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Importance of human influence in systems engineering

implications for autonomous vehicles

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Preface

This thesis was conducted during the fall of 2018 at the department of Engineering Design and Materials (IPM) of NTNU with Associate Professor Cecilia Haskins as supervisor.

The thesis seeks to investigate and develop an understanding of how human interactions affects systems design as well as the impact of digitalization on human activities.

The author would like to express his severe gratitude and thanks to Associate Professor Cecilia Haskins for her guidance, invaluable input and comments, and great discussions. It has been an honor and a delight to work under her supervision.

The author would also like to thank his family and friends for their love and support throughout his studies at NTNU

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Summary

Technological systems are becoming more and more interconnected. At the same time that human activities are becoming more connected to technology. With the merging of these complex systems, systems design takes on a new plane of considerations. The thesis investigates the impact of digitalization on human activities as well as how humans are factored into the design of systems. In order to investigate this, three research questions were posed:

1. What is the background that has led to the phenomenon “digital transformation”?
2. How can we factor human interactions into system design?
3. What is the impact of digitalization on human activities?

The questions were investigated through literature studies along with a case analysis of the introduction of autonomous busses in Norwegian cities. The background of digital transformation is presented through a timeline breaking down important milestones and developments. Human factors in systems design is investigated through a look at multiple design paradigms and how they factor humans into the design process. The case study looks at how humans are factored into the plans for introducing autonomous busses as well as how this digitalization of transport affects the users.

The study found that the affect of digitization is permeating through every aspect of human activities, from interactions and communication, to where they live and how they travel. The existing design paradigms factor human interactions through observations of people in real situations along with embracing differing social and cultural biases to gain a broader insight into how different people will interact with a system. Systems designers must embrace the interactions people have with existing digital systems to further understand their interconnections with systems in general.

Sammendrag

Teknologiske systemer blir mer og mer integrerte. Samtidig som menneskelige aktiviteter blir mer knyttet til teknologi. Med sammenslåingen av disse komplekse systemene får system design ett helt nytt plan å ta i betraktning. Denne avhandlingen undersøker innvirkningen digitalisering har på menneskelige aktiviteter i tillegg til hvordan menneskelige interaksjoner blir medregnet i system design. For å undersøke dette har det blitt stilt tre forskningsspørsmål:

1. Hva er bakgrunnen som har ført til fenomenet «digital transformasjon»?
2. Hvordan kan vi medregne menneskelige interaksjoner i system design?
3. Hva er innvirkningen av digitalisering på menneskelige aktiviteter?

Spørsmålene er undersøkt gjennom litteraturstudier i tillegg til en saksanalyse av innføringen av selvkjørende busser til norske byer. Bakgrunnen til den digitale transformasjonen er fremstilt via en tidslinje som presenterer viktige milepæler og utviklinger. Menneskelige faktorer i systemdesign er undersøkt gjennom en gransking av flere designparadigmer og hvordan de medregner menneskelige faktorer i designprosessen. Saksanalysen undersøker hvordan menneskelige faktorer er medregnet i planene om å introdusere selvkjørende busser i norske byer og også hvordan denne digitaliseringen påvirker brukerne.

Studien fant at effekten av digitalisering trenger gjennom alle aspekter av menneskelige aktiviteter, fra interaksjoner og kommunikasjon, til hvor folk bor og hvordan de reiser. De eksisterende designparadigmene medregner menneskelige faktorer gjennom observasjoner av folk i ekte situasjoner samtidig som de omfavner forskjellige sosiale og kulturelle individualiteter for å få en dypere innsikt i hvordan forskjellige folk samhandler med systemer. Systemdesignere må omfavne interaksjonene folk har med eksisterende digitale systemer for å videreutvikle forståelsen av personer sine interaksjoner med systemer generelt.

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Avtale om gjennomføring av masteroppgave

Denne avtalen bekrefter at masteroppgavens tema er godkjent, at et veilederforhold er etablert, og at partene (student, veileder og institutt) er kjent med og har akseptert gjeldende retningslinjer for gjennomføring av masteroppgaven. Avtalen er videre regulert av lovverk, studieforskrift og studieplanen for masterprogrammet.

1. Personopplysninger

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2. Institutt og studieprogram

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Institutt **Institutt for energi- og prosessteknikk**	
Studieprogram **Master i produktutvikling og produksjon**	Studieretning **Produktutvikling**

3. Avtalens varighet

Oppstartsdato **28. september 2017**	Innleveringsfrist* **21. februar 2018**
Hvis avtale om deltidsstudier, angi prosent:	

** Inkludert 1 uke ekstra p.g.a jul*

All veiledning må være gjennomført innenfor avtaleperioden.

4. Arbeidstittel for oppgaven

Importance of human influence in systems engineering
implications for autonomous vehicles

5. Veiledning

Veileder
Cecilia Haskins

Normert veiledningstid er **25 timer** for 30 studiepoengs (siv.ing) og **50 timer** for 60 studiepoengs (realfag) masteroppgaver.

6. Thematic description

I will be investigating how human factors influence the design process from a systems engeneering point of view. My case study will be on autonomous vehicles in their environment.

7. Andre avtaler

Tilleggsavtale	**Ikke aktuelt**
Søknad om godkjenninger (REK, NSD)	**Ikke aktuelt**
Risikovurdering (HMS) gjennomført	**Ja**

Vedlegg (oversiktsliste)

Risikovurdering

8. Underskrifter

Vilkår	Dato	Underskrifter
Jeg har lest og akseptert gjeldende retningslinjer for masteroppgaven	28 Sep. 2017	Øvin S. Norman Studenten
Jeg påtar meg ansvaret for veiledning av studenten etter gjeldende retningslinjer	28.sep. 2017	Cecilia Haskins Veileder
Institutt/Fakultet godkjenner opplegget for masteroppgaven		Fakultet/Institutt

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Abbreviations

AI	Artificial intelligence
AUP	Acceptable Use Policy
AV	Autonomous Vehicle
DARPA	Defense Advanced Research Projects Agency
GPS	Global Positioning System
IT	Information Technology
LIDAR	Light detection and ranging
NSF	National Science Foundation
NTNU	Norwegian university of science and technology
UBM	Universität der Bundeswehr München
WWW	World Wide Web

1. Introduction

This chapter serves as an introduction to the thesis. It provides an overview of the motivation for the research and why it is of interest to develop further knowledge on the thesis topics. It describes the background of the study, problem statement, objective, the research questions, and the scope, structure, and planning and control of the thesis.

1.1 Background

Society is in continuous motion. Technologies available to the masses today are much more sophisticated than the most advanced technologies available only a generation ago. Today's mobile phones have more computational power than the largest computers had a generation ago (Srivastava, 2005). Artificial intelligence (hereafter referred to as AI) has already infiltrated our society, but only in subtle ways so far. Except for those worried about privacy issues, most are not too concerned about the current AI. However, we are on the cusp of AI becoming more prominent and visible. Machines are being introduced into day-to-day life more and more, and these machines are becoming smarter. One of the most prominent examples of this is autonomous vehicles (AV).

According to the Norwegian prime minister's New Year speech (Solberg, 2018) we must prepare for a brand new future. One in which modernization and digitalization is happening rapidly. "In almost all jobs, tasks will change. There will be more computers, more robots. We must also change if we wish to keep up". (Solberg, 2018, translated from Norwegian by author). However, not everyone is comfortable with change. In an interview with NRK (Aas, Nilsen, & Rastogi, 2017) a woman stated that she would never dare get on a bus without a driver. This is at the heart of the conflict between the insertion of new technology into society, and human reluctance and fear of where digitalization might lead. According to Erna Solberg "in the future there will be more change. We have to get used to it. Not only because it is completely necessary, but also because new technology and new knowledge creates a better society for all". (Solberg, 2018, translated from Norwegian by author)

This thesis will look at how digitization influences human activities with a case study on autonomous busses. It will also look at how the humans designing these systems impact them, with the intention to learn better ways to approach systems design. Finally, it will look at how we can factor human interactions into systems design in order to achieve a more holistic approach to systems design.

1.2 Problem statement

As machines are getting smarter and technology is evolving, they are taking over more and more tasks previously performed by humans. This has led to improvements in many processes. However, design is still a fundamentally human endeavor. In order to achieve a best practice for design, human factors must be incorporated into the design process. According to (Donaldson, 2017, p. 4) systems engineering is the right discipline to tackle the vast complexity of embracing both the technical and social aspects of a system concurrently.

The theoretical motivation of the study is to develop a better understanding of how digitization affects human activities and how human factors affect the design process. The work of the thesis is formulated around the following problem statement:

How does digitization affect human activities and how do these human activities and interactions influence systems design?

To investigate this question, a literature study into how the social sciences can be utilized in systems engineering with a focus on the design phase was conducted along with a case analysis of the implementation of autonomous busses into several Norwegian cities. This led to an understanding of human factors in systems design both practically and theoretically and laid the groundwork for the author to reflect upon and discuss improvements to the design of complex socio-technical systems.

1.3 Objective

The main objective of the thesis is to generate knowledge on human factors in system design, with a focus on how digitization affects human endeavors. In order to build a theory base that will provide the necessary knowledge to answer the problem statement secondary objectives have been established and explored.

The secondary objects are as follows:

1. Investigate existing design paradigms and how they factor humans into the design process

2. Identify and analyze how human-centric sciences are and can be used in systems engineering to influence systems design
3. Use a literature study to analyze and determine which human-centric sciences, and what parts of them, are essential to enhance the approach to systems design
4. Identify, describe and analyze how the digitization of society impacts human activities
5. Use a case study of autonomous vehicles to analyze how human activities affect system design and vice versa.

1.4 Research questions

The thesis will focus on the following research questions:

1. What is the background that has led to the phenomenon "digital transformation"?

2. How can we factor human interactions into system design?

3. What is the impact of digitalization on human activities?

1.5 Scope

This thesis includes a literature study of human-centric sciences in systems engineering, with a focus on the design phase. The literature study will review from a systems engineering point of view what has been written about utilizing different human-centric sciences to improve on systems design. It will also cover some of the most relevant existing design paradigms and how they factor humans into design.

The thesis includes a literature study in the digitization of society and the introduction and eventual prevalence of AI. The study looks at how digitization impacts human activities both generally and specifically in business and the development of products and systems.

Furthermore, the thesis includes a case study of autonomous busses and their introduction into local communities. The case study covers the human factors affecting the implementation of this technology into society. As the technology of autonomous vehicles in itself is a complicated and vast topic, any aspect not pertaining to the implementation of the system has been excluded from the case study, as this is too broad a topic to cover in the thesis.

1.6 Thesis planning and control

In order to execute the research and writing of the thesis some planning and control activities were performed. Some milestones were set in order to consistently track the progress of the thesis and further focus the research. This included meetings to refine the research questions based on the findings of the research. The milestones include the start and end of the thesis, deciding on research methodology throughout multiple meetings, handing in a first draft, etc.

1.7 Structure

The rest of the thesis is organized as follows.

Chapter 2 explains the different research methods used. It explains how the literature study was conducted, how data was gathered, and the method of analysis. The chapter provides an overview of the research process, and explains the research motivation, strategy and design. It explains the motivation of the case study, and how it was conducted.

Chapter 3 presents the theoretical foundation for the thesis. It covers the theoretical foundation on design paradigms and human factors in design as well as a historical review of digitization and AI and their impact on humans and society. Finally, it includes some theory on the state of digitization and AI today and the challenges they present.

Chapter 4 presents the case study on autonomous busses in Norway. It gives an introduction to theoretical background before presenting the findings of the case study.

Chapter 5 provides an analysis and discussion of the theory and results presented. Based on the discussion a recommendation on human factors to improve systems design will be given.

Chapter 6 Gives the conclusion for the thesis and provides a path for further work.

2. Research methods

This chapter provides an overview of the different methodologies applied to the research. This includes a description of the different research phases, research methods, and research analysis methods. The different phases of the research consisted of an exploratory phase where the research questions and scope of the thesis were identified and the descriptive phase where the literature review and case study were conducted. These two phases somewhat overlap, which will be elaborated on in the research overview.

2.1 Research overview

The research process of the thesis is based on the advanced literature review as described in (Machi & McEvoy, 2009). The process consists of six steps as shown in Figure 2.1. The steps starts with selecting a research interest and research topic, then reviewing the literature, leading to a research thesis. This leads to proposed further research, identifying a research project, which leads to research findings and conclusions. The box labelled literature review is further detailed in Figure 2.2.

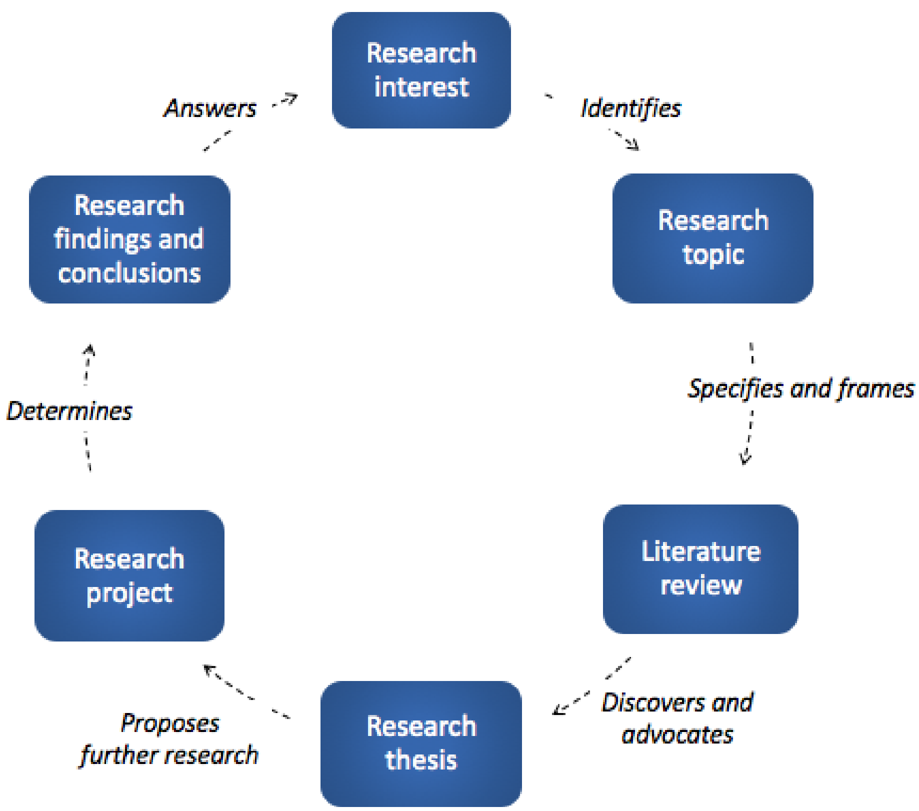

Figure 2.1: The advanced literature review (Machi & McEvoy, 2009)

To further organize the research, a table clarifying the research process has been made based on the steps of the literature review. The process shown in Figure 2.1 is broken down into the following questions:

- Based on the research interest, what is the general area of research?
- Having an idea of the possible gaps in the literature and issues raised elsewhere, what is the central research question?
- What is the general viewpoint of the research?
- What is the project plan or research design?
- Based on the viewpoint of the research, what data should be collected?
- What methods of analysis are being applied to quantitative and qualitative data analysis?
- Are the finding supportable? In other words, are they valid?"

Based on these questions an overview of the research is presented in Table 2.1.

Table 2.1: Overview of the research process

Question	Answer
Identify a broad area of research	Human factors in systems design
Select the research topic	Digitization and humans in systems design
Decide on the approach	Systems engineering competency evaluation
Formulate the plan	Perform a comprehensive literature review and combine it with a relevant case study
Collect the data and information	References from literature and empirical data from interviews
Analyze and interpret the data	methods of analysis
Present the findings	discussion

2.2 Research motivation

This thesis is written as part of the product development department of the Norwegian University of Science and Technology (henceforth referred to as NTNU). The research is conducted within the systems engineering role in product development. The initial motivation for the thesis was William Donaldson's (Donaldson, 2017) article "In Praise of the Ologies" that proposes the lack of- and need for a better understanding of how the human sciences can be used to better systems engineering. Table 2.2 shows a set of competencies identified in a workshop of leading practitioners and educators in systems engineering from Donaldson's article. It shows that human skills in communication and teamwork as well as decision making and influencing abilities and personal values were seen as important professional competencies. Human factors and human systems integration were listed as important technical competencies. This shows that there is already considerations of the importance of understanding the human influences in the development of systems. The objective of the thesis is to garner a greater understanding of human factors and their influence in systems design as digitization becomes more prominent in order to propose actions to improve on the systems design process.

Table 2.2: Technical and professional competencies of systems engineers adapted from (Donaldson, 2017)

Technical competencies	Professional competencies
Core math and science	Systems thinking
Basic engineering	Team/Interpersonal skills
Baseline systems engineering skills	Communication skills
Modeling/Analysis/Control	Conceptualization/User needs/Visioning/Future thinking
IT/Software/Architecture	Sustainability/Global/Ethics/Self-awareness (Personal values)
Human factors/Human systems integration	Making/Influencing decisions
Economics/Finance/Business case	Learning/Adapting mindset

2.3 Research strategy and design

According to Denscombe (2014) a research strategy is a plan of action that has a "distinct research logic and rationale that shapes a plan of action (research design) to address a clearly identified research problem" (Denscombe, 2014, p. 2). There exists a multitude of different research strategies, e.g. case studies, experiments, and literature reviews. Therefore Denscombe (2014) argues that when deciding on a research strategy, there are no right or wrong, good or bad strategies, but rather ones that are useful and appropriate to the purpose of which it is being applied.

For this thesis, the purpose of the research is to uncover the current state of knowledge on human factors in systems design and how digitization affects them in order to further understand how to apply this knowledge to a better approach to systems design. To achieve this, the strategy chosen is to perform an advanced literature study, which according to Machi and McEvoy (2009) is the course of action if the purpose of the research is to uncover a research problem for further study. Furthermore, a case study will be conducted, as, according to Denscombe (2014), the purpose of a case study is to “understand the complex relationship between factors as they operate within a particular social setting” (Denscombe, 2014, p. 2). In this case the social setting is the engineers doing systems design.

2.4 Literature review

To conduct the literature review the six steps of the literature process, as shown in Figure 2.2, from “the literature review” by Machi and McEvoy was followed. The book defines a literature review as “a written argument that promotes a thesis position by building a case from credible evidence based on previous research” (Machi & McEvoy, 2009, p. 4).

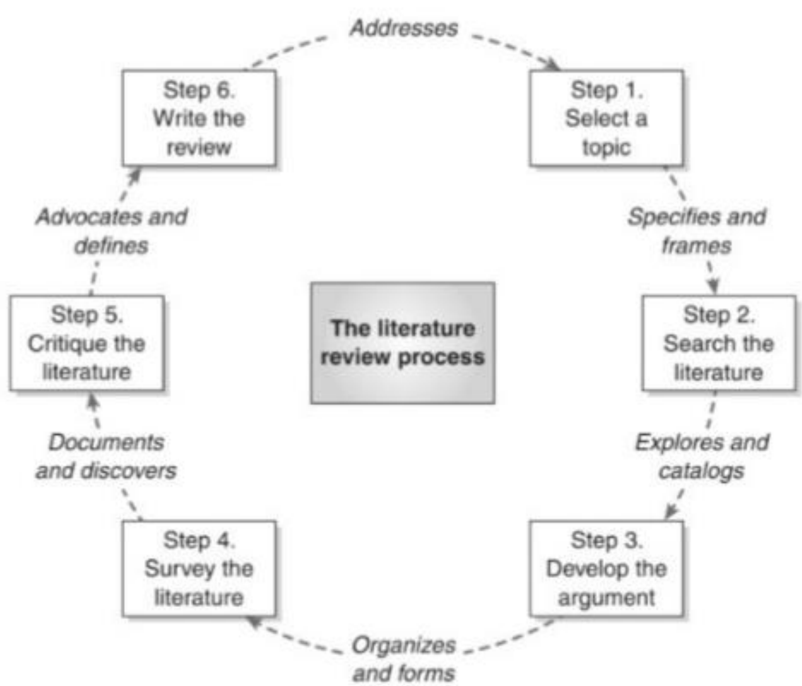

Figure 2.2: The literature review model (Machi & McEvoy, 2009)

The selection of the research topic was based on the problem statement and research questions. It was decided to divide the literature study into two focus areas: human interactions in systems design and the impact of digitization on human activities. If the scope of the results were too wide, the focus was directed at articles within systems engineering and product development. In addition, newer articles were preferred to older ones as the impact of digitization has increased drastically over time as a recent phenomenon.

The databases used for the literature search were Oria (NTNU online library), Google Scholar, and Science Direct. There was no preference towards any of the databases in the search as the merits of the literature found was evaluated on an individual basis. The goal of the search was to garner broad knowledge to enable a thorough investigation of the problem statement. In addition to the databases, selected articles and books were recommended by the supervisor. These articles and books were reviewed and evaluated on the same basis as those in the database search.

When deciding upon keywords to use in the literature search three sets were created, each set representing key interest points in in the study. The literature search was performed by combining words within a set. Words from the other sets were used as filter words to manage the amount of hits, and to make them as relevant as possible. In addition, Boolean operators were used to focus the search. Table 2.3 summarizes the use of Boolean operators. The three sets of keywords are given in Table 2.4.

Table 2.3: Boolean Operators (Machi & McEvoy, 2009)

Operator	Topic search	Descriptor use
And	Narrows	Links descriptors
Not	Excludes	Qualifies descriptors
Or	Broadens	Adds descriptors

As the literature study cover a broad range of terms, many searches were performed. In order to collect and select the appropriate data, the task has been divided into three subtasks: previewing, selecting, and organizing (Machi & McEvoy, 2009). Throughout the searches, the abstract of each paper, book, etc. was read in order to determine if they were of interest.

The more interesting materials were read more thoroughly, before the appropriate works were selected based on their specific contributions to the research, their timeliness, and their credibility.

Table 2.4: Key search words divided into sets

Set 1	**Set 2**	**Set 3**
Systems engineering	digitization	Autonomous
System design	Digital user	Vehicles
Human	Information technology	Self-driving
"Ology"	Artificial intelligence	buss
Design thinking	Internet	safety
Systems thinking	Digital technology	Implications

2.5 Case study: autonomous busses

The main characteristic of the case study is that it focuses on just one instance of the thing that is being investigated. The logic behind this is that there may be insights to be found looking at a single instance that would not be found in a mass study, which might have wider implications. The case study goes into detail on both what is happening, and why it is happening, offering the opportunity to go into enough detail to unravel the complexities of a situation by taking a holistic view of what's going on. The purpose of the case study is to discover information on a situation in greater detail. This information can be used to describe the situation in detail, compare alternatives, or to explore how aspects of the situation are interlinked (Denscombe, 2014).

The case chosen for the thesis is the introduction of autonomous busses in Norway. The main focus of the case is human factors and their influence on the design of the complete system surrounding the introduction of autonomous busses. It is attempted to use the study to find specific interactions that require further study as to their implications to systems design in general.

The case study will be based on documentation evidence. According to Yin (2014) documents have a great overall value and should play an explicit role in data collecting of any case study. He further states that evidence such as news accounts are good for their stability and ability to be reviewed ad infinitum. They are also unobtrusive, not created as an intervention in the case being studied. They also give a broad range of coverage over time, events and settings. Finally, they give a high level of specificity with regards to details of events. The main pitfall of documentation is the inherent bias in any reporting by the document's author. Yin argues that the most important factor in reviewing documentation is trying to identify the objective of any reporting to understand the purpose of the document to not be misled by the documentary evidence and to remain critical in the interpretation of evidence.

2.6 Method of analysis

The method of analysis for the thesis is the review of different kinds of literature for multiple purposes. The analysis is split into four parts.

1. To investigate the background that has led to the phenomenon "digital transformation", a timeline was created based on the relevant literature in order to create a date-to-date coverage.
2. In order to investigate human factors in systems design a comparison of how different authors describe design and other concepts is performed in section 3.2
3. In order to learn more about the functionality of autonomous busses peer reviewed articles along with other literature was reviewed to summarize the history of the development of autonomous busses based on a combination of old and new data
4. To gain insight into the introduction of autonomous busses in Norwegian cities reports from a combination of academic and popular media sources have been followed and the reports have been put into a timeline in order to gain insight into the process.

3. Theoretical foundation

This chapter presents the theoretical foundation of the thesis. It is divided into two main sections. The first section delves into the digitization of society. It will provide insight into how digitization affects human behavior in society at large and more specifically how this affects endeavors in systems design. The second introduces systems engineering as a way to approach systems design. It reviews literature covering human aspects of systems design from the system engineering perspective. It will look at the state-of-the-art of systems engineering and what is being written about human endeavors in systems design.

3.1 Digitization

This chapter breaks down the history of digitization into a timeline, presenting the introduction to digitization before the 1990's, some relevant developments from the 1990's and 2000's, and then present the developments occurring from 2010 until today with some theory on the changes occurring right now. The focus of the theory is digitization that affects human activities.

3.1.1 History of digitization and artificial intelligence pre 1990's

"Digitization originally describes the conversion of analog to digital information and processes in a technical sense" (Loebbecke & Picot, 2015, p. 149). This started in 1947 with the invention of the transistor, laying the foundation for more advanced digital computers (Ament, 2018). Since then the digital computer has been developed and improved at a breakneck pace. This along with the invention of the internet with the first network, the ARPANet in 1969, has been the biggest changes to modern society. The first ever network connection was between the University of California Los Angeles and the Stanford Research Institute on October 29 1969. Just four years later, the ARPANet went international with the University College of London and the Norwegian Royal Radar Establishment connecting to the ARPANet. The networks grew steadily in the 1980's with the expansion of local area networks. In the mid 1980's the US government established a network of five supercomputing centers allowing a growing university population to gain access to functionality previously limited to certain specialized users. In 1989, Tim Berners-Lee a scientist at the European Organization for Nuclear Research (CERN) wrote a proposal for establishing a global hypertext system that became the basis for the World Wide Web (Keefer & Baiget, 2001).

The notion of artificial intelligence has been around since antiquity. Myths and stories about artificial beings endowed with intelligence by master craftsmen were being told as an ancient wish to forge the gods (McCorduck, 1979). This initial inspiration led to programmable computers, and the start of the era of digitization. Some of the first uses of AI was in games. The first working AI program was a checkers player. The program was written by Christopher Stacy and was able to play a full game by the summer of 1952 (Copeland, 2000). The term "artificial intelligence" itself was introduced in 1956 at the Dartmouth conference (Crevier, 1993). In the formative years of AI the research was influenced by among others cybernetics engineering, biology, psychology, communication theory, game theory, mathematics, philosophy, and linguistics (Buchanan, 2005). These fields gave in both the form of advancement in the hardware to test, and the exploration of ideas about what intelligence is. The early AI of the 1950s- and 60s were based mainly on logical inference and resolution theorem proving, a paradigm shift happened in the mid-1960s with the development of knowledge-based systems. This led to machines being able to give expert level assistance in numerous fields (Buchanan, 2005). An example of this is in diagnostic medicine. Machines such as the internist-I used a knowledge-based system along with heuristic computer programs that can construct and resolve differential diagnoses to aid doctors in making multiple and complex diagnoses (Miller, Pople Jr, & Myers, 1982).

One of the most ubiquitous inventions that has come as a part of the AI research movement is the digital computer. Now a part of almost every home and all industries, the development of the modern computer started with Alan Turing's laboratory in Manchester, the IBM and Bell laboratories among others (Buchanan, 2005). This invention has transformed not only business, but also how humans lave their day-to-day lives. Computations that were previously impossible are now done in an instant. The way humans communicate has also been utterly transformed. The computer, and with the advent of the internet, has given us the ability to share information of any kind (text, audio, pictures, video) with the whole world at an instant. The increased processing capabilities of modern computers has also spawned big data analytics as a means to analyze and interpret any kind of digital data (Loebbecke & Picot, 2015). According to Loebbecke and Picot (2015), big data analytics plays a large role in determining the functional scope of our digital products and services as well as being integral to the development of AI and general cognitive computing capabilities. The effects of digitization on society is felt throughout, from the re-shaping of business models, to the transformations of society at large.

3.1.2 1990's

In 1990, the original ARPANet was decommissioned and its users and hosts were moved to the NSFNet created by the National Science Foundation in the US. Prior to 1991, the use of the NSFNet for commercial endeavors was banned under the Acceptable Use Policy (AUP). With commercial users lobbying the NSF, the AUP was abandoned in 1991, and in 1995, the control of the major network access points were transferred to private companies, making the internet a private endeavor (Mowery & Simcoe, 2002). The internet was first brought to the general public with the launch of the Mosaic web browser developed by the National Center for Supercomputing applications at the University of Illinois. The internet experienced an explosive growth during the 1990's. From only 130 websites available in June of 1993 to more than 200 000 by June of 1996 (O'Malley & Rosenzweig, 1997). The development of the HTML document format and the HTTP document retrieval protocol by Tim Berners-Lee and Robert Cailliau formed the basis for the World Wide Web (WWW). The WWW provided a standard set of protocols delivering multimedia content through any browser (Mowery & Simcoe, 2002). In 1991, the second generation of cellular telecom networks were commercially launched in Finland. This was the first digital cellular network. It used the GSM standard, which became ubiquitous with over two billion users from 212 countries. This made international roaming common (Bhalla & Bhalla, 2010).

3.1.3 2000's

In 2002, the number of mobile telephone subscribers overtook the number of landline subscribers. Electronic messaging such as E-mail and SMS became the medium of choice for both business and personal communication (Srivastava, 2005). In 2000, Global Positioning Systems (GPS) became a prolific consumer product as a law that required GPS signals for public use to be degraded was discontinued (Heussner, 2009). Amongst the new uses of GPS was the ability to locate devices with GPS capabilities. This allowed for hikers and boaters to determine their locations, as well as GPS for automobiles, reinventing navigation (Hofmann-wellenhof, Lichtenegger, & Collins, 2012). Another major development of the 2000's was the rise of social media sites. Sites such as Myspace launched in 2003, and Facebook and Twitter both launched in 2006. The sites let users created profiles with personal information and connect with other people, sharing that information. This information also became available to analyze through automated collection techniques giving companies insight into users' online behavior and personal communication (Ellison, 2007).

3.1.4 2010's and beyond

A big issue that affects both the organization of business and the way people live their day-to-day lives is the growing disconnect between work processes, locations, and times. With modern methods of division of labor and cooperation, the workspace, offices and factories, is less relevant then before. The same goes for fixed working hours. "Technology enables spatially and temporally flexible arrangements" (Loebbecke & Picot, 2015). Another big part of the reorganization of business is the increased use of freelancers such as the crowdsourcing of ideas, processes, and even sources (Loebbecke & Picot, 2015). A great example of crowdsourcing is Wikipedia. The burden of work in gathering information, writing it, and editing is on the users, not the owners or employees (Doan, Ramakrishnan, & Halevy, 2011).

Companies such as Apple and Amazon are among companies being transformed by information technology (IT), encouraging a shift from a standardized range of services towards a more dynamic, user driven range of services and products (Brenner, et al., 2014). "Crucial is not only the integration of information technology into almost all objects of daily life and their comprehensive networking capability, but also the intelligent personalization of products, services, and processes" (Brenner, et al., 2014, p. 56). Alongside this is the use of big data analytics, reducing the cost of traditional data collecting and enabling analysis of buyers' behavior. This gives way for decision making on things like what products and services to provide and how to stock up inventories to be computerized and optimized, leading to cost efficiency and less decision making being on the manager of a business (Loebbecke & Picot, 2015). Digitization and information technology also inherently changes the relationship between customer and business. Traditionally the customer has been on the end of the value chain, but as a result of the digital communication between customer and companies, in the trail of data digital users leave, the customer becomes a starting point for innovative and products and services (Brenner, et al., 2014). “The role of users may be changing from informative and evaluative (verification) to more generative (solution elaboration) and sometimes decisional” (Watanabe, Tomita, Ishibashi, Ioki, & Shirasaka, 2017). According to Brenner, et al (2014) the way people use information technology both privately and professionally is going to be a central focus for many decision-making processes in companies going forwards. In order to adapt to the new development cycle driven by the digital user, companies must be willing to remold their business models and strategies, processes and structures, and their IT infrastructure. Figure 3.1 shows the design layers companies must consider revising in light of emergent research on the user, use, and utility of the digital user as an integral part of the whole value chain.

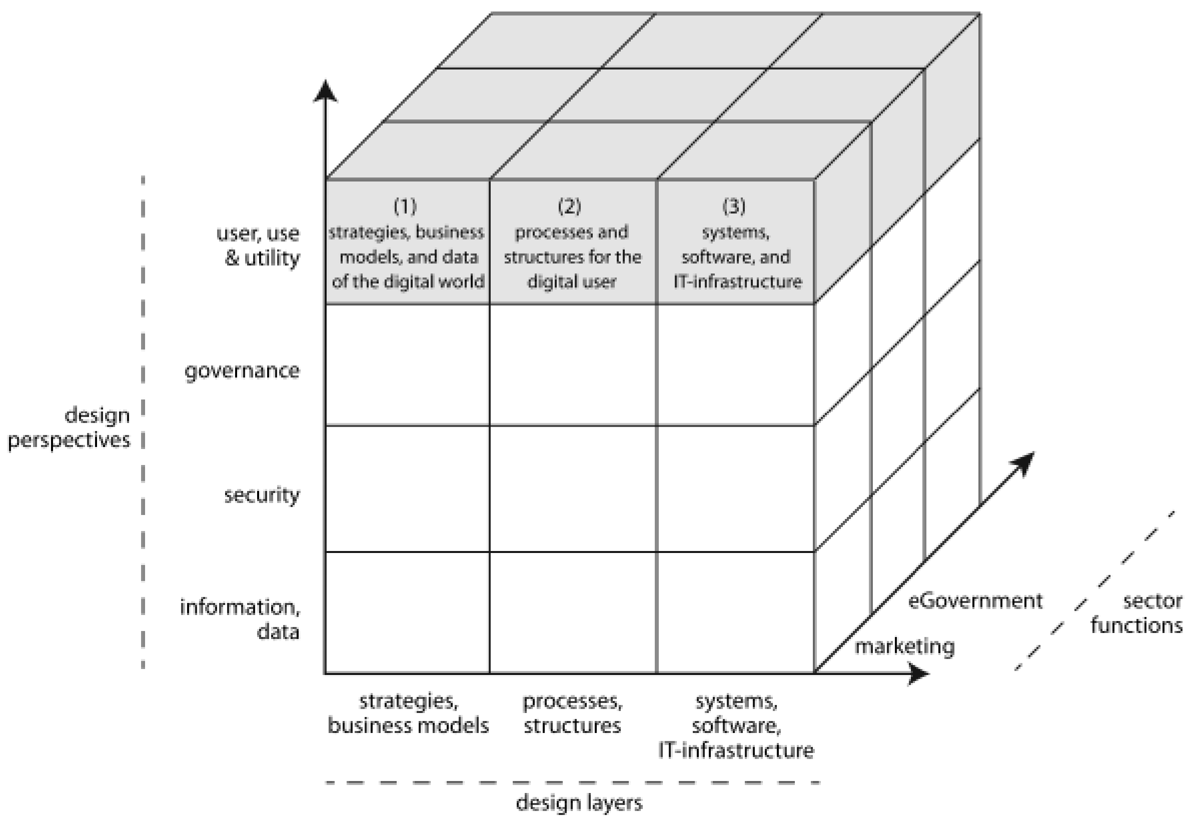

Figure 3.1: User, use, and utility research (Brenner, et al., 2014)

The collection of mass amounts of data from the digital user also comes with concerns about privacy. A little bit will be written on privacy issues and cybersecurity, but the thesis will not go in-depth on these topics, as they are not a focal point of the research. Business has incorporated data driven decision-making based on analysis of data obtained through digitized devices carried by individuals such as smartphones and other devices with inbuilt sensors (Newell & Marabelli, 2015).

There are two main components to digital users leaving traces of information on what they do, like, buy, and other general personal information. The first one is the data captured from sources such as social networks, online shopping, online search engines, and other IT-related activities. The second one is location-based data captured from devices with built-in sensors such as smartphones with Global Positioning Systems (GPS) capabilities. Figure 3.2 shows an overview of some tradeoffs caused by digital technologies leaving traces of information on users. It further shows some discriminations possible with the use of algorithmic decision-making based on the data gained through these technologies (Newell & Marabelli, 2015).

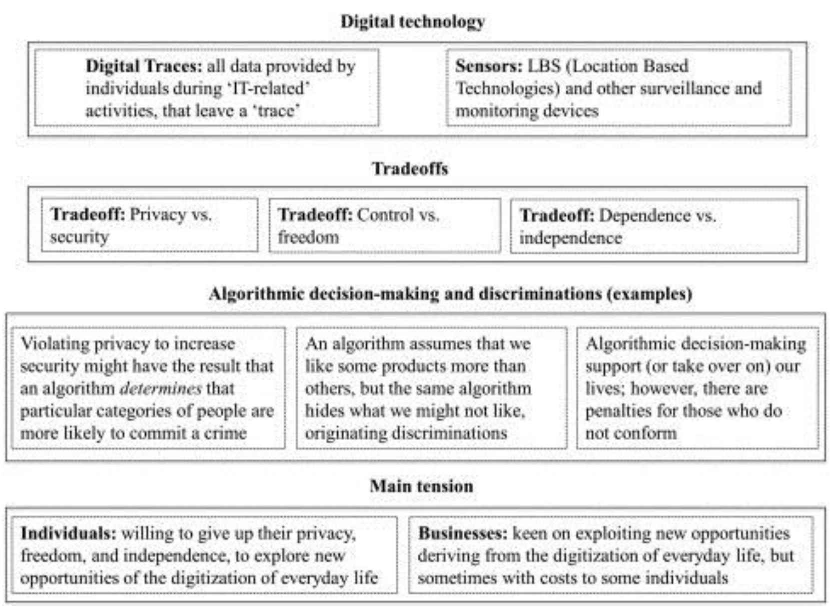

Figure 3.2: Consequences of the traces left by digital technology (Newell & Marabelli, 2015)

A big concern in the modern working world is the replacement of workers with machines. The new intelligent digital machines are starting to take on cognitive activities. Data based systems are perceived to be cost effective less prone to mistakes than humans. With the rapid advancement of AI alongside big data analytics, machines are becoming capable of handling highly complex tasks requiring cognitive abilities on the level of workers of high levels of skill (Loebbecke & Picot, 2015). One instance of this is in the field of surgery. Robots have been- and are being developed to perform or assist in surgeries. The da Vinci robot is being used to hold and position an endoscope in laproscopic surgeries. This has led to a lesser need for surgical assistants in hospitals (Korzep, 2010). It is still uncertain whether more jobs will be lost to machines than created by the digitization of the world. Many jobs and industries of today will be made obsolete as machines become better at cognitive tasks and digital products and services replace their analog counterparts (Loebbecke & Picot, 2015).

“The average life span of companies on the standard & poor’s 500 has fallen from 67 years in the 1920s to just 15 years today” (Downes & Nunes, 2018, p. 100). This change to the longevity of companies is in large part due to digital disruption in industries not largely affected by the first wave of the internet. Autonomous vehicles are fundamentally changing the transport sector. 3-D printing is making changes to manufacturing. Drones and sensors are changing how agriculture is being done (Downes & Nunes, 2018). All these changes prove great challenges for a multitude of businesses’ ability to endure the ongoing digitization.

This change in the lifespan of businesses’ is predicated on a change in human activities. The classic bell-curve of diffusion by Everett Rogers shows how new products are adopted by the market. The classic curve has five steps of a product penetrating the market. The steps are: innovators, early adopters, early majority, late majority, and laggards as can be seen in Figure 3.3. Due to the acceleration of technological improvements, the modern market adoption of innovations has been reduced to two distinct market segments. The red curve in Figure 3.3 shows the modern market adoption of innovations, titled “the shark fin of adoption”. This new curve is endemic of how modern digital users interact with the products of the digital age. The new market segments are divided into trail users who help develop the product, and everybody else. The reason for this compression of the adoption curve is two-fold. One is what is called “near-perfect market information”, meaning that buyers are thoroughly informed about new products even before they are released. The spread of information through social media and other digital channels along with the availability of opinions by trail users means consumers generally know whether they are going to buy a product before it is released. This means that initial sales are no longer indicative of a long lasting success. The other reason for the compressed curve is how continued improvements in prize and performance of digital products lead to a much shorter lifespan of a product being relevant (Downes & Nunes, 2018).

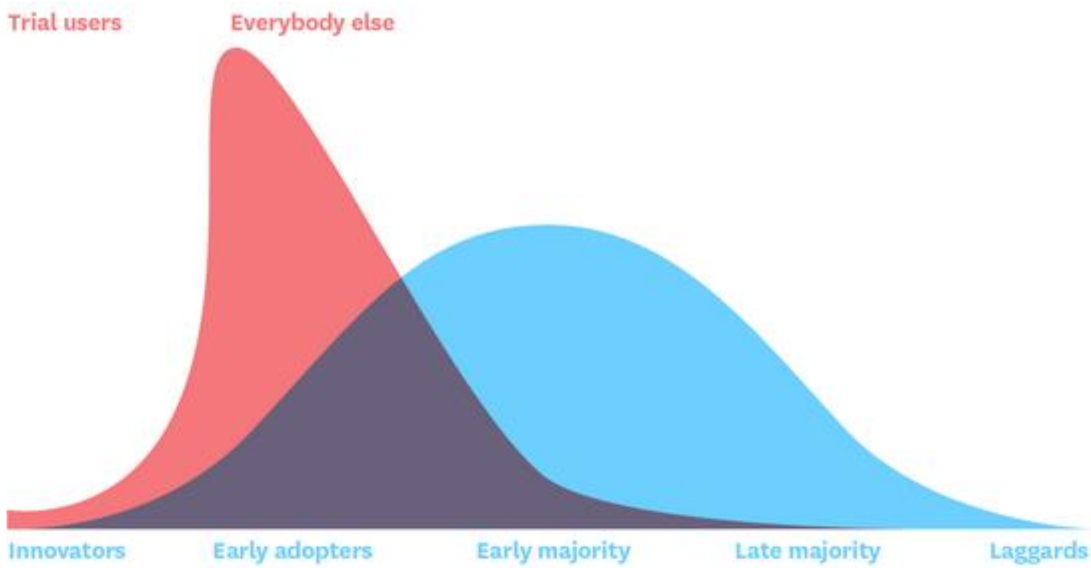

Figure 3.3: The shark fin of adoption (Downes & Nunes, 2018)

The tension of man versus machine in the workplace is an important focus as AI grows more prominent in its capabilities to perform cognitive tasks. For some it is only a matter of the loss of work, while for others it is a matter of increased productivity and less error-filled work. An important part that is often neglected is the role of the human in the system, and how it is the human that designs the system. Multiple studies as recent as 2016 and 2017 indicate that “human capital – including talent and culture – tops the list of important features for an organization’s growth, innovation, and security.” (Chew, 2017). Human traits such as creativity, innovation understanding, judgement, and empathy are crucial to leading and complimenting the work of machines. These traits are critical in the design of systems as they are key to customer experience. A machines inability to understand the emotions of customers is where its limitation lies in designing the processes and systems in companies. The cooperation between human features and digital technologies is imperative to drive innovation (Chew, 2017).

3.2 Human factors in systems design

This chapter introduces systems design. It delves into three relevant design paradigms to investigate how humans are factored into systems design in existing design paradigms. It also provides a comparison of what design paradigms are discussed in different literature.

3.2.1 What is systems design?

"Design is concerned with defining problems and creating solutions of all shapes and sizes" (Wade, Hoffenson, & Gerardo, 2017, p. 722). There are many different approaches to design. Attempts to formalize the design process for a guide to best practices have been made, but there is no one universally accepted method. Most agree that design starts with identifying the problem and ends with a viable concept, but the steps in-between vary depending on the school of thought (Wade, Hoffenson, & Gerardo, 2017). The oxford English dictionary defines design as "a plan or drawing produced to show the look and function or workings of a building, garment, or other object before it was made" (O.E.D., 2018)

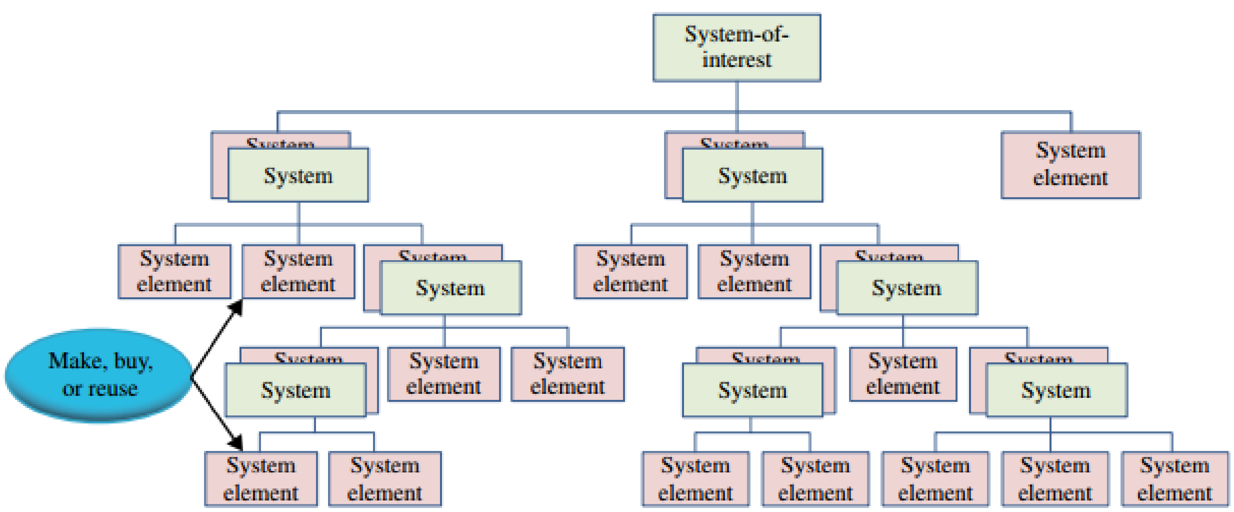

Figure 3.4: Hierarchy within a system (Walden, Roedler, Forsberg, Hamelin, & Shortell, 2015)

According to the Oxford English dictionary a system is defined as "A set of things working together as parts of a mechanism or an interconnecting network; a complex whole." (O.E.D., 2018). An item, or element of a system can range from atomic, i.e. cannot be broken down further, to a system in and of itself. A system can range from a simple one consisting of a few atomic elements, to a highly complex one consisting of lots of subsystems (Walden, Roedler, Forsberg, Hamelin, & Shortell, 2015). Figure 3.4 shows an example of a system hierarchy.

There are many approaches to systems design. The following subchapters will go through a multitude of different design paradigms and describe them, what they seek to achieve, and what they offer specifically. Table 3.1 presents a breakdown of how different discuss design. The crosses indicate that the authors have discussed this design paradigm in their article. The design paradigms presented in this thesis is based on the frequency of use between authors of the different paradigms. Systems engineering was excluded as it is not truly a design paradigm.

Table 3.1: Design paradigms discussed by different authors

Design paradigms mentioned/Authors:	(Watanabe, Tomita, Ishibashi, Ioki, & Shirasaka, 2017)	(Wade, Hoffenson, & Gerardo, 2017)	(Tomita, Watanabe, Shirasaka, & Maeno, 2017)	(Blizzard & Klotz, 2012)
Design thinking	X	X	X	
Systems thinking	X	X		X
Systemic design		X		
Engineering design		X		X
Systems engineering	X	X	X	
Agile systems		X		
Whole systems design				X

3.2.2 Design thinking

Design thinking is a creative problem solving approach or mindset, or "a systematic and collaborative approach for identifying and creatively solving problems" (Luchs, Griffin, & Swan, 2015). According to IDEO design thinking finds innovative solutions by utilizing elements of the design toolkit such as empathy and experimentation (IDEO, 2018). Design thinking encompasses a wide range of tools and frameworks that is grounded in a concern with the human experience (Goble, 2014).

Design thinking has evolved for well over fifty years. Drawing inspiration from a wide field of disciplines such as psychology, engineering, business, art, anthropology and more. The best methods and practices has been identified, integrated and championed by design firms such as IDEO, and academia, specifically Stanford's d.school (Luchs, Griffin, & Swan, 2015).

Wade, Hoffenson and Gerardo (2017) Describes design thinking as a mindset, rather than a process, that lends a holistic approach to creating solutions. Furthermore, they establish that it "relies heavily on establishing empathy with end-users, understanding their social and cultural biases" (2017, p. 3). General Manager of IDEO Tom Kelley in his breakdown of the design thinking development process echoes this. The process starts with building an understanding of the client, the market and the technology, including perceived constraints. It further delves into observations of real people in real situations. Which leads to real understanding of the potential users on a social and cultural level. The process then goes through visualization of potential solutions and users, prototyping, and then finally implementation of the concept that has been developed (Goble, 2014). A similar process for the design thinking development process can be seen in Figure 3.5. It breaks the process down to six steps: understand, observe, define point-of view, ideate, prototype, and test. The process of observing and visualizing the potential users is further echoed by Wade, Hoffenson and Gerardo (2017) stating that "Design thinkers tend to spend a significant of their time understanding the needs of others from an anthropological perspective, creating narratives around the problem and stakeholders" (2017, p. 723).

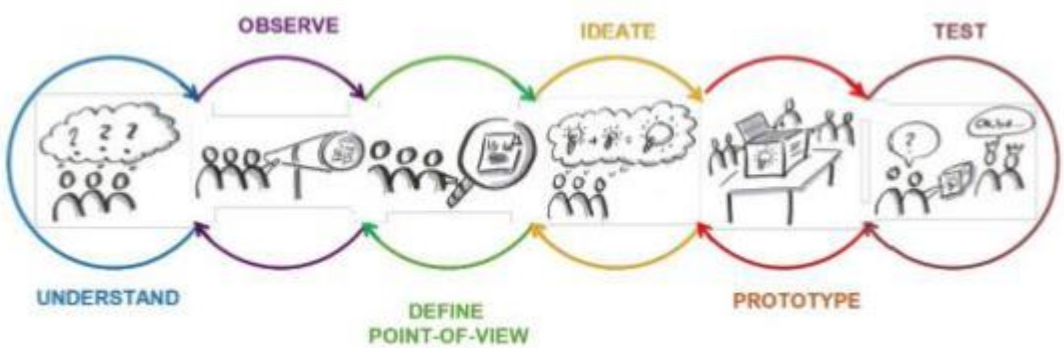

Figure 3.5: Design thinking development process (Wade, Hoffenson, & Gerardo, 2017)

Although it is emphasized that design thinking is a mindset, there are many frameworks developed to capture and organize the process. Figure 3.6 shows an example of a framework for the design thinking development process. The framework is divided into two main components, identify and solve. Design thinking emphasizes the critical nature of identifying the right problems to solve. Many companies focus solely on solving problems, generating lots of ideas, but unless the problems are well defined, the ideas will most likely be unable to generate solutions with the best potential. The framework is further divided into four, discover and define as part of identifying the problem, and create and evaluate for solving the problem. Furthermore, this framework is iterative, going through cycles from discover to define to create to evaluate before going back through discover to fine tune the development (Luchs, Griffin, & Swan, 2015).

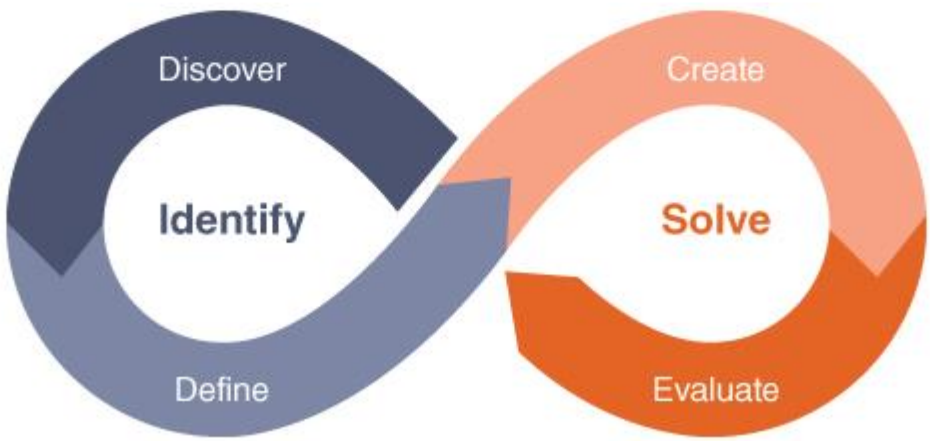

Figure 3.6: Design thinking framework (Luchs, Griffin, & Swan, 2015)

A hallmark of design thinking is its focus on cross-disciplinary teams with different perspectives and abilities. This includes, in addition to the core team, including external participants such as customers, suppliers, and different subject matter experts in specific modes or activities to garner some extra input (Luchs, Griffin, & Swan, 2015). It is further said that design thinking is a team sport. Having teams with diversified expertise from fields such as engineering graphics, human factors, and sociology widens the perspective of the team as a whole with each members eyes allowing them to see things they would not see with a more narrow field of expertise (Denning, 2013).

The design thinking mindset is “a holistic approach to creating solutions to problems” (Wade, Hoffenson, & Gerardo, 2017, p. 723). Communication is an integral part of making design thinking successful. The ability of a team to understand the relationships, connections, and connections between different ideas and nurture these is imperative (Luchs, Griffin, & Swan, 2015). For a company to be able to utilize design thinking it needs to implement a different set of communication than what is needed for incremental innovation. Communication strategies that focus on including the ideas and viewpoints of different team members of different expertise rather than exclude is needed. The communication must be framed to engage and align the members of the team to be able to recognize and utilize all the various perspectives (Goble, 2014).

3.2.3 Systems thinking

In their 2015 article “A definition of systems thinking: a systems approach” Ross D. Arnold and Jon P. Wade defined systems thinking as “a system of thinking about systems” (Arnold & Wade, 2015, p. 670). They further explain that systems thinking consists of three things, characteristics, interconnections between the characteristics, in the way they relate to or feed back into each other, and the function of systems thinking. They further define systems thinking, including the characteristics, interconnections and function, as:

“Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behavior, and devising modifications to them in order to produce desired effects. These skills work together as a system.” (Arnold & Wade, 2015, p. 675)

Systems thinking is greatly concerned with a holistic view of a product, service, or system, with a focus on the interconnectedness of all parts, sub-systems and stakeholders. This includes life cycles of products in a system and interactions with other systems (Wade, Hoffenson, & Gerardo, 2017). Ted Shelton, in his 2013 book “Business models for the social mobile cloud”, compares how system thinkers look at the whole to a great chess player. By viewing the pieces in groups, and finding patterns in the relationships between the groups, decisions are made based on the patterns (Shelton, 2013). The depth of understanding the interconnectedness of a system through systems thinking comes at a scale from recognizing interconnections to creating detailed models and simulations. Figure 3.7 shows a continuum of systems thinking knowledge and skills (Wade, Hoffenson, & Gerardo, 2017).

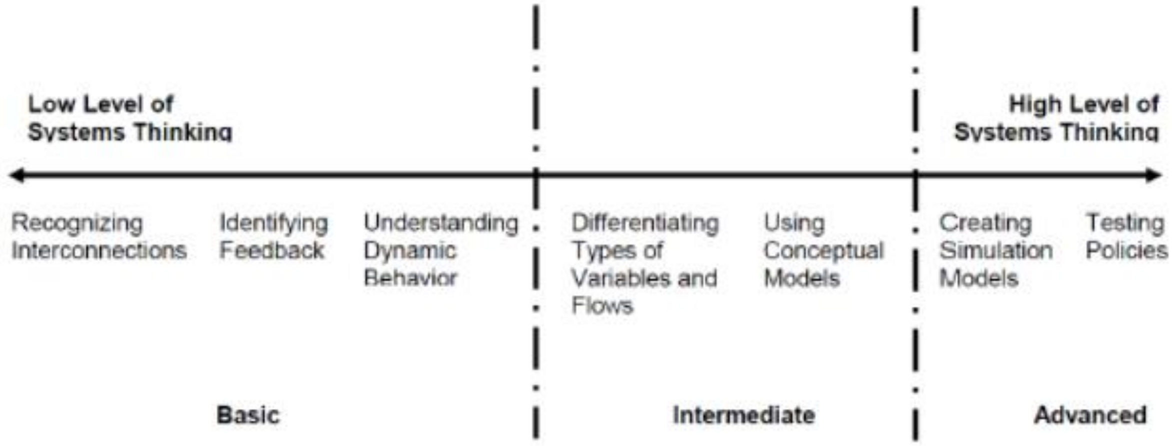

Figure 3.7: Different levels of systems thinking (Wade, Hoffenson, & Gerardo, 2017)

"The great early proponents of systems thinking and systems engineering…implored systems engineers to not lose sight of, and in fact to embrace, the social sciences as key components of our discipline (Donaldson, 2017). A system is highly different viewed through different worldviews. Individual values and traditions of thinking affect the lens through which a system is viewed. This leads to systems thinking embracing multiple comprehensions of a complex situation. People's viewpoints and emotions belong to the situation; systems thinking encourages wide encompassing variety of thought, including these viewpoints and emotions in order not to overlook important connections and features of a situation. Systems thinking encourages the practitioner's reflection on their own worldview, beliefs, and traditions of thinking to understand how they engage with a situation (Hasselmann, 2011).

Systems thinking has been welcomed in design as a helpful mindset for dealing with highly complex problems. Human centric problems in particular, with such issues as sustainability and social innovation, are well suited for a systems thinking approach as it not only welcomes, but also requires complexity.

3.2.4 Systemic design

Systemic design was born from a project at the Oslo School of architecture and design by Birger Sevaldson on systems oriented design. The project was initiated with the purpose of researching how systems thinking could help cope with high degrees of complexity in design. As the connections to systems theories in general became apparent a wider range of international scholars started integrating systems thinking into design and the systemic design research network was formed. This resulted in a symposium on relating systems thinking and design at the Oslo school of architecture and design in 2012. To accommodate a broader range of perspectives and approaches the second symposium in 2013 adopted the broader frame of systemic design (Sevaldson & Ryan, 2014).

"Systemic design is a very recent development that is a synergistic combination of design and systems thinking" (Wade, Hoffenson, & Gerardo, 2017, p. 3). Design thinking takes an empathetic approach to understanding human-centric problems and generating solutions after thoroughly identifying these problems. Systems thinking takes a holistic approach to understanding of all interconnections of a system with the use of modeling and analysis. Systemic design seeks to combine human-centered design approached with a systems thinking mindset to help structure and broaden the view on large-scale, complex design problems (Wade, Hoffenson, & Gerardo, 2017).

Systemic design operate on the three levels of mindset, methodology and methods. The mindset of the systemic designer is the values and habits they bring to the challenge. The mindset guides the application of methodology, which further shapes the selection of methods. Methodology is the reasoning for choosing methods, providing principles and justification for why the chosen methods are the best fit. Similarly, mindset justified the choice of methodology through the values it promotes (Ryan, 2014). These levels of systemic design are interconnected as seen in Figure 3.8.

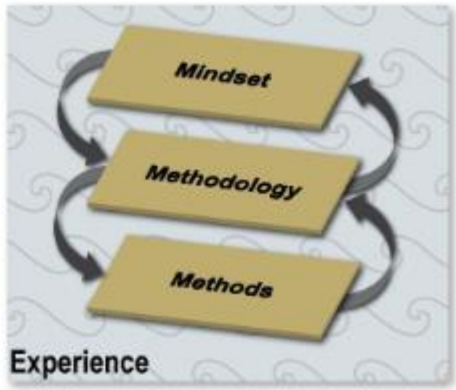

Figure 3.8: Three levels of systemic design (Ryan, 2014)

The mindset of a systemic designer is the values and habits they bring when deciding on a methodology. A characterization of a good systemic design mindset is one who is “inquiring, open, integrative, collaborative, and centered” (Ryan, 2014, p. 6). This mindset emphasizes the systemic designer’s ability to embrace the space between differing ideas and viewpoints, collaborate, and striving for balance in addressing complex challenges with both courage and humility. The methodology of systemic design is an abstract logic that guides the application of a coherent set of methods to a project. The systemic design methodology consists of six activities that combine in a dynamic and fluid mix. The activities are inquiring, framing, formulating, generating, reflecting, and facilitating. The methodology is non-linear and iterative, but is guided by a system. Framing, formulating, and generating is done in a cycle with regular reflection, and subsequent modifications to the direction and process as needed. Meanwhile, inquiring and facilitating are ongoing activities to provide context and cohesion to the process. Systemic design methods include things such as systems maps, casual systems loops, brainstorming, and low-resolution prototyping. The methods are meant to be helpful tools in distilling and sharing best practices between systemic design practitioners as well as to embrace complexity through self-organization and adaption. The main goal of the methods is to combine the systemic methods to avoid reductionist view of problems with the exploratory, collaborative, human-centered approach of “designerly” methods (Ryan, 2014).

4. Case Study: Autonomous busses

This section is a case analysis of the introduction of autonomous busses in Trondheim. The case study will delve into a specific instance of digitization in a complex system and will look at human factors influencing the design of the system

4.1 Theoretical background

The international engineering vehicle standards organization standardized five levels of autonomy for vehicles in 2013. These go from no automation through driver assistance, partial automation, conditional automation, and high automation, to finally, full automation (Riehl, 2017). This section will mainly focus on fully autonomous vehicles.

4.1.1 History of autonomous vehicles

Autonomous ground vehicles have been developed to some extent since the 1970's. With initial efforts being focused mainly on indoor laboratory settings. The first real testing of fully autonomous on road vehicles happened in 1987 with the test vehicle named VaMoRs from the Universität der Bundeswehr München (UBM) completing a drive of more than 20 kilometers on a free stretch with speeds of up to 96 kilometers per hour. In 1995, the UBM's new autonomous test vehicle named VaMP conducted a fully autonomous drive of more than 1600 km from Munich to Odense with about 95 percent of the distance done without any human driver intervention (Dickmanns, 2002).

On March 13, 2004, the Defense Advanced Research Projects Agency (DARPA) conducted a "Grand Challenge" for autonomous vehicles to complete a 140-mile race over rough terrain from Barstow, California to Primm, Nevada. The farthest distance covered in the race was 7.4 miles. The challenge was followed up on October 8, 2005. Twenty-three vehicles competed in a final on a 132 mile unpaved course near Primm, Nevada. Five vehicles managed to complete the course, with 22 out of 23 traveling further than the best result of the 2004 race (Iagnemma & Buehler, 2006). In 2007, DARPA conducted its last "Grand Challenge", this time in an urban setting with realistic everyday settings such as traffic rules, blocked routes, and obstacles both fixed and moving. The urban course was a 60-mile race held at the George Air Force Base in southern California. Six teams were able to complete the race; with Carnegie Mellon's Tartan Racing Team winning the race (Buehler, Iagnemma, & Sanjiv, 2008). In 2009, Google launched a self-driving car project called Waymo. They conducted test-driving in Nevada and California passing 700 000 miles of accident free driving in 2014 (Anthony, 2014). In 2015, Waymo did its first runs of test drives with no safety driver (Davies, 2017).

4.1.2 Technology

This section will give a brief overview of the technology used in modern autonomous vehicles. It will not go in depth, as this is a vast topic that is not the focus of the thesis.

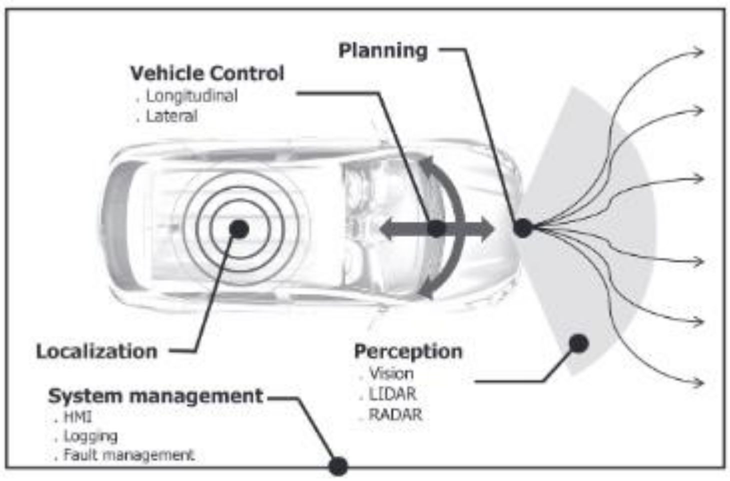

Figure 4.1: Basic functions of an autonomous car (Jo, Kim, Kim, Jang, & Sunwoo, 2014)

Modern prototypes as of 2016 use a combination of GPS, cameras, and other sensors, specifically LIDAR to establish the location of the vehicle, maintain center of lane, avoid obstacles such as other vehicles and pedestrians, and follow a specified route (Guerra, 2016). LIDAR is short for light detection and ranging. LIDAR uses lasers to sense objects in the near environment of the vehicle. The LIDAR system provides high-resolution information on the surrounding environment with the ability to rotate 360 degrees and more than two million readings per second (Seif & Xiaolong, 2016). There are five main functions that operate an autonomous car. These are perception, localization, planning, control, and system management. Figure 4.1 gives an overview of these functions. The car finds its position using GPS and roadmaps. A combination of RADAR, LIDAR and computer vision is used to perceive the surrounding environment such as other vehicles, obstacles, and pedestrians. The planning function uses the information from localization and perception to the behavior and motion of the vehicle. The control functions include steering, braking, and accelerating the vehicle based on the commands from the planning functions. The system management function is the overall supervisory system for the whole autonomous driving system (Jo, Kim, Kim, Jang, & Sunwoo, 2014).

4.1.3 Barriers to implementation

There are many barriers to introducing fully autonomous vehicles to public roads. This chapter will provide an overview of the main barriers and what they entail.

For any autonomous vehicle to be able to drive on public roads legislation will have to be made to cover autonomous vehicles. Issues such as the requirement of the US National Highway Traffic Safety Administration that vehicles have a foot controlled brake is a hindrance to a fully autonomous car such a Google's to be able to be driven on public roads (Riehl, 2017).Certification of the vehicles is another barrier to implementation. Some certification standards have been set, but none that are exhaustive. As of July 2014 California and Nevada have enacted legislation to allow AV certification, but the guidelines vary in scope and detail. The lack of a consistent certification framework and safety requirements also leads to regulatory uncertainty, and litigation and liability issues (Fagnant & Kockelman, 2015). As noted by Marchant and Lindor (2012) for fully autonomous vehicles liability would be fully on the vehicle and its manufacturer. Unlike crashes caused by vehicle malfunctions in conventional vehicles where the owner of the malfunctioning vehicle usually sues the manufacturer, in crashes involving an AV, all parties are likely to sue the manufacturer of the AV. They argue that "liability may present a serious barrier for the production and development of autonomous vehicles, even if the products are socially beneficial overall" (2012, p. 1335). Liability of autonomous vehicles is a highly relevant topic with a master's thesis at the University of Bergen in June 2017 discussing ship-owners' liability for unmanned ships and how current legislation is set up to deal with these challenges (Anon, 2017).

Security of the vehicles towards hacking is a vital issue, as is privacy of the users, in how the data accumulated by the vehicle is treated. This issue has been mostly covered in the section on cybersecurity and privacy in section 3.1.4. The main autonomous car specific security issue is the treat of hacking an AV's control system to cause crashes and congestion. The biggest threat is with a connected fleet of AV's. If market penetration becomes high, a coordinated attack on a fleet of vehicles could spread to cover a large part of a nation's full fleet causing massive damage and loss of life (Fagnant & Kockelman, 2015).

Vehicle cost is a barrier to the implementation of the vehicles, especially for a greater penetration of the market. In a survey in Austin, Texas on peoples willingness to pay they found that for full automation the average added cost they were willing to pay was 7253 dollars (Bansal, Kockelman, & Singh, 2016). Another survey from Cornell University found that the average U.S. household would be willing to pay 4900 dollars extra for a fully autonomous car (Zorthian, 2017). According to Austin Russel, CEO of LIDAR development company Luminar, the first generation of truly autonomous cars will cost about 300 000 – 400 000 dollars (Edelstein, 2017). In his 2017 report, "Autonomous vehicle implementation predictions" Todd Litman (2017) predicts that level five autonomy initially will only be available in higher priced models, and lower priced models will not have complete autonomy for one to three decades.

4.1.4 Potential benefits

According to the Norwegian Public Roads Administration, deficient driver ability contributed to an average of 53 percent of all fatal traffic accidents between 2005 and 2013, with 44 percent of these accidents having high speeds as a contributing factor. Intoxication contributed to 21 percent of accidents (Haldorsen, 2014). In the U.S. the National Highway Traffic safety Administration (2015) reported that for 94 percent of crashes the critical reason for the crash was attributed to the driver. Fully autonomous cars do not have the shortcomings of humans, meaning that the over 40 percent of fatal car crashes in the U.S. involving some combination of drugs, alcohol, distraction, and fatigue could be eliminated, resulting in an at least 40 percent reduction in fatal car crashes (Fagnant & Kockelman, 2015).

The introduction of fully autonomous vehicles may have a great impact on road capacity. It is hard to predict how much due to differences in penetration rates and differing technologies used. Van den Berg and Verhoef (2016) found with a hundred percent switch to fully autonomous cars the expected increase in road capacity varied from one percent in cars that do not cooperate up to 414 percent in cars with very efficient cooperation. They further predict that effects might be much less beneficial in low penetration rates and that the strongest gains might be found in going from many to only autonomous cars.

Fully autonomous cars will be of great significance in enabling the mobility of social groups that are currently unable to drive a car. It could enable the disabled, elderly, and young to potentially utilize cars (Milakis, Van Arem, & Van Wee, 2017). Harper et al. (2016) estimated that the access to fully autonomous vehicles for social groups currently unable to drive could increase the annual light-duty vehicle miles travelled in the U.S. by 14 percent.

4.1.5 Social implications

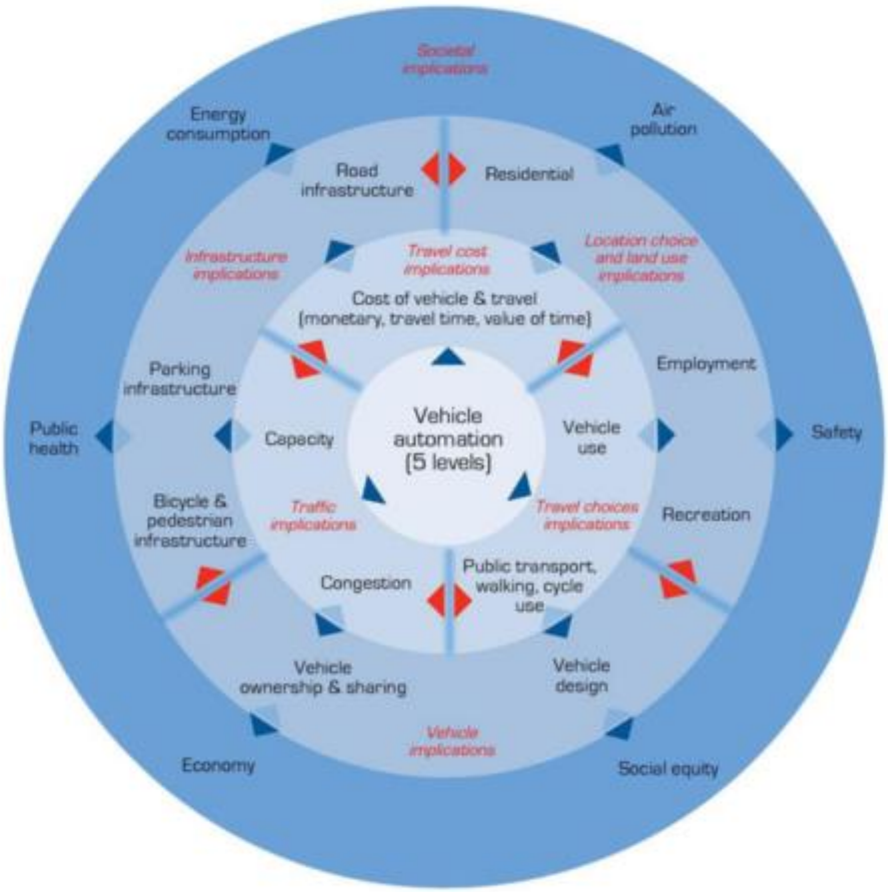

Figure 4.2: The ripple effect of autonomous vehicles (Milakis, Van Arem, & Van Wee, 2017)

Figure 4.2 shows the ripple effect created by the introduction of autonomous vehicles. The first ripple includes the implications of autonomous vehicles on travel cost, traffic, and travel choice. The second ripple goes into the implications autonomous vehicles may have on infrastructure, such as parking and roads, vehicle ownership and design, and use of land and choice of locations for both employment and resident. The third ripple comprises the wider social implications of introducing autonomous vehicles. This includes environmental implications, public health and safety, social equality, and the economic implications.

4.2 Case study

The case study is based on reports from various sources to look at the introduction of autonomous or self-driving busses in Norway. The study tracks the progress and information from November 2015 up until January 2018. A social dynamic model was made to give on overview of the interactions of the autonomous vehicle. The model is shown in Figure 4.3. It shows the connections between the AV and some pivotal issues in order to provide a clear view of some important features to investigate.

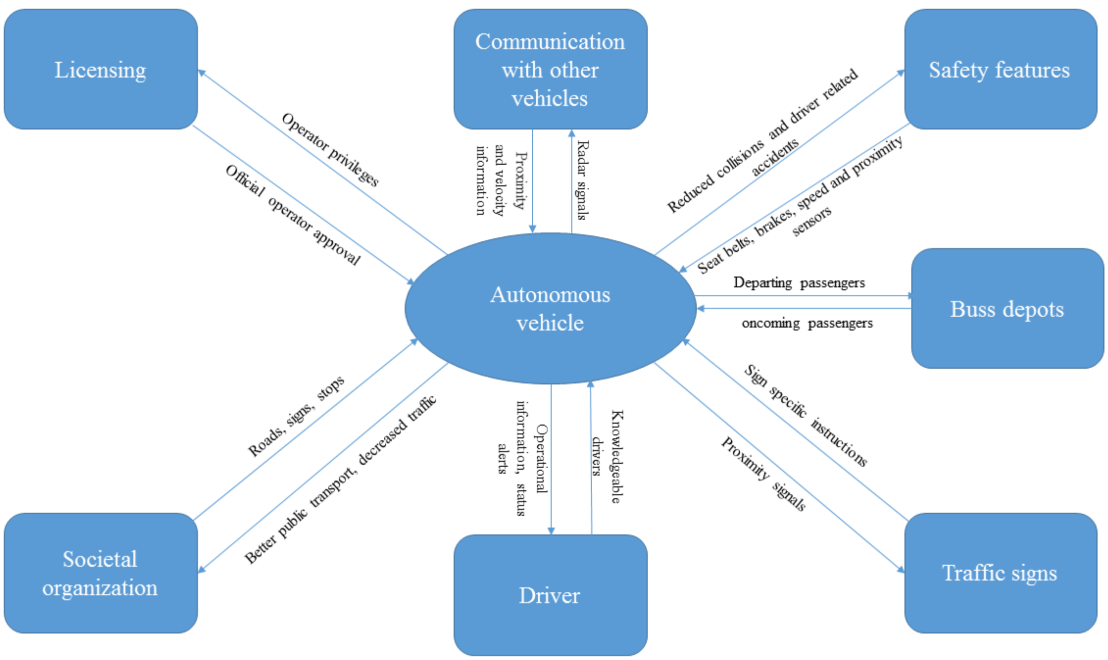

Figure 4.3: System dynamic model of Autonomous vehicles

In 2015 Teknisk Ukeblad (Valle, 2015) reported that the company Easymile was planning a pilot project of self-driving busses in Norway to start in 2016. The law required a driver to operate any vehicle on a public road, meaning they either have to apply for a permit to operate the vehicle without a driver, or have an operator capable of stopping the vehicle. Service and charging infrastructure is among the challenges the project faced. The plan was not for the busses to replace cars, but to help public transport as a service to take people from out of the way places to public transport hubs. They stated that although they cannot know all the possibilities self-driving busses brings, transport of the handicapped and elderly, or cargo transport are among the possible benefits. In 2016 (Valle, 2016) they reported that the first autonomous buss would come to Norway in September 2016. The self-driving minibuses could be a solution to the congestion problems around the cities without the need for major road expansion and the added pollution. They said that the reason we like cars is because they take us from door to door, the busses will do the same, or at least take us from door to public transit hub. The benefit of the busses is that by taking multiple passengers, the number of vehicles on the road will be reduced. They plan for an agile development where improvements found to be necessary will be made continuously.

In 2016 Easymile teste their busses at NTNU in Trondheim. NTNU had to get an exemption from the road traffic law to test the autonomous minibus on campus. The engineer from Easymile, Charleine Martin stated that the bus is very defensive, and pigeons amongst other things have created problems. The busses were not road ready, as any obstacle in the road would trigger an emergency stop, and a human operator would need to start the buss again after assessing the situation. Minister of transport, Ketil Solvik-Olsen commented that it is important to update the law so that it does not stop the development of technology, while still maintaining the safety of all road users (Furberg, 2016).

In June 2017, Aftenposten Reported that from March 2018 self-driving busses will be tested in Oslo or Akershus (Eggesvik, 2017). The testing was planned to go on through January 2019. They plan to test the busses in different locations to learn how the service works in practice. The busses will be ordered through Ruter's app and take you to the location of your choosing within the test area. The hope is that the success of the busses might open up for residential development of areas too far from current public transportation. They hope that the success of the busses might mean that they will take over part of the use of personal cars, reducing traffic. Amidst these reports of early testing of Autonomous vehicles in Norwegian cities Aftenposten released a report on the Norwegian populations opinion on being early adapters of AV technology (Bentzrød, 2017). The report states that that two out of three Norwegians do not think Norway should be early adopters of AV's. Their main concerns are loss of control of the vehicle and the joy of driving.

In October 2017, tek.no (Knudsen, 2017) reports that the testing in Oslo makes it one of thirteen cities in Europe that is testing AV. The company plans to test between 10 and 50 self-driving minibuses that is ordered through an app sometime in 2018. Public relations for Ruter, Sofie Bruun states that they want to test the busses along with their customers. They plan on a pilot testing period of two to three years with testing of different routes on a two to six month basis to build experience and learn from it. In November 2017, Computerworld (Joramo, 2017) added that alongside Oslo, Stavanger and Kongsberg have plans to get self-driving busses on the roads as soon as possible. In addition, Trondheim and Bergen are considering buying Autonomous busses. The Norwegian minister of transport, Ketil Solvik-Olsen says that the development and pairing of more and better driver support systems will most likely have a large impact on traffic efficiency, mobility, environment, and traffic safety. He further states that the purpose of the new law is to uncover the effects of AV's on traffic safety, efficiency, mobility and environment with an aim to more permanent phase AV's into ordinary traffic in the future.

On October 29, 2017 Norwegian political party Høyre posted on their website that the Norwegian government has passed a law allowing for testing of autonomous vehicles that takes effect on January 1, 2018 (Berge, 2017). It states that an applicant for testing of an autonomous vehicle has to be able to substantiate that the vehicle is able to drive itself. One person must also be made to be legally responsible for the testing of the vehicle. The purpose of the law is to allow testing within a framework that maintains traffic and person safety. It is further done to uncover the possible effects of autonomous vehicles on traffic safety, efficiency, mobility and environment.

In November 2017, Shifter (Tandsæther-Andersen, 2017) reported that Telenor is bringing a pilot project for 5G-net to Kongsberg. The partners in the project includes Telenor, Kongsberg municipality, Applied Autonomy, and Kongsberg innovation. The 5G-net provides wholly new opportunities for developing and operating services and control functions for autonomous vehicles. The 5G-net will help utilize and maintain autonomous busses in a more secure and efficient way. This comes as applied autonomy is planning a pilot project for testing Autonomous busses. In December 2017, HA Reported that NSB buys into Applied Autonomy (Bergheim, 2017). They, along with Nettbuss will take part in the pilot project for self-driving busses in Kongsberg. They say autonomous transport might be a supplement to their train customers for easy journey to and from the stations. The same month 3600.no Reported that the self-driving busses will be tested in the streets of Kongsberg by fall 2018 in a project called “Testarena Kongsberg” (Isaksen, 2017). The purpose of the testing of the autonomous minibuses is to learn and adapt solutions for fleet management, control and regulatory functions and to cooperate with other cities and the public sector.

On February 1 2018, Teknisk Ukeblad published a story stating that according to the Directorate of Public Roads no one has applied to test autonomous vehicles on public roads as of February 1 (Andersen, 2018). The story reports that OBOS, Bærum municipality, and Acando have announced plans to start driving autonomous busses at Fornebu that will be transporting guests to Storøyodden beach. According to CEO of OBOS, Daniel Kjørberg Siraj, the autonomous busses will alleviate the parking pressure by the beach along with other benefits for the residents of the area. The plan is for the busses to drive short ranges at speeds of about fifteen km/h with up to twelve passengers. The busses will have a host to help passengers, do safety training and give the necessary information to ensure the safety of the surroundings. The busses have done test runs, but not yet on public roads. They report that although no busses have run on public roads, 15 000 people have been on test runs with Acando’s busses.

5. Analysis and discussion

The purpose of this chapter is to provide a discussion of the theory presented and how it answers the research questions. First, the timeline of digitization is discussed to shed light on the background of the “digital transformation” phenomenon. Secondly, the different design paradigms presented are compared and a discussion on how they handle human factors as part of the design process is presented. Then, how digitalization impacts human activities is discussed based on the theory, and the case analysis is reviewed with respect to what insights it brings to the question. Finally, how the theory answers the problem statement is discussed.

1. What is the background that has led to the phenomenon “digital transformation”?

Digitization describes the conversion from analog to digital. A big enabler of this process was the invention of the transistor, laying the foundation for the digital computer and its rapid development. Alongside the development of the computer was the development of artificial intelligence. Since the first functional AI in 1952, the complexity of tasks AI is able to do has evolved alongside the massive increase in computational power. The development and widespread adoption of the internet has been a big part of the digital transformation. By connecting people digitally it has changed everything from communication, alongside the mobile phone, to information retrieval and sharing, and how work is done. In 2002, the mobile phone had overtaken the analog landline, and text messaging through SMS and E-mail had become a prominent part of communication. The rise of social media became another big platform for communication, further digitizing how humans interact. The rise of search engines led to information retrieval being digitized, with most information retrieval happening through internet search engines such as google. Organization of business has also been altered by the new digital communication. The workspace has a lesser need to be centralized as work can be done from anywhere with access to the same assets as in a centralized office. The last part of the digital transformation is the use of big data analytics. As data from digital users started aggregating with the widespread use of digital technologies that leaves data, i.e. internet activity such as online shopping and social networking, and devices with built in sensors such as GPS, this data could be analyzed and used by AI to learn to perform cognitive tasks that previously required workers of a high skill level. This threefold development of computational power, communicational power, and learning ability of machines has led to developments such as autonomous vehicles and 3-D printing further digitizing society.

2. How can we factor human interactions into system design?

The early proponents of systems thinking and design argued that it was imperative not to lose sight of, but rather embrace the social sciences. Design thinking tries to ground itself in a concern with the human experience. The different design paradigms have different approaches and concerns, but they all include a human focus of some kind. Design thinking focuses on empathy with end-users, with a focus on social and cultural biases. In systems thinking the social and cultural biases are also considered as to how they make the viewpoint of an individual give them a unique lens through which they view a complex situation. Systemic thinking tries to embrace the empathetic approach to problems of design thinking while maintaining the openness to different viewpoints of systemic design. Design thinking embraces human interactions by building an understanding of potential users and their needs by observing people in real situations, along with a focus on cross disciplinary teams with different perspectives and abilities. Systems thinking also embraces the different perspectives of the individual team member, but with a higher focus on the individual practitioners worldview, beliefs, and traditions of thinking, and less on the differing knowledge and abilities of a cross disciplinary team. Systemic design further embraces human interactions as part of the systems design process as an integral part of the systemic design mindset, in order to create an environment to facilitate embracing the space between differing ideas and viewpoints.

3. What is the impact of digitalization on human activities?

Digitization has had an effect on human activities in both their work and personal lives. Digitization of communications through computers and the internet has created a disconnect between work processes and where and when they are done. The internet allows for more work from home or decentralized locations, leading to a lot of people no longer needing to reside in close locations to the offices of the company they work for. The types of jobs available are also changing. Artificial intelligence is learning to do more cognitive tasks, that require a high level of skill, but not necessarily creativity or human understanding of emotions. Digitization and big data analytics has also changed how products are developed.

Big data collection and analysis has led to computerized decision-making on what products to develop and stock up on, making customers an active part of the development of new products. Along with this comes the change in how people adopt products. Interaction with the development has allowed customers to become trial users of new products and influence the development. The availability of information through the internet makes more users aware of new products and has led to a quicker, more informed adoption. The impact of digitization of people personal lives ranges from hew they shop, communicate and interact, and now even how people travel are changing. The advent of social networks, online shopping and search engines have made it possible to do more things from the comfort of our homes. People interact and communicate via social networking sites, creating less dependence on physical connections. Online shopping through companies such as Amazon provides products and services that are user driven and delivered to people's homes. And now, autonomous vehicles are slowly beginning to be introduced, changing the mode of travel.

There have been plans for testing autonomous busses in Norway since 2015. Up until January 1 2018, the law required a driver for any vehicle on public roads, which led to most of the testing in Norway being done on private property, or as demonstrations with special permits for specific locations. The busses will not replace cars or conventional public transport in the near future, but will give people who do not live near public transit hubs an option to access public transit without driving. The plan is for autonomous busses to open up for development in places considered too far from public transport. This could further increase the spreading population already being driven by digital communication making work from a decentralized position possible. This mode of transport also brings a new level of social equity, as people with handicaps or age restrictions making them unable to drive have access to mobility options. Although autonomous busses gives increased mobility, it also gives every aspect of life, from home to work, some digitized aspect.

How does digitization affect human activities and how do these human activities and interactions influence systems design?

Digitization affects human activities on almost all fronts. From how people communicate and interact, to where they live, how they travel, where they work and what type of jobs are available. The design of all modern systems are influenced by these factors. As design thinking observes people in real situations, these situations are continuously being altered by digitization. The focus on communication in all design paradigms presented must consider how a lot of communication is becoming digital. It seems that building an understanding of potential users can be done through big data analytics, providing much wider and more detailed information than the analog methods. It seems that the main focus of the system designer will be to bring an emotional understanding of the information acquired from digital users, and the empathy to understand the emotional values of products and services through a cross disciplinary, multicultural team. Designers must now possess the ability to communicate their differing cultural values and worldviews to obtain a holistic understanding of the potential users. The need for these additional capabilities will eventually drive the education of engineers to include more of what are today considered “soft skills” such as communications and sociology.

6. Conclusions and further work

This thesis has studied the historical digitization of products and services, how this digitization has affected human activities, and how systems designers can factor human interactions into systems design. It has looked to find out how human activities affected by digitization can be factored into the design of new systems.

Digitization was investigated through the creation of a timeline of significant digital transformations, along with a literature study on how these digital transformations have influenced human activities. A case analysis of the introduction of autonomous busses was conducted to gain insight into the effects of digitization as it is happening. To investigate how systems designers can factor human interactions in systems design multiple existing design paradigms were investigated through a literature review to find how they include human aspects into their process.

The study found that the impact of digitization is permeating through every aspect of human activities, from interactions and communication, to where they live and how they travel. The existing design paradigms factor human interactions through observations of people in real situations along with embracing differing social and cultural biases to gain a broader insight into how different people will interact with a system. Systems designers must embrace the interactions people have with existing digital systems to further understand their interconnections with systems in general.

To gain further insight the author recommends further studies of human interactions with new systems as they are being introduced and throughout their implementation. As well as looking at how digital communication and interaction with potential users can provide insight into the emotions connected to new systems and the systems they have interconnections with.

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