Results

The structured overview of use cases and technologies has been extended by industrial use cases and technologies in the segment of wearables. This overview has been successfully used as a base for further steps of the project. Furthermore, it can be reused in upcoming additional innovation projects and it can be easily extended with additional use cases and new technologies.

Following frameworks have been successfully applied and validated:

- UCTM Framework
- Service Design

Following tools have been successfully applied and validated

- Value Proposition Design (Value Proposition Canvas)
- Storyboard
- Value Benefit Analysis
- V² Value Network Notation

A prototype for Proof of Concept of the selected use case “Maintenance Assistance” and technology mixed reality and the product Microsoft HoloLens has been successfully implemented and evaluated in an experiment. First results based on conducted interviews have been presented.

The “Maintenance Assistance” application demonstrated an easy way of finding a task. It enables users to fulfil a task where they are not fully trained on, as it shows the required information at the right time in the right place, which increase the flexibility of employees.
The automated documentation of each task on the one hand saves time for the employee, as no further manual documentation is required and on the other hand increases the transparency of maintenance processes as workflows are documented including timing information.

Due to its generic nature the use case can also be easily extended for training purposes, which could have following effects:

- Better scalability of training resources
- Less trainers required
- Possibility for self-training
- Possibility of sharing of trainings

5.2 Limitations

Following limitations of the implemented system have to be considered. The interface to existing systems where just simulated (hard coded). The development effort for creating required interfaces to existing systems such as the operational data monitoring system is not clear yet. The application has been only tested with a few users (six maintenance engineers who participated in the experiment and a few others who tried it out). The application has been only tested for one task in a training environment that is close to a production environment but still different.

6 Outlook

Finally, an outlook on the next steps, some ideas regarding task generation and placement of holograms and open topics including concerns raised at the end of the project are given in the following chapters.

6.1 What Are the Next Steps?

A detailed analysis of the collected audio and video material is going to be conducted to finally complete the qualitative and quantitative assessment.

The effort for establishing interfaces to existing systems, such as operational data monitoring has to investigated.

Further appropriate tasks for additional implementations have to be identified and evaluated e.g. more complex tasks (Assistance and/or Training).

Ideas for further improvement of the “Maintenance Assistance” application:

- Better feedback for user (what he has achieved at the end)
- Possibility that user can give feedback (on process or on application)

6.2 Generation of Task Instructions

One main aspect of the application is the generation of task instruction and its scalability. Today tasks are digitalized in excel spreadsheets. There is no guarantee for keeping the same structure of a task documentation, which makes it very difficult to directly reuse them in the end-user device.

In the future, tasks might be available in a structured digitalized form. To be “loaded” by the end-user device that only works as interface to the maintenance engineer.

Today tasks instructions, as already mentioned above, are created in excel spreadsheets. Maybe, in the future, they can be created with an application directly with the HoloLens by some experts. This would end up by having one application for “Task Creation” and one application for “Maintenance Assistance”.

6.2.1 Possible Structure of a Maintenance Task (ERM)

Following ERM, shown in Figure 25, shall demonstrate how a maintenance task could be structured in order to make it possible to automatically load required information from a database by any other tool that needs to display the information.

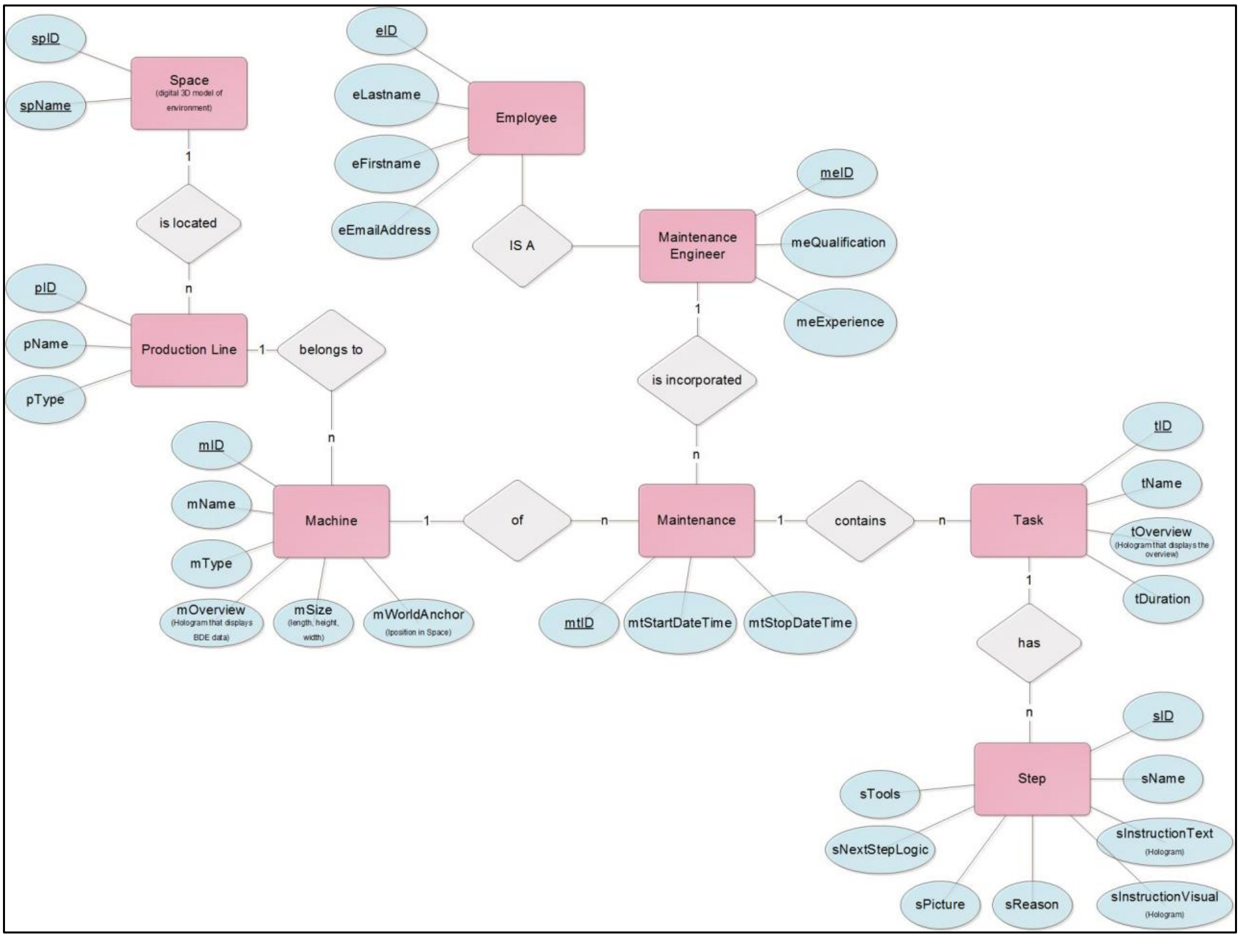


Figure 25: Possible Entity Relationship Model of a "Maintenance Task"

6.2.2 Possible Placement of Holograms

In the Proof of Concept the positioning of the holograms was done manually before the task was started. This of course does not scale in an operational environment. Holograms shall be placed upfront and their position needs to be stored and then loaded into the application when a task is conducted. Following idea maybe used to reduce the initial effort of defining and storing all the positions of the different holograms:

- Manual placement of mWorldAnchor once per Machine (each entitiy) -> defines the position of the machine in space. -> #Machines
- Automated placement of task specific holograms relative to mWorldAnchor in consideration of mSize.
- Manual placement of step specific holograms once per mType and task. Stored as a relative position to mWorldAnchor. For a different machine of the same machine type it would then be sufficient to place its mWorldAnchor at the same place as at the first machine.
  -> #mType * #Task

6.3 Open Topics and Concerns

Following open topics and concerns have been gathered in an expert workshop with Audi Hungaria IT (all team leaders of segment G/FP and process owner for maintenance):

- Hardware is still a prototype
- Integration in company network still open
- Windows 10 is not yet fully rolled out but required for full support of Microsoft HoloLens
- Currently there are only a few provider of HoloLens applications
- Currently only one piece of hardware is available at Audi Hungaria
- How the support is handled in case of issues with the Microsoft HoloLens is still unclear
- Lack of own development capabilities
- Interfaces to existing systems are not defined yet
- Creation of task instructions for HoloLens is still an open topic
- Investigations regarding occupational safety are still ongoing
- Physiological effects (health aspects)

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