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An investigation into trust between an SAV and its passengers

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Abstract

As more and more shared autonomous vehicles (SAVs) are introduced in mixed traffic conditions, it calls upon research exploring the relationship between an SAV and its passengers. It is assumed that in the future SAVs will be completely autonomous, with no operator on-board, resulting in the loss of implicit communication between a driver and a passenger with effects on trust. This served as motivation to perform a study investigating the definition of trust from the passenger's perspective.

Initially a state-of-the-art study was conducted to research previous work and identify existing trust frameworks. Three field studies took place on an operational SAV which included interviews and observations with on-board operator and passengers. The aim of which was to understand the trust dynamics between the operator and passenger but more importantly, between the SAV and its passengers. The results revealed dependency on the operator during the commute in deadlock situations. To investigate trust attributes, interviews and observations were conducted with passengers of a regular bus as well as experts from the field of transportation. *Situational awareness* of the SAV and communication of *SAV intention* were deemed most important towards building trust with caution towards *information overload*. Furthermore, three participatory design studies conducted showed a multi-modal approach as the preferred way of communication, with *visual* and *auditory* modalities being the most favorable choice.

The overall results showed that a communication and feedback channel with an SAV and its passengers is necessary in creating trust in the absence of a driver.

Future studies could use the findings from this thesis as the building blocks for creating a communication interface to enhance passengers trust in an SAV.

Keywords

Trust, Passengers, Shared Automated Vehicles, Communication, Interaction, Communication modalities, Feedback.

Sammanfattning

Fler och fler autonoma fordon (SAV) introduceras i den vanliga trafikmiljön, vilket kräver ökad förståelse för relationen mellan SAV:er och dess passagerare. I framtiden förutsätts SAV:er kunna bli hela autonoma utan varken en förare eller operatör ombord, vilket ändrar förutsättningarna. Det skulle innebära en förlust av den implicita ("tysta") kommunikationen mellan förare och passagerare, vilket är bakgrunden för denna studie om passagerares förtroende för SAV:er.

Studien innehåller fyra delar. Först en översikt av den senaste forskningen om upplevt förtroende, vilket skapar ett forskningsmässigt ramverk. Tre fältstudier gjordes ombord en SAV vilket inkluderade både intervjuer och observation av passagerare och operatörer. Syftet var att förstå dynamiken både mellan operatören och passageraren samt mellan SAV:n och passageraren. Resultaten visar på att fordonet, och därmed passagerarna, fortfarande är beroende av operatören i situationer när fordonet fastnade på grund av problem i trafikmiljön. Den tredje delen av studie handlade om att undersöka olika parametrar för förtroende och genomfördes med hjälp av intervjuer och observationer av passagerare på en vanlig buss samt genom intervjuer med experter från transportbranschen. Det tydligaste resultatet var att SAV:n behövde vara medveten om närmiljön och att visa förståelse och kommunicera sin avsikt var den faktor som var viktigast för att bygga förtroende. Samtidigt fanns risk för ett överflöd av information. Slutligen genomfördes tre designövningar med användare vilket visade på ett behov av kommunikation med hjälp av flera kanaler, där den visuella och ljudmässiga kanaler föredrogs av de flesta användare.

Resultaten tyder på att kommunikation och återkoppling är nödvändigt för att skapa förtroende mellan SAV:er och dess passagerare. Framtida studier bör därför fokusera på att skapa ett gränssnitt mot passagerare som bygger på dessa resultat.

Nyckelord

Förtroende, passagerare, autonoma fordon, kommunikation, interaktion, kommunikationsmodalitet, återkoppling.

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Acronyms

SAV	Shared Automated Vehicle
AV	Automated Vehicle
AD	Automated Driving
HMI	Human Machine Interaction
HRI	Human Robot Interaction

1 Introduction

This chapter outlines the background of the thesis project, motivation and problem. Followed by objectives, assumption and the research question. It is then proceeded by the goals of this thesis project and, lastly, the outline of the document is presented.

1.1 Background

Currently numerous modes of AV (Autonomous Vehicle) are being introduced in everyday traffic scenarios. With a mix of personal autonomous vehicles such as privately owned cars and autonomous public transportation such as a shuttle bus or a Shared Autonomous Vehicle (SAV), the latter is the focus of this project. A lot of work has already been done in this area, with companies and pilot projects like NAVYA [1] and EasyMile [2] in France, Auro Robotics [3] and Local Motors [4] in United States and Autopiloten [5] in Sweden.

Figure 1.1: Autopiloten - Kista. Photo by Nobina.

Considering the current fleet of SAVs, extensive research has been conducted

[1]https://navya.tech/en/autonom-shuttle/ Accessed: 2019-08-28
[2]https://easymile.com/company-easymile/ Accessed:2019-08-28
[3]https://ridecell.com/solutions/autonomous-vehicles/ Accessed: 2019-08-28
[4]https://localmotors.com/meet-olli/ Accessed: 2019-08-28
[5]https://www.thelocal.se/20180125/in-pictures-swedens-first-driverless-buses-hit-the-streets Accessed: 2019-09-09

on the interactions and communication with pedestrians and vehicles including AVs and non-AVs [1] [2] [3] [4] [5] and understanding the effects of vehicle behavior. The results from similar studies gave further insight into the acceptance of such modes of transportation and their impact in terms of safety [6] [7] [5], reliability and trust. But there is lacking a sufficient amount of research into the communication and interaction between the passengers and the SAV. Although most of these SAVs are operating in major urban cities around other actors in a traffic scenario, they still need an operator on-board for safety reasons, in case the operation of the vehicle needs to be taken over. With that being said, it is assumed that in the future these SAVs will achieve full autonomy, meaning they would operate without the presence of an on-board steward while still instilling sufficient amount of trust within the passengers so they feel safe utilizing the service.

1.2 Motivation and problem

As we progress towards the future goal of having SAVs as an effective part of our transportation model, it is necessary to make sure that passengers trust the SAV.

The motivation for this project arises since there lacks a sufficient amount of research investigating the communication between an SAV and its passengers and vice versa. And the elements of such an communication and interaction interface which translate into trust attributes. Some of attributes are context specific and in such situation the interaction between an AV and other actors in traffic is more influenced by social norms instead of traffic laws [8]. This gives rise to situational deadlocks where the AV might behave unexpectedly [9] [10] and more often than not, the driver of the vehicle is expected to resolve such deadlocks. In the current context of public transportation the impact of a driver is often overlooked. They play a key role during everyday traffic scenarios, not just operating the vehicle itself. People rely on the communication between the driver of the vehicle during their daily commute whether it be verbal or non-verbal [6] [11] [12] [7].

One of the main challenges for AVs and SAVs is to instill a sufficient and appropriate amount of trust [13] [14]. Taking the role of the driver out of the equation can give rise to several challenges such as, understanding body language and cues of passengers, and subsequently, their trust. Hoff et al. [15] describes the three main points of trust, with the human operator on-board the AV being one of them. It creates a social interaction gap not only with other actors within a traffic scenario but passengers inside the vehicle as well [16]. With the autonomous bus of the future the driver will not be a part of such a transportation model. However, passengers that would utilize the service still need to express a similar level of trust. Studies show, in particular, that the acceptance of the autonomous bus and passenger's perception of safety is effected by the presence of an on-board operator [17] [18]. And the loss of driver cues might cause trust and confidence to decrease [19] [3]. Duplicating such a cause and effect model by understanding the definition of trust in future SAVs is necessary. Moreover, the attributes which gives composition to such a trust model and the replacement of implicit and explicit communication of a driver, needs further research.

This project looked at the trust framework for HMI design defined by Ekman et al. [20], where they highlight trust effect factors and each individual phase in which these factors come into play. Through their literature study they identified key factors that affects trust while highlighting the events where such factors should be implemented. Furthermore, with the results of the user study they found out where such trust-affecting factors can be placed within their framework, overall providing a more holistic approach o building trust. Ekman et al. defined three usage phases for the identified trust effecting factors: *preuse phase, learning phase and performance phase*. The two phases, *learning phase and performance phase* are considered as they suit the context of this thesis. Moreover, Hancock et al.[21] investigated influences of trust and presented a human-robot trust model consisting of human, robot and environmental characteristics (See figure 1.2). It is important as some of the implications within each of the defined characteristics are used as benchmarks to categorize findings in this thesis. The related aspects of the framework are further broken down during the analysis phase (2.3.2).

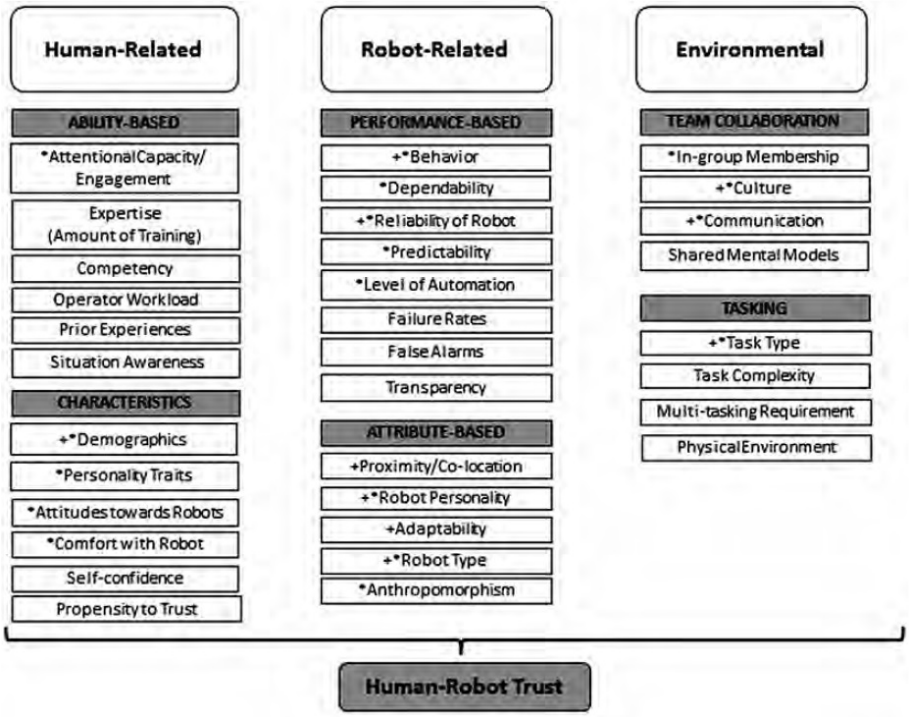

Figure 1.2: Trust development factors in human-robot interaction.

Additionally, it is also necessary to identify the modalities through which trust attributes are best represented. In [22], Lee and See discusses the effects of display interfaces on trust. Furthermore, indicating results with increased trust when the information is displayed consistently and clearly. Some of the research projects making use of such a modality is later on discussed in section (2). Although with such a modality it is important to avoid information overload as it may reduce data quality and performance [23] [24]. Altogether, the discussed reasons provides motivation to further investigate trust relation between an SAV and its passengers.

1.3 Objective

This thesis project investigates trust and its development between an SAV and its passengers. The results of which will contribute towards creating a definition of trust from the perspective of an SAV passenger. Furthermore it will reveal which factors affect passengers trust. The aim of the thesis is to reinforced the assumption that feedback and communication between an SAV and its passengers will influence trust positively.

It is not the objective for this project to develop an interaction prototype between the passenger and the SAV. Moreover, the primary focus of trust building is from the perspective of SAV passengers and not other actors within a traffic scenario.

1.4 Assumption

The assumption in this thesis project is that in the future SAVs will be fully autonomous, meaning they would operator without the presence of an on-board operator [25]. Hence, a clear communication of the SAV's behavior and intention in the absence of a driver will lead to the SAV being perceived more trustworthy with increased acceptability [15] as well as decreasing situations where the SAV could behave unexpectedly [26]. There have been numerous studies showing positive results of AVs interacting and replicating the communication of a driver in terms of safety and trust [4], [5], [6], [7].

1.5 Research question

As more and more SAVs are introduced in urban settings in the mix with other traffic actors, the emphasis on communicating what is in its surroundings to its passengers becomes increasingly vital.

To support the hypothesis the following research question has been highlighted:

–Can a feedback and communication channel with an SAV effect passengers trust?

To help answer the main research question there are further sub questions:

a) *How is trust defined by the passenger of an SAV?*

b) *What are the key factors which affects passengers trust?*

c) *Which are the preferred modalities that helps create the most appropriate level of trust?*

1.6 Goals

The goal of this thesis project is to investigate how a feedback and communication channel can positively effect passengers trust. To answer the research questions the following goals are identified:

1. Research into work relevant to SAV-to-passenger interaction.
2. Investigate existing trust frameworks.
3. Explore passenger's and operator's definition of trust and its attributes.
4. Identify attributes most highlighted in both, literature and field studies.
5. Identify a theme related to trust and its attributes from design studies.
6. Highlight key modalities that contribute towards trust from design studies.

1.7 Outline

This thesis report is divided into three parts (see figure 1.3): Introduction part, Main part and Discussion part.

The second chapter, theoretical framework gives a detailed definition of SAVs, SAE levels of trust with a few examples of SAV pilots. Moreover, trust along with existing research concepts for both external and internal communications are detailed along with related work from the literature study. Chapter three, methodology, describes the ethics and details the methods involved in this research, thus concluding the introduction part.

The main part consists of results and analysis, beginning with results from field studies, followed by interview and observation results from driver, passenger and experts. Lastly, results from three participatory design studies and then analyzing the results.

The discussion part includes results of the thesis project, reflecting on the process and methods, sustainability and ethics and concluded by recommendations and future work.

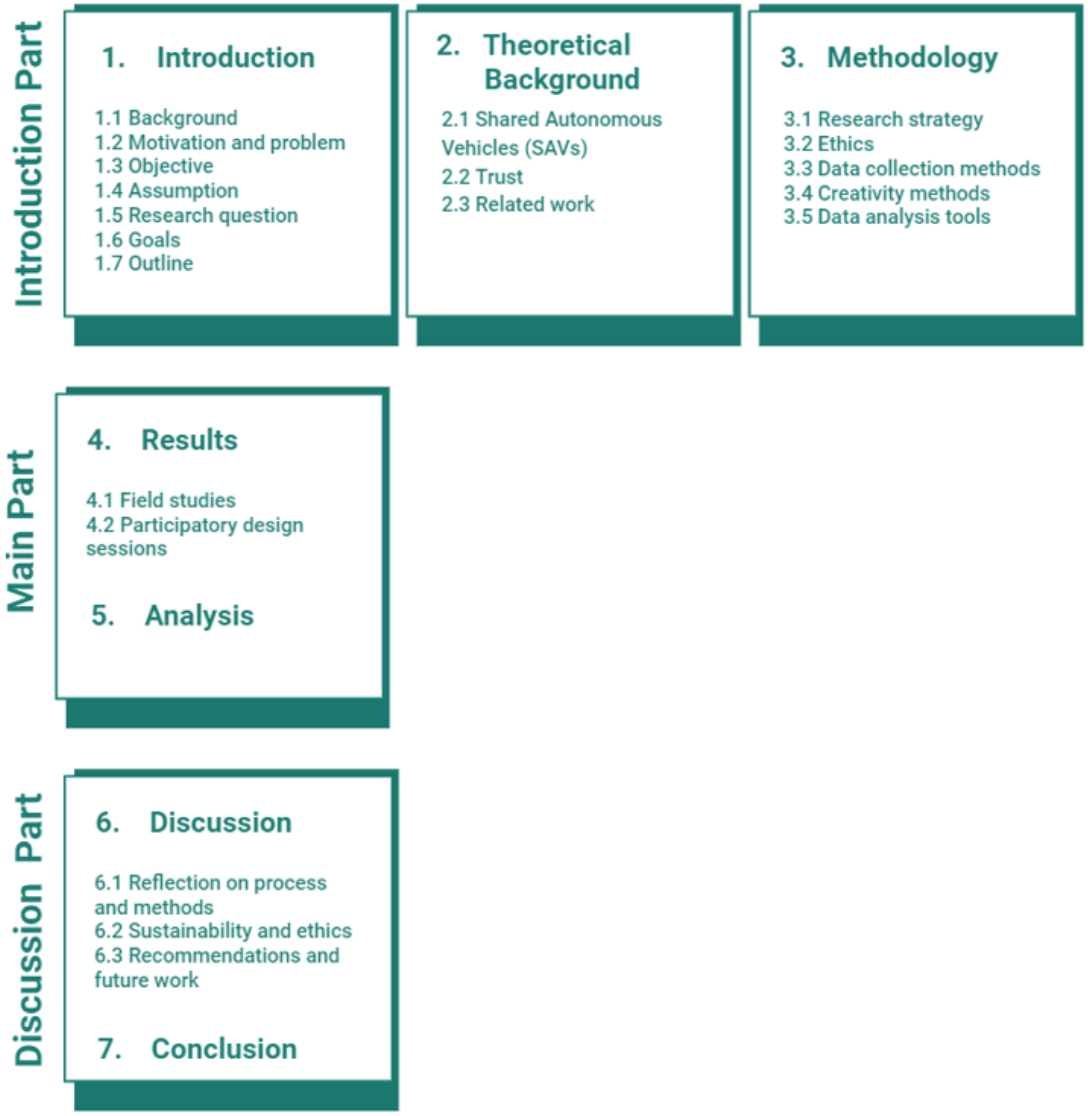

Figure 1.3: Thesis structure.

2 Theoretical Background

In this chapter SAVs are introduced, followed by levels of automation and examples of SAV projects and pilots. Afterwards, trust is detailed and related work including research and design concepts related to trust and literature review on existing frameworks is mentioned.

2.1 Shared Autonomous Vehicles (SAVs)

'Autonomous Vehicles (AVs)' is a term interchangeably used with "self-driving car", "autonomous car", "driver-less vehicle" or a "robot car" depending on the context. In this thesis project the term 'autonomous vehicles' is used. AVs is a vehicle that takes you from location 'A' to location 'B' with none to minimal input from a human on-board, depending on the level of automation the AV is operating at. AVs come equipped with several sensors to understand the environment its operating in. These sensors can include cameras, GPS, lidar and sonar, together they help the AV to asses its surroundings.

A 'Shared Autonomous Vehicle (SAV)' is like an AV that multiple people share, similar to a bus. And are only meant for public use and not private usage and are to compliment regular public transport as a first/last mile solution. In SAVs, there is no steering wheel or brake and accelerator pads which changes the role of the active driver to a passive passenger [26]. Although, due to regulations there is an on-board operator but as assumed within this project, such presence would not be required for future SAVs.

AVs in general are deemed to be the future of transportation in urban environments transforming the industry from privately owned cars to ride sharing services [25] [27]. SAVs are also considered to change the concept of vehicle sharing and ride sharing, as SAVs will have the potential to be summoned by a passenger [28]. And potentially reducing costs associated with private modes of transportation [29] in urban areas.

2.1.1 Levels of automation

There exists several levels of automation ranging from no automation to full automation. The SAE categorized them into six levels (See figure 2.1) from level 0 (no automation, fully human controlled) to level 5 (Fully autonomous, complete system control). Although, it is also worth noting that the level of automation does not define the vehicle but the system. So even a vehicle operating at level 5 could also have a steering wheel, brake and accelerator pads.

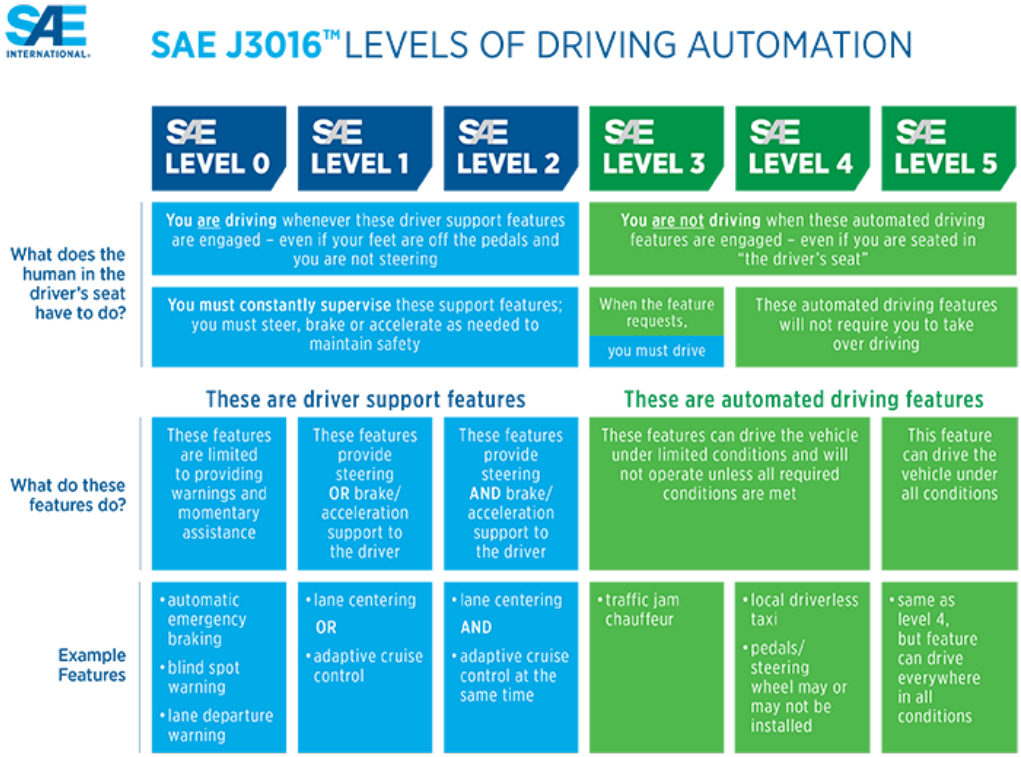

Figure 2.1: SAE: Levels of automation. Retrieved from: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic. Copyright (2014) SAE International.

Most SAVs within the urban areas are operating at level 3 and above, in a controlled environment with relatively lower speeds and little to no traffic. Meanwhile, the on-board operator has to be ready to take over once requested by the system or the SAV runs into unexpected situations.

2.1.2 Example SAV projects and pilots

The research project Autopiloten[6] gave Sweden its first autonomous shuttle in the beginning of January 2018. It was in collaboration with the bus company Nobina, Ericsson, SJ, KTH Royal Institute of Technology, Klövern, Urban ICT Arena, and the City of Stockholm. Two shuttle buses were running on the public road in Kista. The path itself was a pre-recorded 1.5 kilometers long stretch (see route in Appendix A) and the buses could reach a maximum speed of 20km/h with 12 passengers on-board and an operator to take over control if/when necessary. The shuttle stops by itself if it detects something in its way.

Figure 2.2: SAV Autopiloten. Photo by Nobina.

Figure 2.3: SAV at Barkarby. Photo by ITRL.

In fall of 2018 three self driving buses[7], developed by EasyMile, were introduced as part of the regular scheduled transportation service in Barkayby, Stockholm, making it the first of its kind in Europe. The buses operatein the residential area between Stora torget and Barkarby Handelsplats (see route in Appendix A.1) with multiple stops along the route. The buses can reach a maximum speed of 12-15 km/h with an on-board operator who can take over the SAV's control when necessary.

[6]https://www.thelocal.se/20180125/in-pictures-swedens-first-driverless-buses-hit-the-streets Accessed: 2019-09-09

[7]http://www.barkarbystaden.se/ Accessed: 2019-09-10

GACHA[8] a self-driving shuttle bus by Sensible 4 and designed by MUJI which are known for their minimalist design philosophy. The SAV itself is designed for all types of weather conditions and is currently in pilot at Espoo, Finland (see route in Appendix A) at Nokia's campus where it will be utilizing their 5G network. It can seat 10 passengers with an six standing. This four-wheel-drive all-electric shuttle can reach a maximum speed of 40km/h with a range of 100km courtesy of its electric motor. It also has LED light belt around its entire body serving as headlights and communication screens.

Figure 2.4: GACHA Shuttle bus. Photo by Sensible4.

[8]https://www.sensible4.fi/gacha/ Accessed: 2019-09-11

2.2 Trust

So far there has been no universal definition of trust as each of them vary across various domains and is driven by context. According to Schaefer [30], there are more than 300 definitions derived for trust across different research areas. Involving, but not limited to, human-automation trust and trust in software driven systems. Though with such many variations in defining trust, it also provides some commonalities accross domains. Those as mentioned by Hoff and Bashir [15] include, firstly, a truster which can give trust, a trustee to accept the trust and between the two something must be at stake. Secondly, for the trustee there has to be an incentive in place to carry out the task. And lastly, a possibility of failure that would invoke some risk and uncertainty performing the task. Similarly, Lee and See [22] states the need for three components to be present for trust to exist as a requirement. The three components being: agents that can introduce trust and receive it as well, an incentive and a possible outcome involving failure.

Since their is no established definition of trust, the one proposed by Mayer et al. [31] suits the premise for this thesis which states that *trust is a person's willingness to put themselves in a vulnerable position to the actions of the other party, an SAV in this case, with expectations of a positive result or behavior.*

Trust in automation is important [32] and more so within transportation not only limited to its adaptation but also concerning its effects on safety while using the service [15] [17]. Other studies show that the acceptance of the AVs and passenger's perception of safety is effected by the presence of an on-board operator [17] [18]. Establishing trust is not straight forward though as one can either create overtrust with over-reliance on automation or undertrust where the expectations fall short of its actual capabilities [22] [33]. Hence calibrating trust in the system is necessary, which means having comparability between an agent's trust in the system and the capabilities of automation [22].

AVs to passenger model provides multiple opportunities to explore multiple phases of interaction, not just limited to the initial interaction with the vehicle itself. It can be broken down into several phases such as waiting for the vehicle, boarding the vehicle, riding the vehicle or exiting the vehicle.. Each phase offers

a different quality and service attributes to take into account. In doing so a more holistic approach could be undertaken to establish trust. The study by Ekman et al [20] give further insight into trust effecting factors within different phases. Furthermore, the use of different modalities to interact with the passenger also needs to be explored within the given context.

The focus of this thesis is to look into the explicit communication channel between the passenger and the SAV. Trust relies upon context [33], making it important to understand the parameters involved within each context. Examples of such parameters could include unexpected situations, stress, task type, cognitive workload. And in the context of SAV-to-passenger interaction its important to define *'vehicle intention'* and *'vehicle awareness'*. *'Vehicle intention'* defines the AV's next course of action after an incident or an unexpected occurrence. *'Vehicle awareness'* specifies what the AV is seeing around it and its acknowledgement of those elements.

2.3 Related work

2.3.1 Trust in industry: Research and design concepts

AV to external communication

Currently there are plenty of interaction and communication concepts within the industry which provides a glimpse into the future of communication between an AV and other actors in a given traffic scenario, specifically, pedestrians. The examples provided here are to provide a context of vehicle to external communication.

Figure 2.5: Driving modes - AVIP [34]

Figure 2.6: Semcon smiling car. Photo by Semcon.

Figure 2.5 shows the work of Tobias Lagström and Victor Malmsten Lundgren [34] using an LED strip to have as an external communication feature which shows different driving modes (automated driving mode, yielding, resting, start moving). While figure 2.6 shows a vehicle concept developed together by Semcon and RISE Viktoria. The vehicle "Smiling Car" uses an LED display by representing a smile on the front grill of the car, notifying pedestrians that it is safe to cross.

Figure 2.7: Experiment vehicle with LCD screen [1]

In a study done by Clamann et al.[1] visual modality represented by the use of an LCD screen mounted to the front of the vehicle provided visual information to the pedestrians if an when it is safe to cross the road.

AV to internal communication

Trust from passenger's point of view is not explored as much when it comes to other actors in a traffic scenario like pedestrians. There have been some work done to inquire passenger's trust and how it can be enhanced. There are different approaches towards defining trust as well as choosing certain modalities which effect such trust, as can be seen in some of the following examples.

Olli[9], a self driving bus made by Local Motors that can take up to 12 passengers. The distinctive feature of Olli is that it utilizes the cloud-based cognitive computing capability of IBM Watson Internet of Things (IoT) to talk with the passengers using auditory modality. During the commute passengers can ask Olli questions regarding commuting route or questions regarding the SAV's features. It is a path chosen by Olli's to make passengers feel comfortable and build trust between them and the SAV.

Figure 2.8: Olli Self-driving bus. Photo by Local Motors.

Mcity[10] in University of Michigan, United States, is a driver-less shuttle research project with two shuttles manufactured by Navya. The focus of their research was to insight on user behavior and collect data vehicle performance and interaction and passenger's attitude towards the shuttle itself. The shuttle has a display interface (See figure 2.9) inside that communicates major vehicle information with its passengers and is also capable of taking passenger input. Navya's

[9]https://localmotors.com/meet-olli/ Accessed: 2019-09-10
[10]https://mcity.umich.edu/shuttle/ Accessed: 2019-09-12

Autonom[11] shuttle also provides an on-board digital screen to display information and visualize the interior of the vehicle combined with an intercom through which passenger's queries can be answered.

Figure 2.9: Display interface Mcity shuttle.
Photo by University of Michigan.

One of the identified future challenge within Mcity case study was the anticipated problem of changing or taking over shuttle's control in unforeseen dynamic conditions.

In order to make the rides safer and gain passenger's trust Waymo[12] utilized the visual and auditory modalities. Their approach of 'showing less to communicate more' present clean visuals to passengers to keep them updated on their journey, the same approach has been used by Uber in the past to build trust in passengers[13]. The on-screen messages displayed called "status layer" directly communicates with passengers what the car is doing or why it is stopped.

Figure 2.10 shows Waymo's "Status layer" in action where it highlights a passenger crossing the road and conveys it to the passenger. In case of an unusual occurrence, audio will be used to convey what is happening to the passenger.

Some of the challenges and approaches seen in such projects also concur with what Intel highlighted in their approach towards building trust. They identified four main capabilities that should be at the heart of the any passenger to AV communication and interaction: *comprehensive sensing, clear communication,*

[11]https://navya.tech/en/autonom-shuttle/ Accessed: 1029-09-12
[12]https://design.google/library/trusting-driverless-cars/ Accessed: 2019-09-17
[13]https://www.automotiveworld.com/articles/more-stringent-more-technical-ubers-new-look-self-driving-programme/ Accessed: 2019-09-17

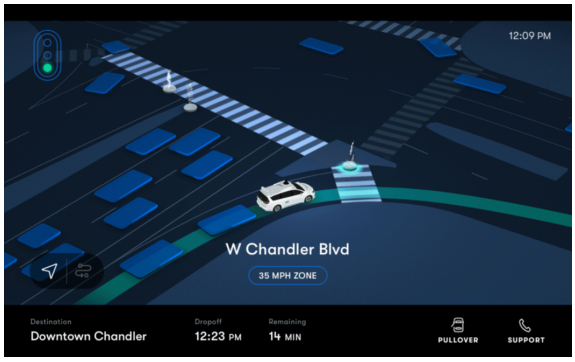

Figure 2.10: "Status layer" Waymo. Photo by Google Design.

response to changes and multiple modes of interaction [35]. Such capabilities will enhance trust and safety for the passengers of the AV.

2.3.2 Literature review

Purpose

The purpose of this literature review was to look into the existing research that has been done with trust in automation involving SAV to passenger communication and existing trust frameworks highlighting trust definition and attributes.

Goal

The goal of the literature review was to get a general definition for trust in automated transport, what influences trust and how to approach creating trust.

Method

To initiate state of the art research was conducted using keyword search consisting of the following words as well as there combinations: *trust, safety, autonomous, automated, vehicle, passenger, pedestrian, communication, feedback, behavior, intention, driverless, driver, public, transportation, framework, interaction*. Search for the keywords was done on Google Scholar, Transport Research International Documentation (TRID), Microsoft Academic, Elservier (Scopus/Science direct) and ResearchGate.

Results

The work of Hancock et al. [21] presents a model of human-robot trust with dimensions that influence human-robot interaction. It consists of three factors that they have explored: human factors, robot factors and environmental-based factors. They further highlight influences of trust in each of these three factors.

- Robot characteristics:
  - Matching behavior with expectation
  - Expressing behavior to be trustworthy
  - Predictability and dependability
- Human characteristics:
  - Mental workload and its unpredictable nature
  - Situational awareness
  - Natural inclination to trust the AV
- Environmental characteristics:
  - Type of task
  - Human's assumptions about an AVs behavior
  - Influence of explicit and implicit communication

These characteristics are used later on in this thesis to categorize findings from interviews and observations.

The work of Hoff et al. [15] also reveals three similar sources for trust within human-automation: Human-operator, environment and the automated system itself. Within their research the aforementioned variables of trust are further defined as dispositional trust, situational trust and learned trust, all three being dependent one each other. Dispositional trust is one's inclination towards trusting automation. Situational trust is dependent on the context of the interaction. And learned trust is driven by the past experience or expectations in relation to the current system.

Ekman et al. [20] investigated how appropriate level of trust is created for an automated driving (AD) system through human-machine interaction (HMI). In their paper they presented a trust framework to aid with implementing trust related factors within an HMI interface. Furthermore, the framework integrates usage phases: preuse, learning and performance, AD events which are divided into 31 events, factors that effect trust and levels that explain each event as in what is happening within each event, what is required from the user and lastly, how can trust be developed. Their findings helps to approach and understand trust through a more holistic approach. Factors identified in their framework were used to categorize results from interviews and observations into a higher level to maintain consistency in qualitative data.

Results from the study done by Oliveira et al.[36] show that passengers would like to know about the state and behavior of the vehicle and other ride related information. Within this study three different screen configurations were implemented to convey vehicle and commute related information to the passengers. In their findings several recommendations were drawn from which the ones relating to interfaces suit the premise of this thesis. They recommend the use of display modality to explicitly convey information, making sure passengers know the state of the vehicle and the actions it is going to perform next. Their study gave insight into the implementation and influence of visual modality to communication with passengers.

Findings from survey of literature for non-verbal signaling and communication of robotic agents [37] show the importance of improving trust between a robot (an SAV in this case) and a human through communicating its intention and behavior. Lee and See identified the implications for creating trust in automation and making them more trust-able. Some of the factors mentioned included: showing the process of the automation and making it simpler to understand, showing the purpose of automation in relation to user goals, understanding the capabilities during automation and over-watching its behavior and evaluating anthropomorphism with modalities such as speech. They also shed light on the significance of using visual modality in creating trust specifically, displays and the type of content that it conveys [22].

3 Methodology

This chapter discusses the research methodologies used within this thesis project. It lays out the overall research strategy, ethical aspects, data collection methods and data analysis tools.

To carry out the research the following methodologies are used during different phases. It is also pointed out in which phase of the thesis a method has been utilized.

3.1 Research Strategy

To guide the work of this thesis towards to objectives defined in 1.3 a research strategy consisting of goals and methods will be adopted, highlighted using the work of Håkansson [38]. Since the objectives of the thesis are geared towards a qualitative outcome, qualitative research method will be adopted. It usually consists of a smaller sized data set and includes understanding their opinions and behaviors towards a set of hypotheses. An *empirical research method* is used to support the overall process of conducting the research as it relies on observations and experiences to extract knowledge from actual experiences. Furthermore, to conduct research using qualitative methods, *inductive research approach* is utilized where the outcome is based a set of qualitative data from observations and opinions. For validity, type 'construct' was applied where the set of qualitative data collect was categorized based upon existing trust frameworks. To maintain reliability, type 'test-retest' was used where the same field study was conducted multiple times with same set of questions.

3.2 Ethics

Users are a focal point of this thesis project when it comes to investigating passengers trust and henceforth, their safety and comfort is of utmost importance. All participants will be provided sufficient background knowledge about the subject matter to be researched and informed about any risks associated with the research [39]. Any data collected would be made sure to be anonymous and no data will be collected without the participants's explicit consent. Any

data collecting will be stored securely and made sure that participant's personal information is not revealed in any form. During the participatory design studies, participants have complete autonomy to stop the exercise at hand if they decide as such. All data collected during this thesis will only be utilized by the author in a manner which helps with the overall goal of improving passenger's trust in an SAV. No data will be shared with a third-party.

3.3 Data collection methods

3.3.1 Literature review

The first method used in the research process was literature review. Initially a state of the art literature research was conducted to look into the work being done related to the thesis project and identify ideas and concept previously researched. All of which was looked into to create the premise for this thesis project. Afterwards the research converged to a more defined area in order to outline possible opportunities to carry the research project in. A majority of time during this thesis was devoted to literature review, not just initially, but also through multiple stages of this thesis to verify and validate the work.

3.3.2 Observations

Observation is a method to collect data when performing a task(s) within the premise of a scenario or situation and is a good way to get insightful data without influencing a user's natural behaviour [40]. Within the premise of this thesis the tasks could include observing how the passengers interact with the SAV, actions the operator and passengers perform before/during/after the commute, the use of modalities and interfaces to communicate with people within the SAV and outside of it as well as actions that actions and interactions with the operator of the SAV.

Observations were made using using fly on the wall [41] and were conducted during the field studies by being physically present on the SAV with the operator and other passengers and directly observing them performing actions as well as during interviews and participatory design sessions.

3.3.3 Interviews

Interviews are a good way to obtain views on a subject matter and create a deeper understanding of it [42] [40]. There are essentially three types of interviews [42] that provide flexibility in how much data can be collected:

1. **Structured interviews:** These types of interview have a pre-defined set of questions with almost no deviation. Such type is used to get very specific information from the participants as it does not contain any follow up questions depending upon participant's response.
2. **Semi structured interviews:** It follows similarly with the structured interview style, with a pre-defined set of questions but allows for more flexibility in terms of participant's response and follow up questions.
3. **Unstructured interviews:** As suggested by its name, unstructured interviews lack any pre-defined set of questions and is rather lead with opening questions. Such type of interviews allows to cover a broader spectrum of subject matter.

Within this thesis project several types of interviews were used based on their situational advantages. During field studies contextual unstructured and semi-structured interviews were used to gather insight into the interactions with an SAV and passenger behavior, in their natural arrangement [43] and to give more room for exploration [44]. Semi structured interviews were utilized during user and expert interviews to investigate current challenges within automation and participant's trust while also allowing users and experts to provide additional information [44].

3.3.4 Participatory design session

PICTIVE is a participatory design technique which is used to aid in increasing user involvement in a design process [45]. Although part of PICTIVE comprises of video recording, to keep a record of the design session, it is not necessary for this project and is hence excluded from the design activity. One of the benefits to PICTIVE is that it creates an informal session so the participants can feel more relaxed and hence encouraging contribution from each participant. Furthermore,

PICTIVE focus on the visual element meaning participants can draw, write, use post-its or cutouts, which helps bringing out a more creative design outcome [46].

In [2], PICTIVE method was used to let the participants come up with interface design to communicate awareness and intent from the autonomous vehicle to the pedestrians. It resulted in four interface prototypes based on the findings from the design session.

Participatory design sessions were held after gathering enough understanding in relation to the definition of trust within automation industry and after having been familiarized with the use of modalities in context of trust building.

3.4 Creativity methods

Creativity methods were used during the initial conceptualization phase. For this phase, Hyper Island's Toolbox and IDEO's Design Kit provided methods in helping brainstorm, synthesize and frame ideas. Initially, *'Idea & Concept Development'* [14], a process by Hyper Island was used to generate ideas. The process itself is inspired by Double Diamond design model. The general steps followed within the process were:

1. Divergent thinking (focusing on quantity rather than quality)
2. Word and image association
3. Mash-up approach (brainstorming ideas with technologies)
4. Ideate
5. Cluster and narrow
6. Selection

'Frame Your Design Challenge' [15] from IDEO's Design kit was used to put the ideas generated in context of a solution framework. Through the iterative process the ideas were put through the same stages which consisted of the following steps:

[14]https://toolbox.hyperisland.com/idea-concept-development Accessed: 2019-09-13
[15]http://www.designkit.org/methods/60 Accessed: 2019-09-13

1. Framing identified problem or probable solution as a design question.
2. What impact might it have?
3. What are some of the ways to tackle it?
4. Identify the context and constraints.
5. Re-framing the question.

3.5 Data analysis tools

3.5.1 Thematic content analysis

Thematic content analysis is used to analyze the qualitative data obtained through the interviews. Thematic analysis helps identify themes within a qualitative set of data [47]. According to [47], a theme manages to identify something of importance within a data set that is associated with the main research question and highlights a pattern with the collected data. Thematic analysis is performed in several phases [48]:

1. Collecting data
2. Coding the data in relation to the research question.
3. Generating themes
4. Categorizing themes in the context of the research question

There are two types of codes; semantic coding and latent coding. Through semantic coding the explicit meaning in the data is exposed. While in latent coding the underlying assumptions are revealed. Semantic coding is used as it fits well the context of this thesis while gathering opinions.

3.5.2 Generic design thinking approach

To evaluate design concepts resulted from PICTIVE, a generic design thinking approach [49] is used. This approach suggests four steps during design conceptualization:

1. *Identifying* existing groups in HCI.
2. *Relating* existing designs to the identified groups at a higher level and analyzing commonalities.
3. *Elaborate and explore* the similarities and commonalities and formulate definitions for designs related to existing groups.
4. *Design, implement and evaluate*: ways of creating new designs that either conform to the existing group or opposes its definition.

4 Results

This chapter details the results from the three field studies involving an SAV, observations and interviews from passengers and on-board operator. Followed by interviews and observations with passengers and drivers of regular bus. Along with expert interviews and lastly, results from the three participatory design studies.

4.1 Field studies

4.1.1 SAV operating at Barkarby, Stockholm

Three rounds of observations and interviews took place at Barkarby, Stockholm where the SAV operates. The bus runs between newly built residential areas and is incorporated in the regularly scheduled bus service and is open for public use. The observations and interviews took place in the spring of 2019 (April 15th to April 17th). While the SAVs have been operating in the said region since autumn of 2018. The route followed by the SAV can be found in Appendix A.1.

Figure 4.1: SAV - Barkarby, Stockholm.

Purpose

The purpose of the field studies was to get a firsthand experience of the SAV running in the region, how it operates and its interaction with the passengers and other actor in a traffic scenario.

Goal

The goal was to gain information about how trust is perceived, both explicitly and implicitly, from the passengers and the operator's point of view.

Method

A semi-structured interview took place with the operator and the passengers on-board the SAV, the interview commenced from the starting point of the SAV until it made one complete loop of its route, which took approximately 35 minutes. Along the way passengers and operators were observed as well. A total of 3 SAV operators (all male) and 8 passengers (5 male, 3 female) were interviewed. The same pattern was applied to the remaining rounds of field studies. The set of leading questions asked during these interviews can be found in Appendix A.1.2. During observations the passengers were random people deciding to ride the SAV and were not aware that they were being observe to ensure it does not influence their behavior.

Results from observations

To begin the journey the operator looked around in the cabin first to see that all passengers are comfortably seated then looked outside to check for the surroundings before the SAV started to move. At this point the passengers already had questions about the operations of the SAV which the operator answered. The operator was on a constant lookout for anything out of the ordinary on course to the next destination. On one particular instance, the SAV was stopped because a car was parked on the sideways impeding its path and the operator had to stop the SAV and get out to ask the driver of the vehicle to move the car. Within the same instance, the passengers concern was directed towards the operator to solve the issue of the parked car. The operator of the SAV explicitly communicated with the passengers that "he was not in control of the vehicle" and that "he couldn't do anything in that situation" but to ask the driver of the car to move. With any unusual occurrence during the ride, the passengers would ask the operator exploring questions like "why did the bus stop?" or "why did it let the other car go first?". The operator conveyed sufficient explanations to the passengers whenever

the SAV would come to a halt or behave out of the ordinary.

Reflection

These are the main outcomes from the observation of both, the operator and the passengers:

- This particular SAV had no interface to communicate with its passengers.
- The passengers directed all their queries towards the operator as soon as the journey commenced.
- During the encounter with another stationary vehicle, the SAV stopped and left the passengers confused as the reason was not explicit.

Results from the interviews

The findings from the interviews provided insight into what was observed with the operators and passengers on-board the SAV. Passengers (n = 7) looked to the operators if they wanted answers to any of their queries or explanation if anything out of the ordinary happened during the journey. To most passengers (n = 6) feedback was important especially in unusual situations. As one of the passengers stated:

"I wouldn't know what to do in such a situation or how the bus will react"

Figure 4.2: SAV stopping unexpectedly. Photo by author.

On longer trips consisting of multiple stops feedback was deemed more important than shorter journeys. The operators were seen as the person in control of the SAV by all the passengers (n = 7), concurring with what was observed. Passengers (n = 3) also referred to the previous occurrence where the SAV stopped but they were not sure why it happened.

The operator of the SAV confirmed what was observed during the commute. In any unusual scenario the passengers expect the operator to take care of it. Although none of the operators were convinced that the SAV is ready to part of regular traffic in a more complicated traffic scenario.

Reflection

These are the main outcomes from interviews with both, the operator and the passengers:

- Operator was in control since the passengers were not familiar or did not know what to do in certain situations.
- Knowing the SAV's intention an behavior was deemed important especially if there was no operator on-board

- Communication and feedback with the SAV was more important during longer commutes.

4.1.2 Regular Stockholm public transportation

To obtain further insight into the definition of trust in a comparable transportation model and elements contribute to such a definition, interviews and observations were conducted in public transportation buses in Stockholm.

Purpose

The purpose of this field study was to investigate how trust compares within the public transportation ecosystem along with what constitute as a trust attribute.

Goal

The goal is to find comparable trust attributes and a general definition of trust that will help establish a framework.

Method

Interviews took place on the public transport buses along route 50 which went from the Lappkärrsberget to Stockholm city center. A total of 21 passengers (15 male, 6 female) were interviewed along with 4 bus drivers (3 male, 1 female). The interviews were conducted in contextual setting and were performed over a number of days during different hours of the day. Passengers and bus drivers were interviewed and observed during this phase. The leading questions can be found in Appendix A.2.1.

Results: Passenger interviews and observations

From the results it was found that most passengers (n = 17) do not think about feedback from the bus or communicating with the bus driver unless something out of the ordinary happens. In case anything unusual happens, according to one passenger:

"The driver would most likely take care of it"

When inquired if the driver of the bus was replaced by a autonomous driver-less bus, the passengers (n = 19) would prefer that the intentions of the buss be conveyed to them in atypical situations. Furthermore, when the word trust was introduced, passengers (n = 19) answers pointed towards the driver of the bus being an anchor point. According to one passenger, in most cases:

"I'll just sit in my seat and look outside the window because I trust the driver and he/she will communicate any necessary information to me"

When discussing driver-less buses, most passengers agreed that in such a scenario they would like know how the vehicle is going to behave and what its deciding to do, specifically in those unexpected situations. When investigated further as to why the majority of the passengers (n = 19) relay their trust in the driver of the bus, a couple of reasons stood out. Firstly, the driver is aware of the situation and is fully in control of the operation of the bus, and secondly, the communication with the passengers is very clear and direct in those rare circumstances.

Results: Driver interviews and observations

The results show that drivers are well aware that they are in control of the bus which makes them the focal point of trust during commutes. When asked for further elaboration, one of the driver stated:

"They [passengers] do not realize the amount of communication [implicit] that occurs and only if something unusual happens, they would usually express their trust in us to take care of it"

When asked about communication and feedback with the bus, all of the drivers felt that it is important and why most passengers might not see it that way is because:

"We absorb the feedback, we see what is out there and decide what to do. Which is why the passengers do not see it but now take us [drivers] out of the bus and see how it changes the need for such feedback and communication"

According to results from the study conducted by Salonen [17] the presence of a

driver was deemed important of the passengers.

4.1.3 Results from expert interviews

Findings from the interviews with experts from Uber, Scania, Volvo and Intel showed the importance of a clear communication of vehicle intention and behavior to its passengers in creating trust.

"When talking about autonomy, especially at level 4 and level 5, it is immensely important that the passenger(s) of the vehicle know exactly what is going on"

A need for a communication and feedback interface between the passengers and the SAV was stressed upon. In terms of higher levels of autonomy in the future, communicating the exact actions of an SAV and its intentions or future course of actions needs to transparently conveyed.

"Its not about communicating more but communicating clear"

A practical example of such a system's affect on trust was used by Uber Technologies when they implemented a center console interface in Uber taxis which showed the passengers what the vehicle was seeing. Their research results suggested towards people increased trust through such an interface.

"Usually the chances are higher when using a multi-modal communication channel"

Experts also emphasized the use of multiple modalities to instill higher trust in passengers, not just relying of one such as visual or haptics.

Reflection

These are some of the key points that stood out during the interviews and observations with bus passengers, bus drivers and experts:

- Passengers by default trust bus drivers to take care of any situation
- Trust is a combination of implicit and explicit communication
- Trust is an unconscious process and only during unexpected scenarios can its importance be revealed.

- Knowing what the vehicle is doing and why is important.
- According to experts trust needs a more holistic approach
- A multi-modal implementation creates higher chance of instilling trust.

4.2 Participatory design sessions

To understand and evaluate how the participants view trust three design sessions were held with different groups of participants (n = 12). The sessions lasted about 45 minutes during which each participant provided reasoning to their visual representations followed by a discussion session between participants.

Figure 4.3: Discussion and feedback session.

Figure 4.4: Design study held at ITRL. Photo by author.

Purpose

The purpose of the participatory design session was firstly, to understand the definition of trust relating to an SAV, secondly, to gain insight into representation of trust through the use of preferred modalities and interfaces.

Goal

The goal was to have interface designs created by participants using different modalities, and subsequently, identifying commonalities between the design outcomes.

Method

All participants had previous knowledge about autonomous vehicles but none of them had ever experience an SAV for themselves. Participants were briefed

regarding the project and afterwards were presented with a printed image of the inside of an SAV. The participants were informed that they were free to approach the image whichever way suitable which included options like sketching onto the image, writing, using post-it notes. Emphasis was on visualization of their own thoughts regarding the task at hand. Participants were interviewed afterwards to get insight into the drawn sketches.

Results

The figure below shows some of the sketches made during participatory design sessions. The objective of these sessions was not to come up with a interaction concept but to highlight 'what' constitutes as trust and 'how' can it be translated through the use to different modalities, but more importantly trying to figure 'why?'.

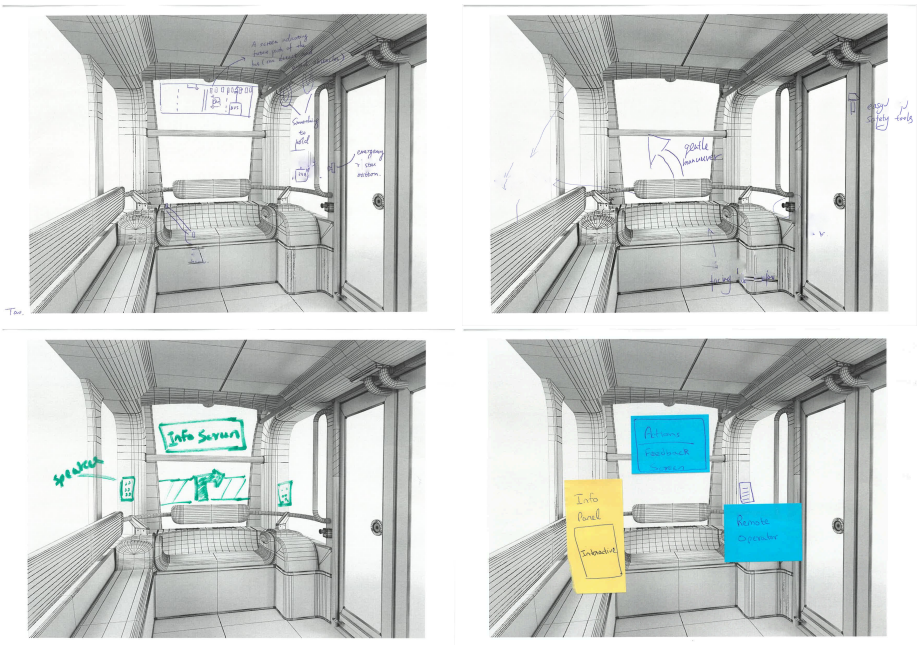

Figure 4.5: Results from participatory design sessions

From the participatory design study participant's designs and interviews were assessed and analyzed in a qualitative manner to identify and extract the main theme or meaning from the data [47]. The data was coded into different categories some of them included: *"communication between the SAV and the passenger", "awareness from the SAV", "SAV behavior", "information modality", "intention on the SAV", "too much information".*

Table 4.1: Results from design study sessions

Modality	**Participant's choice**	**Implemented by # of participants (N = 12)**
Visual	Display panels	12
	Display with text-only	2
	Projection on windscreen	6
	LED lights	8
	Display with human character	5
	Interactive screens	10
Auditory	Speakers	11
	Beeping sounds	6
	Intercom	7
Physical	Haptic feedback from SAV interior	4

Table 5.4 summarizes the results from the participatory design sessions. The sessions highlighted three main modalities of choice: *visual, auditory and physical.* Results reveal that visual modality was the preferred choice of participants. With majority of the participants relying on multi-modal approach instead of using one modality.

Furthermore, the choices of the participants were coded and post-session interview and discussion results show the leading factors of trust for participants are: SAV's situational awareness and intention of the SAV. As expressed by some of the participants:

"I would like to know what the vehicle will do in such case"

"Knowing the exact intention of the SAV is more useful"

"I'm more concerned with the course of actions the AV will take"

Moreover, the choices of participants were also coded after post-interviews revealing the context for each modality as seen in the table 4.2.

Table 4.2: Common themes within participants choice of implementation

Participant's choice	Context of use
Display panels	Communicating awareness Communicating intention Showing SAV status/mode Journey information
Display with text-only	Showing SAV status/mode Journey information
Projection on windscreen	Communicating awareness Communicating intention Showing SAV status/mode Journey information
LED lights	Communicating awareness
Display with human character	Communicating awareness Communicating intention Showing SAV status/mode
Interactive screens	Communicating awareness Communicating intention Showing SAV status/mode Journey information
Speakers	Communicating awareness Communicating intention Journey information
Beeping sounds	Communicating awareness SAV status/mode
Intercom	Communicating awareness Communicating intention
Haptic feedback	Communicating awareness

Following the generic design thinking [49] the choices made by the participants were matched to higher level category that represented the same idea as the participants choices. As an example, one participant explained his choice by saying "Seeing what the vehicle is seeing can help me trust it more", such statement was classified as 'communicating awareness'.

5 Analysis

All the results gathered from observations and interviews from the field studies, expert interviews and participatory design studies are summarized and analyzed here in relation to the research questions for this project.

The findings are used to answer the sub-research questions and hence the main research question.

First sub-research question:

How is trust defined by the passenger of an SAV?

A higher level categorization [49] of all the interviews gave insight into the definition of trust. Although trust is very subjective to each individual, within the premise of thesis it was observed to be constructed by the combination of these main components:

- *Situational awareness*: It suggests that the SAV can show that it has clearly acknowledged an external subject and is aware of its presence within its vicinity.
- *Communicating intention*: It suggests that the SAV clearly shows its next course of action after encountering a situation out of the ordinary.

Although it has to be noted that many participants feared the amount of information that will be part of SAV - passenger interaction. It reveals the importance of avoiding *information overload* [50] [51] [52] that might lead to creating information anxiety [53] as identified by one participant:

"Too much information would cause confusion"

The importance of clear communication was stressed by an expert from Uber stating:

"More can be communicated by using less. More information can often lead to complexity"

Second sub-research question:

What are the key factors which effect passengers trust

Table 5.1 shows similar themes found in responses from participants during interviews and discussions. The responses were coded to maintain consistency with the set of qualitative data. Examples of codes for robot characteristics classification were “feedback from the vehicle”, “not communicating errors”, “actively responding to unexpected situations”. These findings gives insight into the attributes that defines trust for passengers of the SAV.

Table 5.1: Thematic analysis revealing similar themes within participants response in robot characteristics.

Robot characteristics	**Similarity to participants response (N = 53)**
Anthropomorphism	4
Predictability	27
Dependability	31
Adaptation to automation	18
Active response and engagement	34
Mode of communication	26
Interface aesthetics	16
Feedback	37

As can be seen in table 5.2 showing similar themes related to human characteristics. Example codes used were “unexpected situation leading to stress”, “being aware of the surrounding”, “more interactions can be more stressful”.

Table 5.2: Thematic analysis revealing similar themes within participants response in human characteristics.

Human characteristics	Similarity to participants response (N = 53)
Stress	38
Attentional capacity	15
Workload	23
Situational awareness	47
Tendency to trust	7

Identified themes related to environmental characteristics can be seen in table 5.3. Example codes utilized were “what is in the surroundings”, “identifying incidents”, “the task vehicle is performing”, “who has the right of way”.

Table 5.3: Thematic analysis revealing similar themes within participants response in environmental characteristics.

Environmental characteristics	Similarity to participants response (N = 53)
Communication	48
Mental models	11
Task type	23
Societal/Cultural impact	10

Results from the three participatory design studies provided answer to the third sub-research question.

Third sub-research question:

What are the preferred modalities that help create the most appropriate level of trust?

With 10 different design created by 12 participants, the use of *visual displays* stood out the most (see table 5.4). It was the majority choice as a preferred way of communication alongside *interactive screens* and *speakers* in communicating SAV awareness and intention. But information overload should be taken into consideration even though some participants chose a multi-modal interface, its effectiveness threshold was not within the context of this thesis and is yet to be explored.

Table 5.4: Results from design study sessions

Modality	**Participant's choice**	**Implemented by # of participants (N = 12)**
Visual	Display panels	12
	Display with text-only	2
	Projection on windscreen	6
	LED lights	8
	Display with human character	5
	Interactive screens	10
Auditory	Speakers	11
	Beeping sounds	4
	Intercom	7
Physical	Haptic feedback from SAV interior	4

Within the participatory studies, the two phases *learning phase* and *performance phase* defined by Ekman et al [20] were considered. The first phase *preuse phase* included trust affecting factors before the passenger's physical contact with the SAV which were not within the premise of this project. Participants were informed to exclude concepts pertaining to before physical contact with an SAV.

Together these sub questions provide a framework to answer the main research:

"Can a feedback and communication channel with an SAV effect passengers trust?"

The set of qualitative gathered in this study signifies the impact of communicating the SAV's state and its behavior to passengers. With most passengers identifying the need for knowing the behavior of the SAV and what it intends to do, specifically in deadlock situations [9], [10]. All 12 participants from the design studies through their design sketched identified the significance of keeping the passenger of the SAV informed. The same pattern was observed during field studies and expert interviews. Results signify SAV *behavior* and its *intention* among other factors to be fundamental to creating trust. And among the two most participants preferred to know information about the next course of action (*intention*) for the SAV as stated by some participants:

"If I know the what the vehicle is going to do next, I'll feel more relaxed"

"Seeing what the vehicle is seeing would make me trust it more"

As mentioned by Lee and See, the content of what is being displayed and the format in which it is displayed has a significant effect on trust [22]. The aim of this was to investigate how can trust be influenced positively. The defining attributes of trust found in this thesis correlates with what is mentioned in other studies ([15], [20], [22], [21]) for creating trust. The attributes found to affect trust the most are; *transparency and feedback*: which includes providing consistent, ongoing feedback about the SAV and its actions, *appropriate communication interface*: using modalities which communicate clear and are easy to use.

6 Discussion

The aim of this thesis was to investigate trust between SAV and its passengers by performing qualitative studies. Initial field study gave an existing definition of trust that was used to put the problem into context of the trustor/trustee, incentive and risk. Through the findings it was seen that the implications of trustor/trustee relationship were not explicitly known by the trustee.

Through existing frameworks some common trust affecting attributes were highlighted and these attributes were consistently found during the various field studies. Identifying such attributes also shed light on the fact that trust in itself should be approach from a more holistic point of view. As several of these attributes showed dependency on one another.

Interviews and observations revealed the role of the driver in many instances but it often goes unnoticed by the passengers. In such cases, trust is guided through the driver of the AV from passengers almost as intuitive response. Drivers acknowledged that point of view as being trust anchors for passengers.

"They [passengers] do not realize the amount of communication [implicit] that occurs and only if something unusual happens, they would usually express their trust in us to take care of it"

The implications of the driver-passenger relationship might be perceived blurry at this point in time since these SAVs are being used as a last/first mile concepts mostly. But with time such SAVs are deemed to act as on-demand transport service or ride-sharing service within a mixed traffic scenario, which will add to more complexity in the trustor/trustee relationship.

Though as seen with SAV projects operating in different contexts, such as, a residential complex or a business park, it might influence how one perceives trust. Number of people utilizing such service will impact others perception of trust or if people are commuting in groups. A small instance of such a case was also noticed during one of the field study with the SAV when the respondent mentioned that if more people are utilizing the SAVs service regularly then he will be inclined to trust it more.

The design studies also revealed the multi-modal approach as it best serves the need to understand trust from a holistic perspective. Multiple modalities would create a more suitable context to accommodate more passengers that might be susceptible to the use of specific form of modality. Although as the performance of the SAV and its functionality keeps on improving, people will need less communication with the SAV to trust it.

All of this served as the reason to why the qualitative study was picked as it gave insight into the motivations behind peoples choices and understanding of trust more holistically.

6.1 Reflection on process and methods

This research project followed the process outlined in Chapter 1.7. During the state-of-the-art literature study, a broad scope research was conducted to establish a general context of trust within autonomous transport. Afterwards, the research was narrowed down to define the context of the thesis. Ideally, adapting a more narrower approach would have provided more time to explore existing research topics in depth. The field studies following the study could also have been benefited from a more in depth approach, with a better understanding of trust influences.

During the three participatory studies some design sketches were explored and ideally, elaborating further upon those could have helped transform them into interaction concepts. Additionally, design study with the experts could have provided additional insight from the perspective of industry, however due to most interviews being remote and time constrained, it was not a viable option. Additionally, performing the design studies on the actual SAV itself could have revealed further cues that might have been missed in theory. However due to the unavailability of the SAV, it was not possible to do so.

Field studies were conducted after acquiring existing knowledge regarding trust which helped during contextual interviews and observations. However, since the number of passengers utilizing the SAV were limited, higher number of passengers would have given a more diverse set of data. During the interviews on pubic buses most participants were students, having a mixed demographics could have given

a different perspective on the approach towards trust and its implications.

Overall through the use of semi-structured interviews a good balance was achieved in terms of the information gathered and its scope pertaining to the context. The use of Hyper Island's Toolbox and IDEO's Design Kit helped the brainstorming sessions where the participants managed to explore their creativity without any constraints.

6.2 Sustainability and ethics

Some aspects of ethics are previously discussed in section 3.2. The focus of the is research project was to investigate the interaction between an SAV and its a passengers by exploring trust between the two, to make SAVs more trustworthy and hence safer to utilize its services. Understanding what generates trust in SAVs can lead to higher rates of acceptance [17], [18] and increase accessibility. As the current fleet of SAVs have a lot of potential to improve, its necessary to make sure its passengers instill the same level of trust in them as they would with a regular bus that has a driver on-board. As in some traffic scenarios actions are preceded by social norms than traffic laws [8] thus identifying such attributes of trust becomes vital to effective performance of an SAV whilst maintaining sufficient trust with passengers and pedestrians. Moreover, such insight into the constructs of trust would also help avoid situational deadlocks [9], [10] where the passenger would not have sufficient knowledge about the next course of actions.

SAVs could potentially have an environmental and societal impact by changing the dynamics of an urban area by helping people transition from using privately owned cars to using shared transport solutions such as SAVs. Resulting in more space, less traffic and increased efficiency compared to privately owned cars. In this thesis an effort was made to highlight the importance of trust once the driver of the vehicle is removed out of the equation.

6.3 Recommendations and future work

Through he studies conducted in this thesis project, it was revealed that passengers of an SAV would prefer to know about the behavior and intention

of the vehicle. Preferred modalities were also revealed through design studies to achieve such communication channel. But further research needs to be conducted to get more quantifiable results understanding the implications of trust. Future research could implement and test communication interfaces on an SAV using a multi-modal approach to understand the results during vehicle operations. Though further investigation would be necessary to understand the balance between the right amount of information conveyed, to avoid information overload. Furthermore, the use of AR and VR is one of the many ways to do so but it needs be robust and intuitive to outcome comparable information. In addition, accessibility should also be considered for creating communication interface early on in the design stage. One way to do so would be to involve people with accessibility issues (for instance, sight or hearing) or experts of the field in the design process.

Extending the research to include multiple SAVs operating in different contexts, operating environment, regulations could also provide additional information. Since this project was limited to one type of operational SAV with limited number of passengers utilizing it, a bigger demographic would broaden the scope of existing assumptions and limitations. Furthermore, understanding the context of use for a modality relative to age should be explored further, since the design study involved a younger demographics, their choices might differ from an older demographic giving further insight into the trust affecting factors. Additionally, cultural implications should also be investigated, in terms of expectations with automation and cultural influences of trust [33] [22].

Overall, trust should be approached from a holistic perspective instead of dividing it into individual events. Though further research is necessary to find the appropriate amount of trust, making sure passengers trust in SAVs is properly reflected with the SAVs capabilities. Otherwise it might lead to what Lee and See [22] called overtrust and distrust. Overtrust would cause the passenger to trust the SAV beyond its capabilities whereas with distrust, it falls short of what the SAV is capable of.

7 Conclusion

The objectives of this thesis project was to identify the definition of trust, primarily from the perspective of the passenger. And what trust affecting factors contribute to such a definition. With the assumption being that in the future SAVs would be operating without the need of an on-board steward. And the SAV would need to communicate information with its passenger.

Research revealed the number and variations when it comes to the definition of trust. To establish a definition suitable with the premise of this thesis, literature review was conducted. It also revealed existing trust frameworks which were constituted of various trust affecting elements. After gaining sufficient knowledge an initial field study was conducted with an operational SAV to understand the operational behavior and its interaction with the passengers. The results indicated towards the reliance on the operator of the vehicle both, as an explicit conscious decision as well as an intuitive reaction by the passengers.

Field studies and interviews revealed key trust affecting which resonated with trust elements found in existing frameworks. And to maintain consistency with the set of qualitative data, the identified factors were mapped to a high-level category. Participatory design studies provided additional insight into such elements which correlated with findings from previous field studies conducted in this thesis. It also revealed the preference of modality in order to communicate with the passengers, where most of the participants picked a multi-modal approach, with visual and auditory modality have higher preference.

Overall, studies conducted uncovered the importance of *situational awareness* and knowing the *intentions* of the SAV contributing to developing trust.

In conclusion, this thesis project contributed in: a) defining trust from the passenger's perspective, b) identifying key factors that affect passenger's trust, c) highlighting which modalities are most preferred to create trust in passengers. And altogether, qualitative evidence signifying the effect of communication between an SAV and its passengers to positively influence trust.

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Appendix A

A Field studies

A.1 EZ10 - Barkarby, Stockholm

A.1.1 Route

The route taken by the SAVs operating in Barkarby[16], Stockholm as seen in figure A.1.

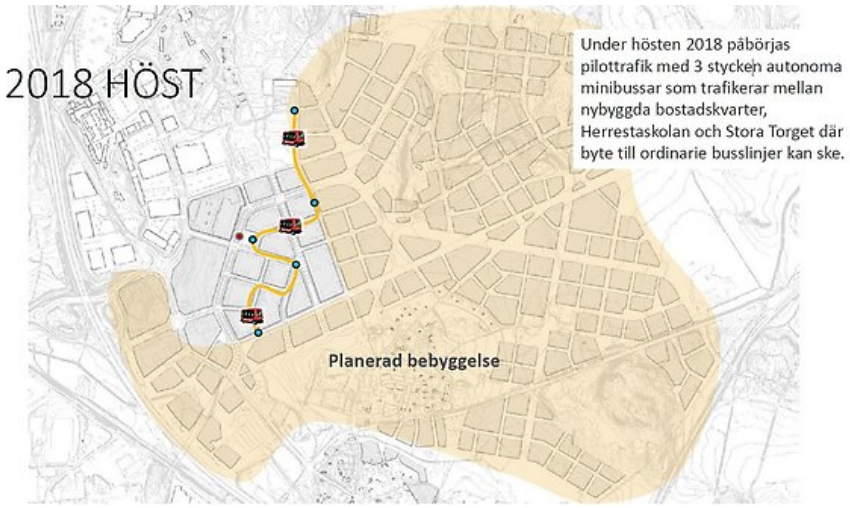

Figure A.1: EZ10 - Barkarby SAV route. Graphic by Järfälla municipality.

A.1.2 Interview questions

Operator

1. What's the passenger's reaction when they ride the SAV?
2. How does the communication between the passengers and the SAV work?
   (a) Do the passengers communicate with the steward on board?
   (b) Do you communicate with pedestrians and other vehicles?
3. Do the passengers feel safe riding the SAV?
4. Do the passengers express their trust in the SAV?

[16]http://www.barkarbystaden.se/ Accessed: 2019-09-12

5. What do passengers do in unexpected situations?
6. What do you, as the steward do in such situations?
7. Do you explain what happened, to the passengers?

Passenger

1. How do you feel riding the SAV?
2. Do you trust the SAV taking you from point A to B?
   (a) What is trust to you when commuting?
3. Do you feel the need to know what the SAV is doing during your commute?
   (a) What's most important to know?
   (b) Do you have a preferred way of knowing such information?
4. Do you feel safe riding the SAV?
5. Do you trust the steward on-board?
6. Would you ride this SAV if there was no steward on-board?
7. How often do you commute using this SAV?

A.2 Bus 50 - Stockholm city

A.2.1 Interview questions

1. How would you define trust?
2. How often would you say you communicate with the driver of the bus for information?
   (a) What kind of information is important to you?
   (b) Do you trust the driver of the bus?
3. Would be willing to use the same bus if it were driver-less?
4. What would make you trust such a vehicle more?