IMPACT OF HMI ON DRIVER TRUST FOR LEVEL 4 AUTONOMOUS DRIVE LONG HAULAGE TRUCKS

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AYÇA ODABAŞI UYANIK

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The thesis of Ayça Odabaşı Uyanık,

has been approved by:

____

Jury Member

(Thesis Advisor)

____

Jury Member

____

Jury Member

(External Member)

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To my dear husband Eren and our lovely son Teoman....

ABSTRACT

While the technological advancements in Level 4 autonomous drive trucks, which can drive by themselves under limited conditions, are being communicated as a way forward to increase road safety, as well as to improve working conditions and provide relaxation to long haulage drivers onboard, it is important to understand the user acceptance factors so that this technology can provide the expected benefits. This study focuses on one of the user acceptance factors, i.e., trust of the drivers. The goal is to study the effect of Human Machine Interface (HMI) screen elements in supporting trust for Level 4 autonomous drive systems for long haulage trucks. Semi-structured interviews were conducted with 12 truck drivers to understand the current status of drivers' trust, to identify drive maneuver instances where trust needs to be supported, and to develop an in-depth understanding of trust support via HMI screen elements for status and information share. Paper prototypes of HMI screen design proposals were used as probe materials during the interviews and discussed from trust build up perspective towards autonomous drive technology perspective. Interview questions and drive maneuver instances for further investigation were defined based on a preliminary trust questionnaire that was administered to 9 participants. Autonomous drive technology trust constructs that were used during the interview and in the questionnaire were defined through literature reviews in psychology and human machine interaction. Results show that main driver of trust to Level 4 autonomous trucks relies with driver experience with system competency, but it is not enough on its own. HMI screen elements are important for drivers throughout the trip. They become especially important to support feeling of reliability to autonomous system under changing weather conditions and feeling of safety during autonomous drive maneuvers through transparent status and information sharing. HMI screens can build up confidence by providing adequate solutions to watch over the road and other vehicles in autonomous driving mode. Findings from this study indicate that it is a dramatic change for long haulage truck drivers to hand over the drive to an autonomous drive system for extended durations. Considering the critical drive decisions they give during the journey for situation management, strictly following a zero-risk driving characteristic and continuously considering what could go wrong, HMI screen element designs can facilitate transparency of autonomous drive system, support trust and accelerate this transition period from current truck technology to autonomous drive trucks and assist with technology acceptance.

ÖZET

Uzun yol çekicileri için geliştirilmekte olan ve sınırlı parkurlarda sürücü müdahelesine ve gözlemine gerek olmadan gidebilen Seviye 4 otonom sürüş sistemlerinin, yol güvenliğini arttırması, çekici sürücülerinin çalışma şartlarını iyileştirmesi ve yolculuk esnasında dinlenmelerine imkan tanıması gibi faydaları olacağı beklenmektedir. Sistemin teknik geliştirme çalışmalarına paralel olarak çekici sürücülerinin otonom sürüş teknolojisini kabul etmelerindeki faktörleri ve özellikle bu teknolojiye duydukları güveni kullanıcı odaklı tasarım geliştirme bakış açısıyla incelemek, bu teknolojinin sürücülerinin çalışma ve yaşam şartlarına adaptasyonu açısından önemlidir.

Araştırmanın amacı çekici araçların kabin içindeki ekran arayüz içerik tasarımının Seviye 4 otonom sürüş sistemi teknolojisine olan güveni sağlamaktaki etkisini değerlendirmektir. Çekici sürücülerinin mevcut durumda bu teknolojiye duydukları güven durumunu anlamak ve otonom sistem durumu ve bilgi paylaşımına dair ekran arayüz içerik tasarımlarının güven duygusunu nasıl desteklediğini irdelemek için 12 çekici sürücüsü ile görüşmeler yapılmıştır. Kağıt prototipler şeklinde hazırlanan ekran içerik arayüz tasarım önerileri sürücülerinin incelemesine sunulmuş, toplanan bilgilerle çekiciler özelinde Seviye 4 otonom sürüş sistemine olan güvene olumlu etkileri tartışılmıştır. Görüşme sorularının hazırlanması ve hangi sürüş manevralarının görüşmeye dahil edileceğinin belirlenmesi amacıyla bir ön anket hazırlanmış ve 9 sürücüye dağıtılmıştır. Görüşme ve ankette yer verilen otonom sürüşe dair güven olgusunu etkileyen faktörler hem psikoloji dalında, hem de makina-insan arayüzü alanlarında literatür incelemesi yapılarak tespit edilmiştir. Elde edilen bilgiler ışığında çekici sürücülerinin otonom sürüş sistemine

güvenmesinin aslen sistem yeterliliğinin tecrübe edilmesi ile oluşacağı, ama tek başına yeterli olmayacağı çıkarımına ulaşılmıştır. Ekran arayüz içerik tasarımlarının yolculuk boyunca güven duygusunun pekişmesinde önemli bir rolü olduğu, özellikle değişen hava koşullarında sistemin tutarlı bir sürüş sergileyeceğine, manevralar esnasında sistem durumu ve bilgi akışını şeffaf şekilde sağlayarak sürücülerin kendilerini emniyette hissetmelerine, yolu ve diğer araçları izleme ihtiyaçlarına doğru şekilde cevap vererek güven oluşumunu destekleyeceği görülmüştür. Çalışmada sürüşü devrederek uzun süreli otonom teknolojisini kullanarak seyahat etmenin çekici sürücüleri için büyük bir değişim olduğu anlaşılmıştır. Bugünkü yolculuklarında sürücülerin değişen şartlara göre pek çok durumsal kararlar verdikleri, seyir esnasında oluşabilecek tüm olumsuzlukları önden düşünerek sıfır risk ile bir sürüş profili sergilerdikleri bilgisi ışığında, sistem durumunu ve bilgi akışını şeffaf şekilde sağlayacak ekran arayüz içerik tasarımlarının otonom sürüş teknolojisinin benimsenmesini olumlu etkileyeceği sonucu elde edilmiştir.

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LIST OF ABBREVIATIONS

ABS: Anti-lock braking system

ADAS: Advanced Driving Assistance Systems LIDAR: Light Detection and Ranging

AI: Artificial intelligence

HMI: Human Machine Interaction

ATRI: The American Transportation Research Institute Critical Issues in the Trucking Industry

CTAM: Car Technology Acceptance Research Model

ESP: Electronic stability program

HCI: Human Computer Interaction

NHTSA: U.S. Department of Transportation National Highway Traffic Safety Administration

Rpm: Revolution per minute

SAE: Standards of Automotive Engineering

TAM: Technology Acceptance Model

TCS: Traction Control System

TOR: Take over request

UTAUT: Unified Theory of Acceptance and Use of Technology

CHAPTER 1
INTRODUCTION

Studies in the development of autonomous driving technologies are progressing. By taking on board a smart co-driver via technology, Beiker (2012) indicated potential improvements mainly in road traffic safety.

Traffic road safety is solely not the only factor in the consideration of technology advancement in autonomous driving systems. With a grow in e-commerce industry and increasing customer demand for fast delivery of goods, overall efficiency for route optimizations, increasing number of operation hours, and reducing the amount of time spent on the road with empty trailers is a need in trucking industry (Dawkins & Gundogdu, 2021), as well as reduction in greenhouse gas emissions as dictated by recent emission regulations (United States Environmental Protection Agency, 2022).

From the truck drivers' perspective, a contextual study performed by Trösterer et al. (2017) reported that autonomous drive systems are expected to be effective in reducing driving stress overall, increase the popularity of being a truck driver with the use of this technology, allow drivers to perform other tasks during the journey and decrease the driver turnover rate. With a similar perspective, Richardson et al. (2017) listed the potentials of autonomous driving technology as increased comfort in drivers' working conditions alongside with safety and economical efficiencies such as maximized fuel consumption efficiency.

To achieve the expected benefits, it is an important matter to understand the user acceptance aspects of autonomous driving technology for long haulage trucks

(Dawkins & Gundogdu, 2021). Despite the advantages listed above, there are some concerns regarding autonomous driver technology implementation for trucks both from drivers' and fleet owners' perspective. Loss of driving pleasure, uneasiness with feeling of being redundant, safety and reliability issues, and legal liability issues are some of the highlights listed in Richardson et al.'s study (2017). Since the driver is not likely to be in charge of a full driving task with the introduction of this technology, Trösterer et al.'s report (2017) highlighted possible issues such as; need for extensive work for legal regulation adjustments, loss of social contact platforms for the drivers, reliability of the technology, a fear towards malfunction, need for special training to be able to interact with the system, a need for full level of concentration build up when the driver takes back the driving task and overall trust build up to the technology.

Truck driving is an activity that takes place in a quite complicated context, therefore before a full autonomous truck is launched there is considerable amount of work that needs to be done. The multi-functional role of drivers, acting as logistics planner, load lasher, on-road maintenance provider, and the custodian of the loaded goods in addition to the conventional driving task brings along additional rationales to consider for the continuation of driver presence in high and full autonomous systems. Therefore, it is possible to say that expected benefits of long haulage truck autonomous driving can flourish only with careful consideration of technology acceptance requirements deemed by drivers and with achievement of driver and autonomous system working as a team and collaborating to complete the journey together.

To achieve a successful and smooth journey by collaboration between drivers and autonomous driving systems, previous studies (Choi & Yong, 2015; Trösterer at al., 2017; Shahrdar et al., 2018) defined trust as the key factor and focused on related trust factors.

It is seen that previous studies for trust towards autonomous trucks are rather limited compared to cars. Despite past analytical studies with special focus on trust factors for autonomous cars, comparably small number of autonomous truck literature studies adopted a rather broad approach for technology acceptance (e.g., Fröhlich et al., 2018; Richardson et al. 2015). To create a contribution, this study aims to provide a trust factor specific approach towards autonomous drive technology acceptance for long haulage trucks.

While several vehicle systems contribute to trust, this study only explores human-machine interface (HMI) system. On-board HMI devices play a significant role for building driver's trust as they are the main platforms through which drivers and autonomous driving systems interact (François et al., 2019) and information share occurs. For this reason, the goal of this thesis is to define the impact of HMI screen elements and transparent information share in trust build up towards high autonomous long haulage trucks and answer the following research questions:

- What are the set of parameters to measure trust towards High Autonomous Long Haulage Trucks?
- How does HMI screen elements for system status and information share contribute to driver trust in High Autonomous Long Haulage Trucks?

- What are critical drive maneuver instances that require further trust support with HMI designs?
- If and how the drivers' preferences on HMI screen elements would change from traditional long haulage trucks to autonomous drive long haulage trucks from trust perspective?

1.1 Scope

In order to answer the research questions, the study in this thesis takes a qualitative approach. Considering the different levels of autonomous driving technology as defined by SAE International (2021), this study focuses on Level 4 autonomous trucks. This level of autonomous driving technology was selected because of its high potential for near future implementations. Level 0 to Level 2 systems provide features that support the driver therefore they are not considered as automated driving. In comparison to Level 4, Level 3 systems have the downside of frequent driver take over needs and Level 5 systems have considerable amount of road infrastructure, regulation, and testing validation needs. Level 4 autonomous trucks are self-driving trucks with no need of driver take over since they operate under rather limited road conditions such as in geo-fenced routes, therefore more likely to be regulated and offered as upcoming technology.

Initially, a literature review was conducted on truck driving and road safety issues. Then autonomous drive technology, technology acceptance models and role of trust studied. Informed with studies on user acceptance and trust from the fields of psychology and human machine interaction, trust related parameters are identified, and a preliminary trust questionnaire was administered. Through the findings of trust questionnaire, interviews are conducted to address trust lacking drive maneuver instances and if HMI screen element designs can provide positive support to drivers' trust towards autonomous driving technology (Figure 1.1).

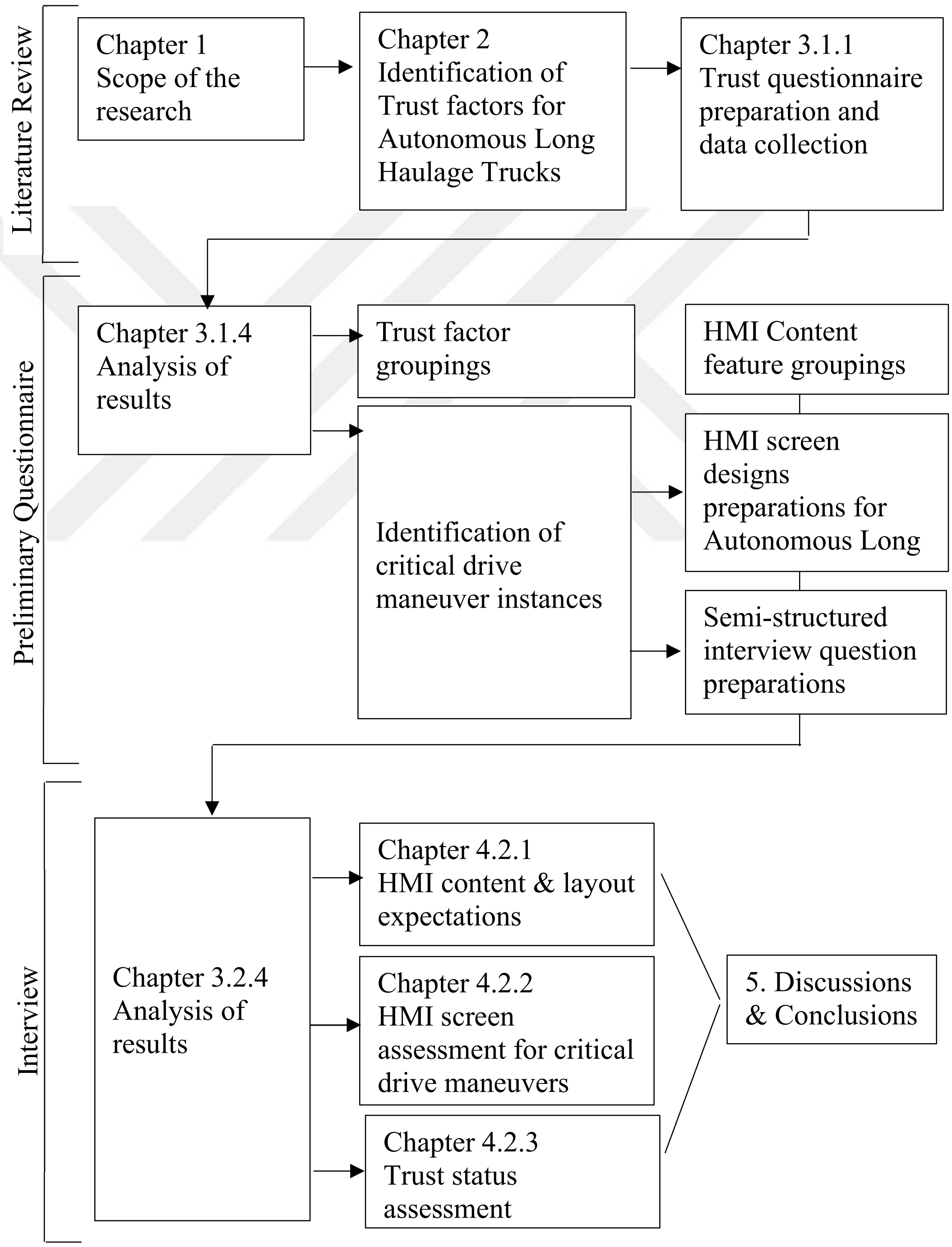


Figure 1.1: Research design

CHAPTER 2
LITERATURE REVIEW

2.1 The Literature Review Flow

The literature review conducted for this research initially started with identification of trucking issues in the industry (e.g., ATRI, 2019) and contextual studies performed by Trösterer et al. (2017) and Richardson et al. (2017) to link how and to what potential autonomous drive technology can address these issues. With a focus on technology acceptance models referred in Choi and Yong (2015), Venkatesh et al. (2013), and Osswad et al. (2012) relevant references are followed particularly for identification of trust factors towards autonomous systems and measurement of trust. Since the thesis study aims to contribute to literature from trust towards autonomous long haulage trucks perspective, references from trust measurement articles as listed in Table 2.1 are followed to propose additional trust factors from psychology (Abdul-Rahman & Hailes (2000); Robbins (2016); Leimeister et al. (2014); Lyons (2013)) and extend trust factors listed in Jian et al. (2000)'s study.

2.2 Current State Analysis of Trucking

According to The American Transportation Research Institute Critical Issues in the Trucking Industry Survey (ATRI, 2019), which was conducted with quantitative methodology with 2,119 participants - composed of truck carrier drivers (% 35.3), carrier fleet companies (%51,1) and rest from other stakeholders - top three operational challenges experienced in trucking industry were listed as driver shortage, hours of service and driver compensation and the findings are displayed in the Figure 2.1. The survey results showed that driver shortage and hours of service issues have been in the highest-ranking position for three and nine consecutive years, respectively. ATRI survey indicated that driver shortage is an issue particularly for long haulage trucking, where trip durations in the delivery of goods are typically long. Regarding the hours of service, survey results described the issue being driven mainly by inflexible working conditions where drivers are unable to adjust driving times based neither on their rest needs nor traffic congestions (ATRI, 2019). In addition to ATRI (2019) report, studies performed by Trösterer et al. (2017) and Sullman et al. (2002) listed common issues of truck drivers mainly as safety, loose of concentration during drive activity and being tired because of long trips. These findings about driver fatigue and road safety issues are supported by data from Transportation National Highway Traffic Safety Administration statics (NHTSA, 2022) under section 2.3.

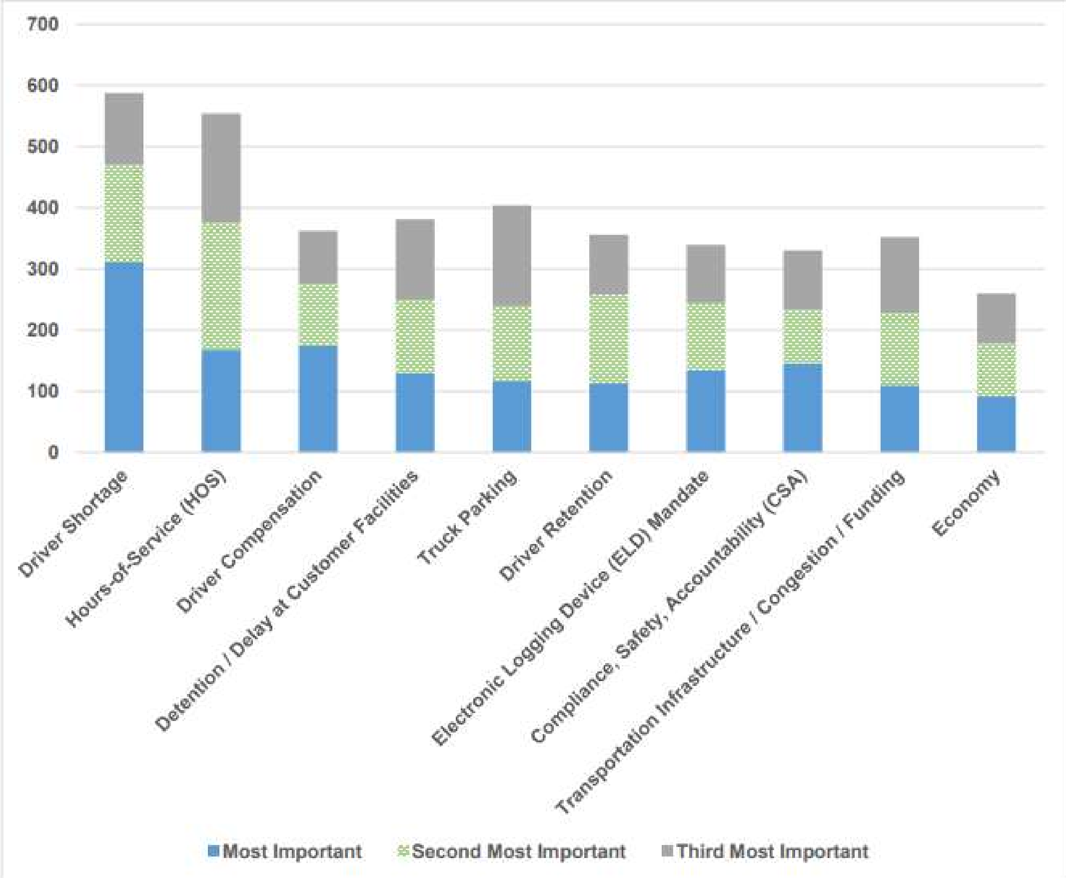


Figure 2.1: Trucking industry issue prioritization scores (ATRI, 2019, p. 7)

2.3 Road Traffic Safety Issues

Transportation National Highway Traffic Safety Administration (NHTSA, 2022) reports showed that driver involvement is high in crashes. The content analysis on NHTSA (2022) reports listed under Appendix 1 highlighted that the number of average fatal crashes was 32.044 per year between 2010 and 2019 (Table A1.1) and average number of driver involvement per year in these crashes was 48.073 (Table A1.2) in United States. This analysis indicates that the majority of the crashes involved multiple drivers in a fatal accident, drawing an attention to driver performance. Related factors for driver involvement in fatal crashes between the years 2010 and 2019 were studied, by grouping them under two headings such as driver behavior related and all others in Table A1.3. Although more than one factor may be listed for the same driver, analysis showed that majority of the factors are indicating a driver behavior fault for fatal crashes. Similar information was found in Hendricks' (1999) article, stating that for 99% of the crashes out of 723 crashes occurred within the years of 1996 to 1997, there was a driver behavior fault involved. Therefore, with acceptance and usage of autonomous drive technology in the society, a reduction of driver faults and improvement of road traffic safety is rationally expected.

NHTSA (2022) reports separated statistics for long haulage trucks, trucks with gross vehicle weight exceeding 15 ton, for fatal crashes. The analysis of fatality rates involving long haulage trucks between 2010 and 2019 showed an annual average of 4.198, which was 13% of total fatal crashes in average (Table A1.4) and the trend is increasing every year. (Table A1.5). Due to large weight and size of the long haulage trucks, crashes are quite severe, and consequences are expensive to cover. With an additional perspective on less severe cases, accidents with property damages only, truck owners are faced with challenges like getting the truck repaired, coping with the loss of secondhand value, and trying to compensate the loss for downtimes. Therefore, it can be interpreted that there is an increasing interest towards additional in-vehicle safety features, advanced driver assistance systems and autonomous driving technology in trucking business (Dawkins & Gundogdu, 2021).

2.4 Description of Autonomous Driving Technology Levels

With recent technology progress and onboarding of advanced driver assistance systems in transportation industry, SAE International (2021) defined multiple autonomous driving levels, ranging from Level0 to Level 5. According to SAE International definitions, Level 0 to Level 2 systems provide driving assistance with features listed in Figure 2.2 and drivers perform driving tasks, monitor system drive performance as well as the road during the trip. Level 3 to Level 4 autonomous systems use remote and ultrasonic sensors, multi-stream cameras, radar systems, a LIDAR (light detection and ranging) system and control unit systems to be able to perform the driving task under limited conditions, such as in geo-fenced routes or under certain speed limits.

Although drivers do not have to monitor the road or vehicle controls in a continuous manner in a Level 3 system, they can be asked to take-over the driving task when the journey extends beyond geo-fenced areas or when there is a system failure. This take over request should be realized by the driver within a specified time duration (SAE International, 2021). According to SAE International description for Level 4, autonomous system is capable to perform a safe stop maneuver when the operating conditions do not meet autonomous driving requirements, therefore a Level 4 system removes the need for a take-over request in a specified time window when compared with a Level 3 system. A Level 5 system is the most advanced autonomous technology among all SAE International levels, where there is no need for a driver to complete a journey, regardless of road and environmental conditions. However, a Level 5 autonomous technology needs advanced technical system developments, such as a complete renewal of road infrastructure as well as redefinition of traffic regulations. When considering Level 5 autonomy, other tasks and responsibilities of the driver such as logistics planner, load lasher, on-road maintenance provider, custodian of the loaded goods and main decision maker for critical maneuvers still remains unanswered for the time being.

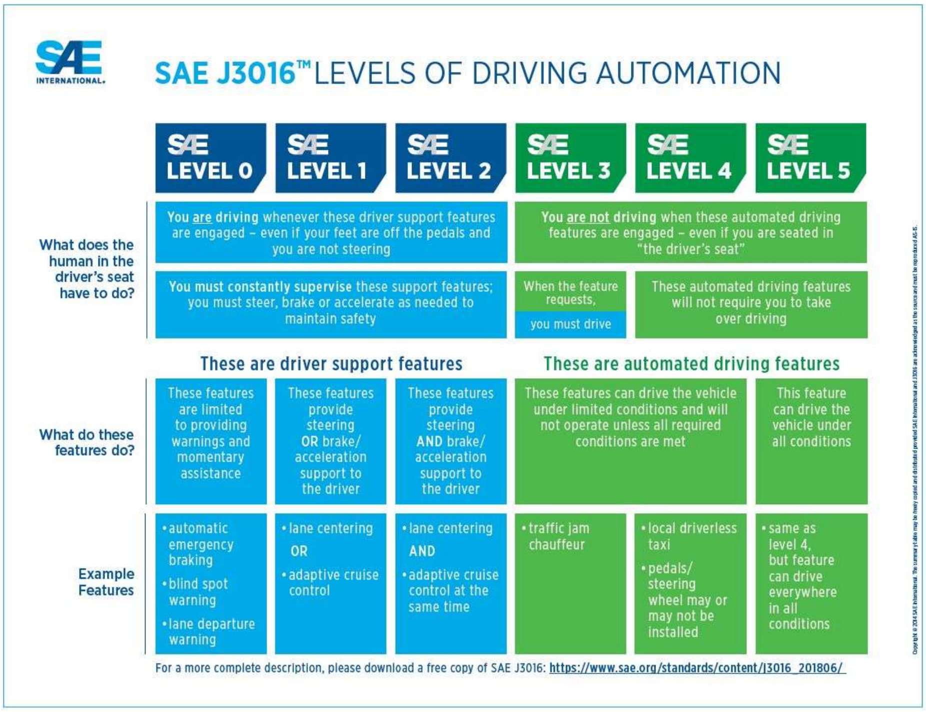


Figure 2.2: Levels of driving automation (SAE International, 2021)

When the desired improvements, such as improved road traffic safety, fast delivery of goods, overall efficiency for route optimizations, increased number of operation hours, reduction in driving with empty trailers and decreased greenhouse gas emissions are considered (Dawkins & Gundogdu, 2021), Level 4 autonomous drive systems are more promising when compared to Level 3 systems, based on two studies performed by Louw et al. (2015) and Van den Beukel et al. (2018)**.** Driving tasks occur in complicated contexts and since the autonomous driving system is continuously receiving information about the vehicle, as well as the environment, a Level 3 system may require frequent driver take-overs. Louw et al. (2015) observed that taking back the driving task upon a take-over request (TOR) from a Level 3 autonomous system resulted in drivers' extended reaction times, low situation awareness to environmental conditions, issues with instant stable lane keeping and unmodulated braking when compared to a continuous manual driving during the transition phase. In a study presented at 6th Humanist Conference in 2018, Van den Beukel et al. correlated the length of the transition time required for the driver to take over driving task in a safe mode with his level of engagement in a secondary activity.

Level 4 systems are advantageous over Level 3 systems in terms of driver take over requirements. Although a Level 4 autonomous system requires road infrastructure developments, it is still less compared to Level 5 system. Therefore, when compared with a Level 3 and a Level 5 system, Level 4 autonomous driving has a higher potential for the safety and efficiency benefits that can soon be realized, therefore, this thesis study is focused on Level 4 autonomous driving technology.

2.5 Autonomous Driving Trucks and Driver Interaction

It is an important matter to study the interaction between drivers and autonomous drive trucks. When the complex nature of truck driving is considered, it is important to investigate not only the driving task itself but also other responsibilities and liabilities of the driver, such as but not limited to, route planning, on-road maintenance, and security of goods in transportation. Autonomous driving technology is an artificial intelligence (AI) algorithm in essence and there are studies regarding the interactions between the driver and the smart system. The scope of these studies were mainly related with safety (Van den Beukel et al., 2018; Brandenburg & Epple, 2018; Debernard et al., 2016; Krupenia & Selmarker, 2014). For safe driving task transitions between autonomous drive systems and drivers, Van den Beukel et al. (2018) investigated the conditions through which a safe hand over to a driver can occur in Level 3 autonomous systems. Brandenburg and Epple (2018) studied the preferred modalities, procedure and presentation in the design of takeover requests for Level 3 and above autonomous drive levels. Regarding situation awareness of drivers, Debernard et al. (2016) studied on HMI designs to create the right level of in-truck and environmental awareness for safety. Krupenia and Selmarker (2014) worked on a methodology development project for measuring and improving drivers' mental model of the autonomous vehicle through sound and visual information interfaces so that drivers' supervision and controller roles were supported during the journey. Regarding the interfaces of the driver and the autonomous truck, Fröhlich et al. (2018) made a study on the willingness of drivers to accept autonomous truck cab as a future workplace and factors related to acceptance, so that future system designs can consider these interactions. Richardson et al. (2015) investigated how future autonomous driving truck can be adjusted to allow physical exercise interactions to improve fitness conditions of the drivers. Another study conducted by Nordenson and Winberg (2018) focused on the definition of potential new roles for drivers with introduction of autonomous drive systems and development of an ideal truck cab interior design for a drive pattern on a highway ring operation. The goal of studying interactions between truck drivers and autonomous driving systems is important in identifying user acceptance aspects for the technology. Only with relevant and valid user acceptance aspects information analysis, it may be possible to support the development phases of autonomous driving technology and achieve the desired benefits with its active use in long haulage trucks (Dawkins & Gundogdu, 2021).

2.6 Technology Acceptance Model (TAM)

Information technology has been one of the pioneer areas where the acceptance of a new technology is continuously being studied deeply, as human performance is enhanced in great magnitude with use of computer systems. For a complete understanding of user behavior intention towards acceptance for a new technological system Davis (1989) tested the effect of two independent variables, namely perceived usefulness and perceived ease of use, on information technology acceptance.

Perceived usefulness can be described as the belief of the user that using a particular technology will excel his capability and perceived ease of use can be described as easy use of the system not requiring too much effort. Davis’s study (1989), conducted for user acceptance on computers, reported strong positive findings regarding these two variables and technology acceptance. He named the study as Technology Acceptance Model Theory (TAM) and recommended considering other variables such as intrinsic motivation, beliefs, and attitudes for user acceptance intention as future work.

Since autonomous driving context is very different to information technology and user interaction cases, pure usage of TAM may be limiting. Therefore, literature review in this thesis shifted to focus more on extended versions of TAM, which are more comprehensive to cover driver, vehicle, and autonomous technology interfaces. Two versions of extended TAM theory, which are called Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2013) and Car Technology Acceptance Research Model (CTAM) (Osswad et al., 2012), included further variables in addition to perceived usefulness and perceived ease of use. The studies of Venkatesh et al. (2013) and Osswald et al. (2012) considered social influence, anxiety, facilitating conditions, ease of use, socio demographic factors, self-efficiency, perceived safety, and performance expectations as factors that affect drivers' acceptance for autonomous vehicles. In a study, Fröhlich et al. (2018) specifically worked on high autonomous driving trucks, and acceptance of these trucks as future workplaces using extended TAM theory approach. In their paper, correlations of constructs such as usefulness, ease of use, attitude, personal characteristics, and trust were tested with acceptance of highly automated truck as a future workplace. The outcome report of their questionnaire survey indicated the presence of a correlation between autonomous truck acceptance as a workspace and the following constructs: ease of use, usefulness, suitability, positive expectations, negative expectations (negative correlation), technology openness and trust. With the use of extended TAM theory approach for autonomous driving technology, Fröhlich et al. (2018) was able to identify factors that affect drivers' acceptance for autonomous technology in trucks that would allow them to work, engage in secondary activities or rest.

In another study performed by Choi and Yong (2015) about investigating the acceptance factors for autonomous technology, extended TAM theory approach was used again, with further constructs added to Fröhlich et al. (2018) study, such as perceived risk, locus of control and sensation seeking. This research was not specific for truck drivers and possibly refers to car drivers (not clearly mentioned in the paper), however, in addition to defining more diverse set of constructs for acceptance, it included subdivision dimensions for trust: system transparency, technical competence and situation management. The conclusion part, composed on the analysis of questionnaire surveys, displayed a correlation between acceptance of autonomous technology and variables such as perceived usefulness, perceived ease of use, external locus of control and the three trust dimensions: system transparency, technical competence, and situation management.

Although studies of Fröhlich et al. (2018) and Choi and Yong (2015) slightly differed in terms of focus points of the acceptance of autonomous technology, former in a truck specific environment and latter in a more general vehicle environment, there were commonalities among the variables identified for acceptance of technology. In both studies, it was seen that acceptance of autonomous drive technology is affected by two variables, perceived usefulness and ease of use, as previously identified in TAM theory. The other common variable between Fröhlich et al. (2018) and Choi and Yong (2015)'s studies was trust.

One of the reasons why trust came forward as an outcome in these studies can be explained in reference to Giddens's book, The Consequences of Modernity (1990). He explained trust as a cognitive process that operates under uncertainty of conditions and the outcome. Under full transparent operation conditions, there is no obvious need to develop trust to another party, as the thought process and act planning would be highly visible. Autonomous driving technology, in essence, is run by AI, which is using machine-learning algorithms through data (Bergstorm, 2020). In an environment where a person travelling in an autonomous vehicle does not have the full information on what data feed had occurred, through which processes, and how the algorithm learns and decides how to act, it is a rational expectation that trust would be a factor to affect acceptance of autonomous technology and is proposed to be highly important.

2.7 Trust

Trust can be conceptualized in many ways, which makes it difficult to cover under single explanation. However, it is possible to state that trust is a process triggered under a degree of uncertainty in the lack of knowledge how the other party will act (Leimeister at al., 2014). To understand the contributors of trust and the trust build up process for the autonomous vehicle technology acceptance, trust categorizations were reviewed in psychology.

According to Abdul-Rahman and Hailes (2000), trust was categorized as, interpersonal, system and dispositional trust. Interpersonal trust is the outcome of the assessment of the truster agent to a trustee agent for a specific task. According to Robbins (2016), the assessment variables were grouped under four main titles: competence in the context, motivation for commitment, exertion, and past experience.

System trust approach is more a built-in trust approach, for a functioning system, division, or similar group identity in which the general operations do include a trust to function (Leimeister et al., 2014). This approach is in coherence with a teamwork model (Lyons, 2013), where in a framework of work division, responsibilities were defined and made visible for clear understanding among group identities. Lyons (2013) said that with the help of this process visibility and understanding of the roles and responsibilities, parties in the organization can make forecast and predict other group actions.

Dispositional trust is independent of the agents and roles above and describes the general perspective and belief in trust (Robbins, 2016). This category of trust was defined to include impressions, reputations, past experiences with similar situations or context and Ekman et al. (2018a) stated that trust formulates even before a relation, or an interaction is established.

Trust, as a concept, is studied for many human and computer interaction areas (HCI). To name a few, Schaefer (2013)'s study about human to robot trust, considered interpersonal trust and automation trust simultaneously, and identified specific trust factors such as competence, reliability, predictability, dependability towards robots. With use of these trust factors, trust measurement scale was developed through experimental methods and recommended to be used in the subjective measurement of trust. Smart home devices and trust towards these devices from privacy perspective is another related area where, trust concept was undertaken for human computer interactions (Zheng et al., 2018). Structured interview methods were applied in Zheng's study to identify what were the participant priorities for these devices and the sensitivity that relies with trust towards the data privacy. Results showed that usefulness and device connectivity are valued the most and trust towards device manufacturers are key for perceived protection of privacy data, indicating system competence and impressions are related trust factors (Zheng et al., 2018).

Regarding trust towards autonomous drive systems, Kyriakidis et al. (2015), through a research study with 5000 participants, suggested that perceived safety was a high priority item in trust to autonomous driving systems. A similar outcome was reported in Carlson et al.'s study (2014), performed for autonomous vehicles and autonomous diagnostic systems, that participants gave a high priority to safety of the system, considering the dynamic nature of driving.

Considering these previous studies for HCI and autonomous drive technologies, it is proposed to combine interpersonal, system and dispositional trust variables with trust variables in the literature for HMI as described by Lee and Moray (1992) and include perceived safety, with a translation of these terms for autonomous trucks:

- Competence in context: System competence
- Motivation for commitment: System intention
- Commitment in exertion: System integrity
- Past experience: Reliability (also to include past trials with similar systems)

- Teamwork - process visibility: Predictability
- Impressions: Expectations
- Perceived safety

There are previous studies regarding interpersonal, system and dispositional trust approach towards autonomous drive technology, with an analytical analysis of trust factors (Choi & Yong, 2015) for cars. Long haulage trucking is a commercial transportation activity and comes with different operation conditions, responsibilities, motivations, and priorities when compared to driving cars. These contextual differences, which were captured in detail in Trösterer et al.'s (2017) research, raise a necessity to re-study the trust dimensions specifically for autonomous trucks. Fröhlich et al.'s (2018) study was focused on a truck specific context for acceptability of performing secondary activities during autonomous drive; however, this study did not approach the technology acceptance model with a deep multi-dimensional trust factor perspective. Current study aims to contribute to the literature by filling this gap.

2.8 Trust Measurement

When previous works performed in measuring trust towards autonomous driving vehicles were studied, it is seen that various methodologies were used.

Choi and Yong (2015) studied the factors that drive people to trust an autonomous vehicle and performed a survey with 552 participants. They applied quantitative data analysis on survey results to measure general trust construct, and trust sub-constructs (system transparency, technical competence, and situation management).

Ekman et al. (2018a), in their research for defining a framework for HMI design, worked on performance (what), purpose (why), process (how) and general perception as factors effecting trust. They used qualitative field research methodology and performed interviews about trust to system with participants who experienced specific events during a Level 3 autonomous driving mode.
Ekman et al. (2018b) used quantitative and qualitative methods simultaneously in their study to measure trust to autonomous driving systems during and after an autonomous drive. In their study with 18 participants, an autonomous driving environment set up was created using Wizard of Oz technique. During the drive, quantitative data was collected for event specific level of trust alongside with think-aloud sessions to capture affective responses. After the drive, a survey was used to collect general trust ratings on a Likert scale (Jian et al., 2000) and a trust curve was plotted over time. In depth interviews with the participants were performed using the trust curve plot as a discussion material. Ekman (2018b) explained the reasoning behind using mixed methodology as the need to access rich data for a better understanding of trust.

Walker et al. (2018) worked on creating an objective and a real time indicator for measurement of trust to autonomous driving technology. With the aid of using a driving simulator, 30 participants' gaze duration on a secondary task were collected during autonomous drive and they were also asked to fill in a trust questionnaire on a 1 to 7 Likert scale (Jian et al., 2000). Walker et al. concluded their study by stating that gaze durations correlated with trust survey results and could be used as real time objective measurement for trust to autonomous driving technology.

Uggirala et al. (2018) quantitatively measured the uncertainty of an autonomous system and showed its correlation to general trust, and trust subdivisions (competence, reliability, predictability, faith) and for measuring trust, used a 1-7 Likert scale trust questionnaire.

Helldin at al. (2013), in their study tested the effect of presenting autonomous system uncertainty information on trust by using mixed methods. They used a driving simulator to collect quantitative data about the look away times, the characteristics of the maneuvers performed (steering wheel angles and applied break forces) and utilized Jian et al.'s (2000) 1 to 7 Likert scale trust questionnaire.

In Carlson et al.'s (2014) study, they aimed to identify the factors that affect trust to autonomous driving cars and automated diagnosis for medical applications for safety critical and brand dimensions. They used survey method to collect data on the ranking of 30 factors that were identified by literature research regarding trust. The research concluded that there could be a central model for trust with specifics for different domains.

Payre and Delhomme (2015) in their study concentrated to understand how manual control recovery in a high autonomous vehicle was affected from factors such as trust, training, and practice. Manual control recovery times were measured in seconds and the level of contextual acceptance of autonomous driving and trust were collected using 1-7 Likert scale questionnaire surveys.

Based on the literature review performed on trust measurement, two outcomes were achieved. Firstly, it was seen that in most of the previous studies survey research, qualitative field research, and experiments were used together in measuring trust (Table 2.1).

Table 2.1: Summary of methods to measure trust

Reference	**Summary**	**Methodology**	**Topic of interest**
Choi and Yong (2015)	Investigate what factors drive people to trust autonomous drive technology.	Survey research	system transparency, technical competence and situation management correlations with trust
Ekman et al. (2018a)	Define a framework for HMI design to support trust to autonomous drive technology.	Qualitative field research	List of trust affecting factors
Ekman et al. (2018b)	Measure trust to autonomous driving systems	Survey and Qualitative field research	Cognitive trust development process to autonomous drive.
Walker et al. (2018)	Correlate gaze behavior with trust level to autonomous drive.	Experiment and Survey research via use of simulator	Objective and a real time indicator for trust measurement

Uggirala et al. (2018)	System uncertainty correlation with trust	Experiment and Survey research via use of simulator	Driver interventions with autonomous system
Helldin et al. (2013)	Identify the effect of presenting system uncertainty information on driver trust	Experiment and Survey research via use of simulator	Presentation of system uncertainty information to the driver
Payre and Delhomme (2015)	Investigate the effect of elaborative practice and trust on emergency manual control take over	Experiment and Survey research via use of simulator	Reaction time measurement for emergency manual control take over

Secondly, it is an interesting finding to see that most of trust questionnaires used in the literature refer to Jian et al. (2000)'s empirical study for developing a trust scale for automated systems. In Jian et al.'s (2000) study, various words to describe trust and distrust were collected initially, and then rated for their relatedness to trust and distrust by 120 participants. According to a paired comparison analysis performed on those ratings, 15 trust keywords and 15 distrust keywords were identified, and further clustering studies were done to group these words in terms of meaning similarity (Table 2.2). Jian et al.'s (2000) paper proposed to use these trust clusters, and called them as trust factors, to develop a trust measurement scale.

Table 2.2: List of 15 trust keywords and 15 distrust keywords with trust factor numbers for meaning similarity (Jian et al., 2000)

Trust Factor Number	**Distrust Related 15 words**	**Trust Factor Number**	**Trust Related 15 Words**
1	Deception	6	Assurance
	Lie		Confidence
	Falsity	7	Security
	Betray	8	Honor
	Misleading		Integrity
	Phony	9	Fidelity
	Cheat		Loyalty
2	Sneaky	10	Honesty
	Steal		Promise
3	Mistrust		Reliability
	Suspicion		Trustworthy
	Distrust		Friendship
4	Beware		Love
5	Cruel	11	Entrust
	Harm	12	Familiarity

This thesis study put an effort to enrich Jian et al.'s (2000) trust measurement method with addition of further trust factors identified by literature review under section 2.7 towards autonomous drive vehicles, and added system competence, system intention, predictability, expectations and perceived safety. Reliability and process integrity already existed in Jian et al.'s (2000) trust factors list, therefore they were not included as additional (Table 2.3).

Table 2.3: Additional trust factors and their trust factor numbers

Trust Factor Number	**Trust Factor**
13	System Competence
14	System intention
15	Predictability
16	Expectations
17	Perceived safety

These 17 trust factors define a baseline for assessing driver's trust to AD long haulage trucks in this study, with a qualitative approach, rather than quantitative. To better frame the research, screen systems, such as the clusters and center screens that provide majority of information flow processes and create a medium for driver and truck interactions are selected as the focus area in trust analysis and possible impact of HMI screen elements on long haulage truck drivers' trust perceptions through trust factors listed in Tables 2.2 and 2.3 are studied.

CHAPTER 3
METHODOLOGY

To collect in-depth information about the impact of HMI screen elements on driver trust for Level 4 autonomous long haulage trucks, a qualitative interview study was conducted and supported by a preliminary quantitative trust questionnaire (Figure 3.1). The aim of the trust questionnaire was to inform the interview phase, arrive to an assertion about trust status of drivers towards autonomous long haulage trucks and identification of instances where drivers were lacking trust to the system. With the identification of further points to explore trust towards Level 4 autonomous drive trucks, in-depth interviews were conducted to understand how HMI screen element designs can positively impact driver's trust to the truck.

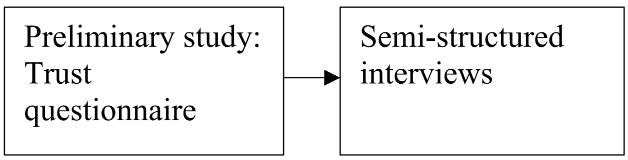


Figure 3.1: Research methodology

This research was approved by Ozyegin University's Institutional Review Board. All participants were given a consent form to sign prior to data collection.

3.1 Preliminary Study: Trust questionnaire

3.1.1 Research Instrument

The trust questionnaire was composed of 3 sections: 1. general belief questions about autonomous drive technology 2. questions that ask participant responses imagining that they are travelling with a Level 4 autonomous drive truck, and 3. driving routes, drive durations and demographic information questions for participants. Among total of 34 questions, there were 19 1-5 Likert scale, 4 open ended, 9 demographic, and 2 yes/no questions.

1-5 Likert scale, ranging from 1- Disagree to 5-Agree, was preferred over 1-7 Likert scale because the research subject is about a new technology which is not yet available for drivers use and a 1-5 scale resolution would be good enough to collect participant input with regard to this technology. The questionnaire was designed to include 17 trust factors, both from Jian et. al.'s (2000) trust factors (Table 2.2) and the additional trust factors defined for autonomous drive vehicles (Table 2.3). Each trust factor had a corresponding question, with use of keywords that would be meaningful for autonomous drive trucks. Trust Factor: 10 Reliability and 6 Confidence initially had one corresponding question for each as well. During initial test, these factors were modified to include two questions. Road conditions and weather conditions were included as separate questions for Trust Factor: 10 Reliability. In a similar manner Trust Factor: 6 Confidence question was also modified to include two individual questions for road watch over and system watch over respectively to collect more valid information from participants. Trust questionnaire question match to relevant trust factor can be seen in Table 3.1 where top keyword was selected to name the trust factors.

Table 3.1: Trust questionnaire questions match to trust factors

Trust Factor Number and Name	Trust- Distrust Keyword	Trust Questionnaire Question
1 Deception	Deception	I believe using autonomous system will deceive me.
	Lie	
	Falsity	
	Betray	
	Misleading	
	Phony	
	Cheat	
2 Sneaky	Sneaky	I feel that autonomous drive system is tracking me at the background even it is inactive.
	Steal	
3 Mistrust	Mistrust	I mistrust autonomous drive system.
	Suspicion	I would approach how autonomous drive system will act and why with suspicion.
	Distrust	
4 Beware	Beware	I need to be alert during autonomous drive mode.
5 Harm	Harm	Autonomous drive system maneuvers may create harmful results.
	Cruel	
6 Confidence	Confidence	I do not need to watch over the system maneuvers during autonomous drive mode.

		I do not need to watch over the road during autonomous drive mode.
	Assurance	
7 Security	Security	Autonomous drive technology will increase road safety.
8 Integrity	Integrity	Autonomous drive technology will take right maneuver decisions.
	Honor	
9 Fidelity	Fidelity	I can plan a shorter trip since I can take a rest during autonomous driving mode.
	Loyalty	I will be less tired since autonomous drive technology will support during the journey
10 Reliability	Reliability	Autonomous driving system will perform a consistent drive under changing road conditions.
		Autonomous driving system will perform a consistent drive under changing weather conditions.
	Promise	
	Honesty	
	Trustworthy	Do you think autonomous drive systems for long haulage trucks are trustworthy?
	Friendship	
	Love	
11 Entrust	Entrust	I can trust autonomous drive system on highway and hand over the drive.

12 Familiarity	Familiarity	I am familiar with autonomous drive technology.
13 System Competence	System competence	Autonomous drive long haulage trucks can successfully drive on highways.
14 System Intention	System intention	I can put a meaning to some of autonomous drive system maneuvers.
15 Predictability	Predictability	I can foresee autonomous drive system maneuver intention.
16 Expectation	Expectation	What would be your expectance from autonomous drive technology in long haulage trucks?
17 Perceived Safety	Perceived safety	I would feel safe during autonomous drive mode.

Other questions were designed to cover what the main use function of autonomous drive for long haulage trucks should be, what this technology should provide to develop driver trust, and from which sources participants learn about autonomous drive technology.

The questionnaire was prepared in Turkish, which was all participants' native language. The full questionnaire document is listed under Appendix 2.

3.1.2 Data Collection

The trust questionnaire was pretested with one truck driver to fix errors, if any. Although the questionnaire was initially prepared in Google forms as an on-line form, the pretest study showed that the participant was slow and uncomfortable in using the computer keyboard, so it was decided to use printed forms to be filled in ink for rest of the participants for their convenience.

During data collection, participants were informed about the goal of the research, followed by brief information share on what a Level 4 autonomous driving system is and what are its capabilities. To understand the participants initial trust perspective and trust expectations from autonomous driving, and to identify the critical conditions under which there is lack of trust, they filled in printed trust questionnaires. Filling out the trust questionnaire took 20 minutes in average per participant.

3.1.3 Participants

To increase the validity of the research, it is important to include participants who have a valid driving license to drive long haulage trucks, and actively perform long haulage truck driving. Participants were recruited from an international logistics company and a commercial vehicle manufacturer company, working on an autonomous drive truck design at the time of the study. A purposeful sampling was applied. Truck drivers with a valid long haulage truck driving license (C or CE class driving license) and who actively work as long haulage truck drivers were contacted. Participation was on voluntary basis and no incentive was given.

9 participants, all male, with an average age of 40, and holding a valid C or CE class driving license attended the research. In the time of the research, participants actively performed long haulage truck driving and their annual driving distance average was 91,000 kilometers. Majority of them drive for the complete duration of

daily and non-stop drive times allowed by traffic laws on highways. Table 3.2 shows the participant demographics.

Table 3.2: Participant demographics summary for trust questionnaire

Information	**Data**
Gender	9 (Male)
Age	6 (31-40), 2 (41-50), 1 (51-60)
Education graduate level	1 (Primary school), 2 (Middle school), 6 (High school)
License hold	4 (2-5 years), 1 (6-10 years), 2 (11-15 years), 2 (16+ years)
Annual driving km average	4 (40-80,000), 4 (81-120,000), 1 (120,000+)
Nonstop drive time	6 (4-5 hours), 3 (less than 4-5 hours)
Daily drive time	6 (9-10 hours), 3 (less than 9-10 hours
Driving route	6 (international), 2 (domestic highway), 1 (domestic), 1 (urban)

3.1.4 Data Analysis

While the initial plan was to collect more data, the data collection was interrupted with the Covid-19 pandemic lockdown precautions of the country the research was conducted in. At the same time, the participants' responses were not showing major differences. Therefore, the data collection stopped after the 9th participant.

All responses were transferred to an excel spreadsheet. Participant verbatims were carefully studied regarding main use function of autonomous drive technology, driver expectations and features that Level 4 autonomous drive truck must have to build trust. HMI content feature grouping were performed for responses to open ended questions. Additionally, 1-5 Likert scale trust questionnaire results were analyzed by descriptive statistics. Results were used to establish a detailed understanding of drivers' trust status towards autonomous long haulage trucks, and identification of instances where there was a lack of trust.

3.2 Semi-Structured Interview

Based on the insights from trust questionnaire regarding the areas to explore driver trust towards long haulage autonomous drive technology, semi-structured interviews were conducted. During the interviews, current technology cluster image, HMI image cards and HMI screen element design proposals in the form of paper prints were used as probe materials to collect insight from participants on how HMI screen element designs can positively impact driver trust.

3.2.1 Interview protocol

The semi-structured interview session was composed of 3 stages: 1. understanding the participants views on the most important features on current truck screens, 2. their expectations from a Level 4 autonomous truck HMI screen elements, 3. layout exercise and feedback on Level 4 autonomous truck HMI screen designs. Participants were initially provided a brief information on what a Level 4 autonomous driving system is and what are its capabilities. Then they were interviewed in a semi-structured manner to collect insight about current screen content they use more frequently and deem as important as well as their HMI screen expectances from a Level 4 autonomous truck. To probe discussion, they were given a current technology truck screen image (Figure 3.2), 18 HMI graphic cards (Figure 3.3) and an empty 74x21 cm white canvas, representing a screen size wide enough to allow touch and view interactions while seated in driver seat. The current technology screen image in Figure 3.2 was selected among others as it is from a truck brand that is commonly available in the logistics company fleet and participants are mostly familiar with. The design of 18 HMI graphic cards marked with * belong to same truck brand and others are uniquely designed by researcher for this thesis. These were purposefully used in the study to represent screen feature groupings for Level 4 autonomous drive trucks.

Figure 3.2: Current technology screen image. From *F-Max Kullanıcı El Kitabı*, by Ford Trucks, n.d. (https://www.fordtrucks.com.tr/Uploads/Documents/pdf/f-maxkullanicielkitabi.pdf)

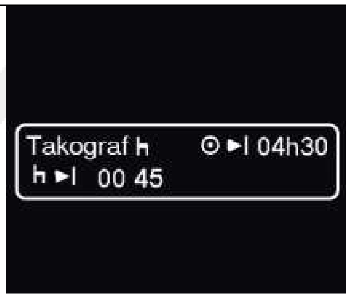
Consumption levels*

Vehicle schematic*

Tripometer*

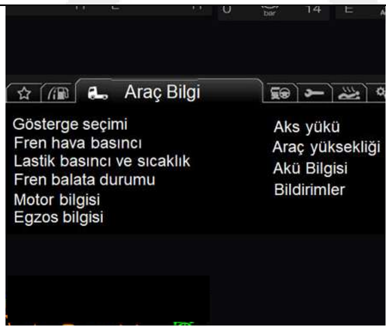
Speedometer*

Rest Break

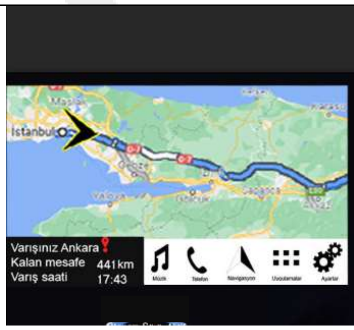


Tachograph

Malfunction indicators*



Vehicle Information*



Navigation*

Road Tracking

Vehicle sensors

Autonomous Drive active

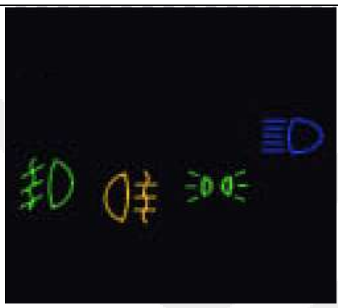
		
Weather Conditions*	Cruise Control*	Safe Driving Distance*
		
Exterior Lighting*	Rpm meter*	Vehicle Systems*

Figure 3.3: HMI graphic cards nomenclature. Note for * marked graphics: From *F-Max Kullanıcı El kitabı*, by Ford Trucks, n.d. (https://www.fordtrucks.com.tr/Uploads/Documents/pdf/f-maxkullanicielkitabi.pdf)

Participants were asked to review HMI graphic cards and comment on whether the graphics were sufficient to meet their expectations from a Level 4 autonomous truck HMI screen content. Then drivers were requested to place the graphic cards they deemed as necessary onto the canvas as tabletop layouts and asked to explain why they chose particular placements.

After photoshoot session of the layouts, interviews continued with participant assessments of 12 different HMI screen designs, which represented moments of screen interactions starting from drivers first entrance, handing over the drive to autonomous system and trust critical drive instances (Figure 3.4). The graphic designs of these screens are uniquely developed for this thesis and were used in this study as probe material to collect insight on the proposed content and layouts. The findings of Ekman et al. (2018a) were used as a guide for HMI screen designs, as their study related what effects trust during autonomous drive events and provided recommendations on what and how information should be shared.

The selection of the drive maneuvers creates the link between the first part of the research, trust questionnaire, and the second part, semi-structured interviews. Trust critical drive maneuver instances were selected based on the findings from the trust questionnaire to increase validity of the research for long haulage trucks. Finally, participants were asked whether they can trust Level 4 autonomous truck to rest or sleep during the journey, alongside with their further suggestions regarding HMI screen designs to positively impact trust. Participant demographic information were collected at the end of the interview. Complete set of semi-structured interview questions and HMI screen designs can be seen in Appendix 3.

Figure 3.4: One example of 12 HMI screen designs used as probe material.

3.2.2 Data Collection

The data collection took place in February 2022. All participants were interviewed individually. Interviews took place at a private room where the participants work. Interviews took from 45 to 60 minutes. All the sessions were audio recorded. Notes were also taken during interviews. Photo shootings were performed for the layout placements that participants performed with the use of HMI graphic cards they selected. Participation was on voluntary basis. Drivers were not given any incentives.

3.2.3 Participants

Participants were recruited from an international logistics company with specific approvals from the company operation manager. 12 male participants, with an average age of 44, and an average 20 years hold of C or CE class driving license attended the research. At the time of research, their annual driving distance average was 133,000 kilometers, and majority of them drove for the complete duration of daily and non-stop drive times allowed by traffic laws on highways. Table 3.3 shows the participant demographics.

Table 3.3: Participant demographics summary for semi-structured interview

Information	Data
Gender	12 (Male)
Age	1 (<30), 4 (31-40), 4 (41-50), 3 (51-60)
Education graduate level	2 (Primary school), 3 (Middle school), 4 (High school), 3 (University)
License hold	4 (6-10 years), 1 (11-15 years), 7 (16+ years)

Annual driving km average	7 (81-120,000), 5 (120,000+)
Non-stop drive time	11 (4-5 hours), 1 (more than 4-5 hours)
Daily drive time	10 (9-10 hours), 1 (less than 9-10 hours), 1 (more than 9-10 hours)
Driving route	12 (international)

3.2.4 Data Analysis

Participants' responses became redundant after the 8th participant. To ensure that there were no major differences, 4 more interviews were conducted. All audio recordings were transcribed by the researcher. Verbal data was analyzed using HMI screen feature contents grouping.

The initial analysis of transcriptions and interview notes revealed most used or referred HMI screen elements. Further analysis was conducted to compare drivers' comments on these elements in current technology screens and drivers' expectations from a Level 4 autonomous drive long haulage truck. To enable the analysis, screen elements were explored and rationally grouped according to the way of driver interaction with a bottom-up approach. Vehicle systems group represented feature contents that normally do not require a driver intervention besides monitoring. Consumption levels group represented consumables during the journey and requires monitoring and frequent refill by the driver. ADAS systems levels group represented driving task support technology features if any installed in the truck and requires driver enabling. Malfunction group represented gauges that activate automatically if there is a malfunction. Rpm meter group represented engine revolution per minute information and Speedometer group represented the speed information of the truck per hour, both directly influenced by the driver or ADAS system if enabled. Weather conditions group represented feature contents such as outside air temperature, weather forecast and road surface status information. Tachograph group represented total drive time, pause time, rest time and speed limit obeyance status of the driver during the journey. Others group represented any other features that are not covered under previous groups, corresponding to 9 feature contents groupings in total. Table 3.4 lists 9 screen elements and corresponding pictorials used in interview phase, and Table 3.5 shows feature contents grouped for each screen element.

Table 3.4: Nine most used or referred HMI screen elements for current technology and autonomous drive technology truck screens. Note for marked graphics: From *F-Max Kullanıcı El kitabı*, by Ford Trucks, n.d. (https://www.fordtrucks.com.tr/Uploads/Documents/pdf/f-maxkullanicielkitabi.pdf). Note for marked graphic: From *The Intelligent Tachograph DTCO 4.0*, by VDO Fleet Europe, n.d. (https://www.fleet.vdo.com/products/dtco-40/)

Screen element	**Current technology screen**	**Autonomous drive screen**
Rpm meter		
Consumption Levels		
Speedometer		

<table>
<tr><td>Malfunction</td><td>
</td><td>
</td></tr>
<tr><td>Vehicle Systems</td><td>
</td><td>

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<tr><td>ADAS systems</td><td>
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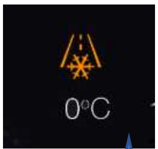
<tr><td>Weather

conditions</td><td>
</td><td>

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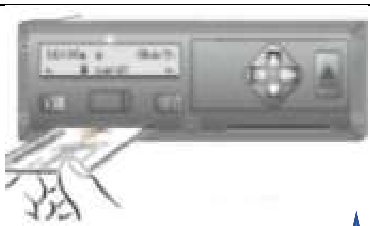
<tr><td>Tachograph</td><td></td><td>
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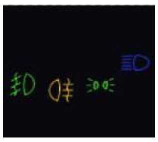
Other	Picture not applicable	  

Table 3.5: Feature contents grouping for 9 HMI screen elements

Vehicle Systems	Engine temperature, engine oil level, tyre pressure, brake pad level, battery status, air pressure, exhaust regeneration gauges, maintenance period information
Consumption level	Fuel level, Ad Blue level
ADAS systems	Cruise control, ESP, lane tracking, TCS, trailer ABS, vehicle ABS gauges, road tracking, autonomous drive range, safe driving distance tracking, warning systems, autonomous vehicle sensors
Malfunction	Malfunction gauges
Rpm meter	Rpm meter dial
Speedometer	Speedometer dial
Weather conditions	Outside temperature
Tachograph	Trip time, pause time, rest time screens
Others	Navigation, multimedia screens, truck-to-trailer attachment screen

With regard to participant screen layout screen exercise, the photographs of participants' HMI layout designs were analyzed for prioritization according to their placements in three zones. Figure 3.5 outlines these three zones: central placement for high priority HMI graphics or two lateral placements for secondary priority HMI graphics.

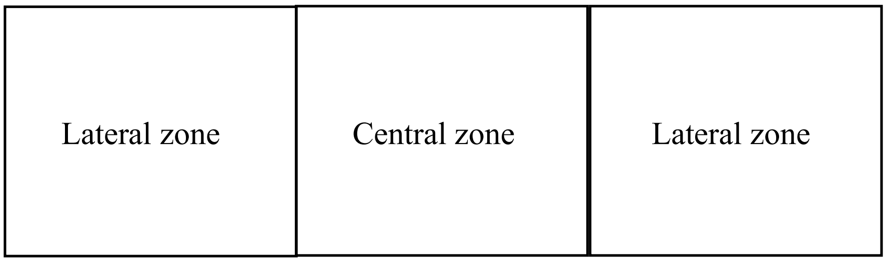


Figure 3.5: HMI graphic layout zones (between the lines is central zone, to the left and right are lateral zones)

Findings from paper HMI screen prototype reviews are summarized under Results section, together with participant recommendations both for further improvements on these screen designs and for graphics used to support trust to autonomous drive technology.

CHAPTER 4
RESULTS

4.1 Trust Questionnaire Results

The results to the trust questionnaire indicated that participants did not have solid trust built into autonomous drive system for long haulage trucks yet. Participants' responses were close to fifty percent split between who think it is trustworthy and others who do not have an idea or not in agreement (Figure 4.1).

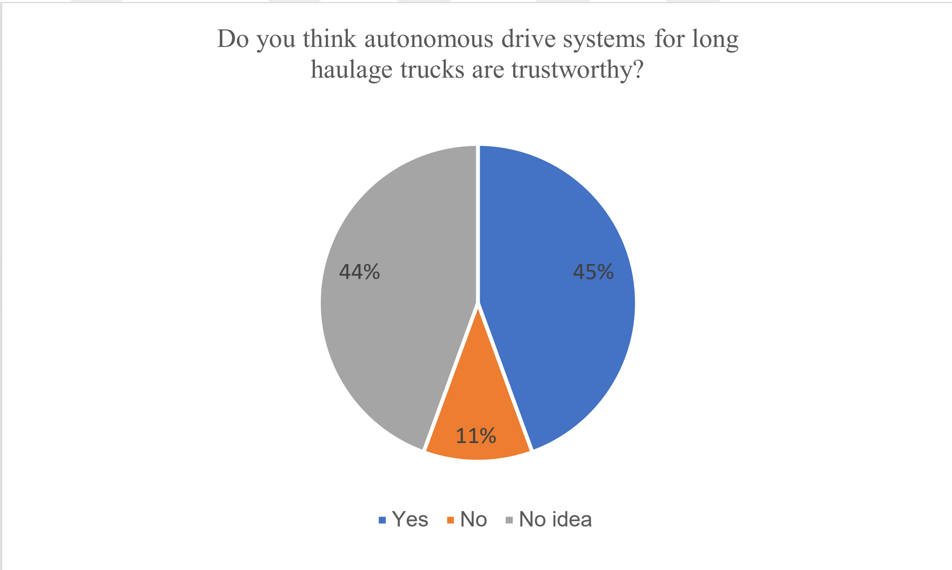


Figure 4.1: Participant response chart for trust questionnaire question about trustworthiness of autonomous drive system for long haulage trucks

When the replies to the open-ended question "What are the attributes that autonomous drive system for long haulage trucks should meet to build up trust?" were analyzed, it was seen that issues related to Trust Factor 13: System competency was mentioned more frequently by the participants. Thus, System competency can be interpreted as a highly important factor for trust build up to autonomous drive system for trucks (Table 4.1). The results show that majority of the participant responses were able to be grouped under defined trust factors, and there was only one outlier. Participant P25221's comment "Should operate under my control" does not directly relate to any of the trust factors and might indicate another keyword/theme to consider in the future.

Table 4.1: Participant response analysis to open-ended question: What would be the features that an autonomous truck must have so that you can trust the system? (Participant numbers start with P and are shown in parenthesis.)

Statement	**Cluster Number**	**Trust- Distrust Key Word/Theme**
"To be developed by competent and highly qualified engineers" (P2523)	6	Confidence
"To be extremely safe for me" (P2519)	17	Perceived safety
"Extremely safe for others" (P2519)	7	Security
"Able to recognize traffic and road signs" (P5176)	13	System competence
"To do lane tracking" (P2522)	13	System competence
"Able to keep safe driving distance with vehicle in front" (P2522)	13	System competence
"To have good reflexes" (P2522)	13	System competence
"Have gone through long tests" (P2517)	6	Confidence
"To be able to try and experience the system" (P6378)	10	Reliability

Further analysis studies show that participants' response to main use of autonomous drive and their expectations from autonomous drive technology showed similarity. For both questions, participants referred to Trust Factor 9: Fidelity more than other trust factors (Table 4.2, 4.3).

Table 4.2: Participant response analysis to the question: What is the main use function of autonomous driving technology for long haulage trucks?

Statement	**Cluster Number**	**Trust- Distrust Key Word/Theme**
"To provide some rest to the driver during the journey" (P2523)	9	Fidelity
"Safety" (P2524)	17	Perceived safety
"To support the driver to get some rest" (P2522)	9	Fidelity
"To eliminate distractions during daily trips." (P2522)	17	Perceived safety
"To provide driver some ease" (P2521)	9	Fidelity
"Safety" (P2517)	17	Perceived safety
"To lower operating costs" (P2517)	17	Fidelity
"For comfort and rest" (P5176)	9	Fidelity

Table 4.3: Participant response analysis to the question: What is your expectance from autonomous driving technology for long haulage trucks?

Statement	**Cluster Number**	**Trust- Distrust Key Word/Theme**
"To Provide rest to the driver on the highway" (P2523)	9	Fidelity

“Safety” (P2524)	17	Perceived safety
“Drive comfort” (P2524)	9	Fidelity
“Driver to trust the system” (P2521)	11	Entrust
“Lower operating costs” (P2517)	9	Fidelity
“Drive safety” (P2517)	17	Perceived safety
“Comfort for the driver” (P2517)	9	Fidelity
“To be protected from accidents and other incidents” (P5176)	7	Security
“To make our life easier” (P6378)	9	Fidelity

To be able understand the current status of participants’ trust toward Level 4 autonomous driving, a separate analysis is performed for questions with a 1 to 5 Likert scale rating (1 representing Disagree, and 5 representing Agree) and responses were ranked in a descending order for Agree and Somewhat Agree ratings (Table 4.4). The highly ranked results showed that Level 4 autonomous drive technology met majority of trust factors such as Trust Factor 13: System competence for highway driving and 9: Fidelity. However, it missed some other trust factors, such as 17: Perceived safety during autonomous drive maneuvers and highway exists, 10: Reliability of the autonomous drive system during changing weather conditions, and 6: Confidence -the need to monitor the road in autonomous drive mode on a continuous basis. Participants agreed with the statements that they need to stay alert during the autonomous drive since system maneuvers may result in harmful results. These findings indicated that although Trust Factor 13: System competency read out to be the most important factor to build in trust according to trust questionnaire responses, it was not enough by itself and must be supported by 17: Perceived safety, 10: Reliability and 6: Confidence factors. Ratings for other trust factors showed that results were scattered among participants.

Table 4.4: Table showing participant responses in a ranked order for agree and somewhat agree to trust questionnaire

Trust Factor Number	**Trust Factor Name**	**Trust Questionnaire**	**Agree**	**Somewhat agree**	**Neutral**	**Somewhat disagree**	**Disagree**
9	Fidelity	I will be less tired since autonomous drive technology will support during the journey	67%	22%	11%	0%	0%
7	Security	Autonomous drive technology will increase road safety	44%	44%	11%	0%	0%
13	Competence	Autonomous drive long haulage trucks can successfully drive on highways	56%	22%	22%	0%	0%
8	Integrity	Autonomous driving system will take the right maneuver decisions	33%	44%	22%	0%	0%
15	Predictability	I can foresee autonomous drive system maneuver intention	44%	33%	11%	0%	11%
10	Reliability	Autonomous driving system will perform a consistent drive under chancing road conditions	22%	44%	11%	11%	11%
9	Fidelity	I can plan a shorter trip since I can take a rest during autonomous driving mode	44%	22%	22%	11%	0%

11	Entrust	I can trust autonomous drive system in highway and hand over the drive	22%	44%	22%	11%	0%
14	Intention	I can put a meaning to some of autonomous drive system maneuvers	22%	22%	33%	11%	11%
6	Confidence	I do not need to watch over the system maneuvers during autonomous drive mode	11%	33%	11%	22%	22%
10	Reliability	Autonomous driving system will perform a consistent drive under changing weather conditions	0	22%	11%	44%	22%
17	Perceived Safety	I would feel safe during autonomous drive mode	0	33%	11%	0	55%
6	Confidence	I do not need to watch over the road during autonomous drive mode	0	22%	33%	0	44%
4	Beware	I need to be alert during autonomous drive mode	67%	22%	11%	0	0
2	Sneaky	I feel that autonomous drive system is tracking me at the background even it is inactive	33%	44%	11%	11%	0
5	Harm	Autonomous drive system maneuvers may create harmful results	44%	11%	33%	0	11%
3	Suspicion	I would approach how autonomous drive system will act and why with suspicion	33%	22%	44%	0	0
3	Mistrust	I mistrust autonomous drive system	11%	22%	44%	0	22%
1	Deception	I believe using autonomous system will deceive me	0	22%	44%	0	33%

Findings from trust questionnaire indicated drivers needed trust factors such as 17: Perceived Safety to be supported during autonomous maneuvering, 10: Reliability to system under changing environmental conditions and monitoring of autonomous system interactions with road and other vehicles. These findings were used in the design of semi-structured interview questions to further focus on the reported issues.

4.2 Semi-Structured Interview Results

4.2.1 Participants' Expectations from Autonomous Drive and HMI Layout

Findings from semi-structured interviews further helped to understand the moments of distrust to autonomous drive technology. Among all participants, there was a general unwillingness to hand over the drive to autonomous drive system to perform take-over or highway exit maneuvers, as well as lack of trust to let autonomous drive system run under poor weather conditions. Only 17% of the drivers saw extended duration of rest, like sleeping, in an autonomous truck as a possibility.

With regard to responses for HMI layout questions; it is seen that all the participants verbalized their preference to keep current technology screen elements in autonomous drive truck HMI as well. Participants' comments about their preferences and the HMI layouts they performed indicated participants' need to see more ADAS system related elements in HMI screens significantly increase with the idea of travelling with a Level 4 autonomous truck. Drivers opting for more ADAS related elements to be displayed in HMI screens resulted in preferences for a different HMI screen layout than current technology. Road tracking feature in

HMI screen was highly prioritized by all of participants to be able to monitor road, other vehicles and full environment with the enhanced vision display of autonomous drive technology. Additional warning features both visually as well as in the form of audial chimes were also desired.

The comparison of participants' comments about most used and deemed important screen element in current technology and their expectations from Level 4 autonomous drive long haulage truck HMI screens were helpful in further understanding of users' needs and wants. Results showed that while drivers referred to Vehicle systems theme as the most important HMI screen element in current technology, ADAS systems theme took the highest priority for Level 4 autonomous drive technology. Vehicle systems were considered as the second most important screen element in autonomous trucks. Rest of the elements did not show a significant change when questioned for inclusion in HMI screens from current technology trucks to Level 4 autonomous trucks (Table 4.3). When drivers were talking about their expectances from a Level 4 autonomous drive truck HMI screen, they frequently mentioned drive monitoring features (i.e., lane tracking, road tracking, autonomous drive range, safe driving distance tracking, warning systems, vehicle sensors – mainly ADAS system themes) which created this significant change in priority.

Additional features were also discussed, such as an integrated tachograph system and navigation screens located in HMI, multimedia screens, screen personalization features, and truck-to-trailer attachment screens (referred as king pin attachment) as an additional safety feature. These are captured under Others in Table 4.5.

Table 4.5: Feature content count of participant responses and grouping under 9 HMI screen elements for screen gauge questions (* indicates inclusion of new features mentioned by participants)

	Vehicle Systems	**Consumption Levels**	**Malfunction**	**ADAS systems**	**Speedometer**	**Rpm meter**	**Tachograph**	**Weather conditions**	**Others**
Which cluster gauges do you use most often today in your truck?									
	28	8	8	7	4	4	5	2	
Which screen gauges do you refer today in your truck to make sure everything is going well during the journey?									
	23	8	7	2	4	1	1	0	
When you consider yourself in a Level 4 autonomous drive truck, what would you expect to see in the screen?									
	13	8	5	18*	8	4	2	1	6*

Among many discussions with participants about HMI screen contents, it was interesting to see how Participant 310101 approached HMI screen expectation questions. He said he would like to image himself resting in the truck and not watching screens during autonomous drive. He verbalized his need to feel totally safe to be able to do this and explained the system competency of the autonomous drive technology as the main driver for a feeling of safety. He further exemplified how he developed trust in the efficiency of automatic transmission in his truck today, through continuous monitoring of the system. When automatic transmission system changed gears, at what gear system chose to travel on different road courses, how it reacted in uphill and downhill conditions and how much fuel consumption was achieved at the end of the journey were all the things that the participant assessed and compared based on different driving conditions. Participant was assured about the efficiency of the automatic transmission with personally seeing improved fuel consumption figures and experiencing shifter selection patterns similar to his way of driving. This monitoring-based practice encouraged him to use automatic transmission and he had been using it since then. Considering all the semi-structured interview notes and analysis results of the participants' HMI layout prototypes, it is be said that outcomes were in line with the findings from trust questionnaire: Participants felt the need to closely monitor the autonomous drive system, to feel safe with its technical competence handling the driving task, to be assured that truck is aware of its surrounding and performs driving accordingly, in a manner that resonates with driver's drive style characteristics.

When the participants' HMI layouts on 74x21 cm canvas were studied, it was seen that road monitoring card was positioned at the central zone by most of the drivers, indicating a high priority (Figure 4.2). This result can also be interpreted as the confirmation of the drivers' need to watch over the road and other vehicles. Priority given to road monitoring graphics was followed by positioning of an integrated tachograph feature and malfunction gauges in the central zone as well.


Otonom sürüş
sensörleri:OK
Takograf h 04h30
00 45
Araç sistemleri:OK
48
KM/H
0
120
12
RPMx100
0
30
11242 km
8:56:37
357 km
35,7 l/100km
35,7 l/100km
Mola vermelisiniz
0005423 km
PWR
55 km/h
0°C
D12


İstanbul
Varışınız Ankara
Kalan mesafe 441km
Varış saati 17:43
48
KM/H
0
120
ola vermelisiniz
55 km/h
0°C
D12
0005423 km
PWR
11242 km
8:56:37
357 km
35,7 l/100km
35,7 l/100km
Takograf h 04h30
00 45
Araç sistemleri:

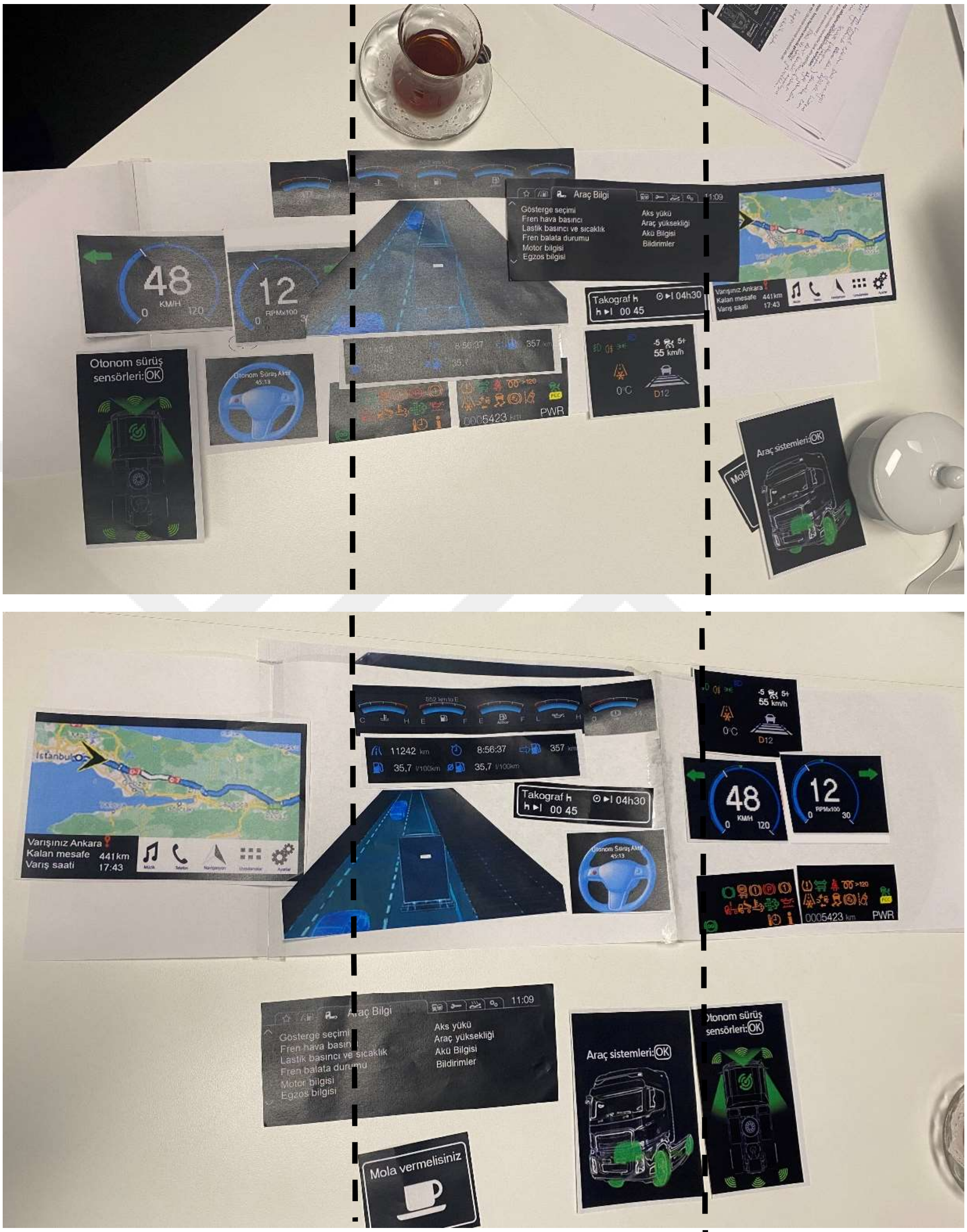


Figure 4.2. Examples of participant HMI layouts (Participant numbers from top to bottom: P40201, P40203, P310101, P170101)

Further inspection of the participant HMI graphic layouts showed that some drivers preferred to move speedometer, Rpm meter and consumption level graphic cards to lateral zones, which is indicating a change in typical layout of current technology truck screens.

When the HMI layouts are analyzed from a content perspective, referring to Table 3.4 HMI screen elements groupings for current technology and autonomous drive technology trucks and a comparison is made, it is seen that participant layouts and verbal descriptions showed a tendency for a similar screen content preferences between current technology and autonomous drive trucks, and the biggest difference lies in prioritization of these HMI screen contents. Table 4.6 captures some of participant responses for each HMI graphic card.

Table 4.6: Some participant responses to HMI graphic cards

Consumption levels	"What matters most is the remaining fuel rather than consumption levels, I would prefer remaining fuel display in liters not in rage kilometers." (P40203)
Malfunction indicators	"These are important, and should have them right in front of me." (P40202)
Road Monitoring	"I would feel at ease when I see this screen" (P170101) "I would like to have this screen even when I am in charge of driving." (P120102)
Speedometer	"We mostly drive at a stable speed of 90 km/h, which is maximum allowed on the highways." (P40203)
Tachograph	"We check tachograph regularly, over the head installation position today is not practical, like it to be in the screen" (P40201)

	“If tachograph jams, it should not stop vehicle from running.” (P50101)
Vehicle systems	“These are important, I should see them at all times.” (P40202)
Autonomous Drive active	“I would like to know that the system is active.” (P50101)
Cruise Control	“I need this to check on autonomous drive speed, and to intervene if it is operating outside the range” (P50101) “Need to have this. There is a fine if tachograph records show speed limit violation.” (P120101) “Would like warning chime if speed limit is exceeded.” (P120102)
Navigation	“I do not use navigation on familiar routes but still would like this screen to operate in truck mode, show bridge heights and truck allowed roads.” (P120101) “Should not go to sleep mode in autonomous driving, I need to know my location” (P50101)
Vehicle Sensors	“I could not put a meaning for this graphic. But it should show other vehicles around and if there is radar system fault” (P50101)
Weather Conditions	“Must have. Should also have sound warning for severe temperature drops, conventional graphic does not attract attention” (P40203)
Exterior Lighting	“Must see lighting on/off status graphic. On/off control should not be operated via touch screen menu, creates distraction issue during manual drive” (P40203)
Rpm meter	“May not be required, we mostly use automatic transmission” (P40203)
Rest break	“We give a break after 4,5 hours continuous driving, but if I am drowsed off, I would like system to warn me,

	even to call the office so that I am given an extra break.” (P40203)

When the participants were asked which HMI graphic cards were deemed most important to support trust to Level 4 autonomous drive system and ensure that the journey is going well, ADAS systems, Vehicle Systems and Weather conditions were rated as highest (Table 4.7). However, it was interesting that 3 out of 12 participants said they would not trust the autonomous drive system to hand over the drive under no condition, only for a couple of minutes enough to prepare a cup of tea in the truck, and until traffic regulations recognize and authorize automated driving respectively.

Table 4.7: Feature content count of participant responses and grouping under 9 HMI screen elements for autonomous truck screen gauge questions

	Vehicle Systems	**ADAS Systems**	**Consumption Levels**	**Malfunction**	**Speedometer**	**Weather conditions**	**Tachograph**	**Rpm meter**	**Other**
Which screens would be most important to trust and make sure everything is going well during the Level 4 autonomous drive journey?									
	6	13	3	3	2	4	1	1	1

4.2.2 Findings on Moments of Screen Interactions

Participants comments on 12 HMI screen designs, which represented multiple moments of screen interactions starting from drivers' first entrance to the truck to trust critical drive maneuver instances, were summarized respectively in the below sections.

4.2.2.1 Welcoming and Navigation screens

Welcoming and Navigation screens are the first screens that were shown to the participants to represent the first moments of interactions.

When the screen on the left in Figure 4.3 was reviewed, majority of the participants said that their main priority was to complete the journey as quickly as possible and achieve early arrival to the destination point. This was then followed by fuel consumption performance. Therefore, the offered choices in the welcome screen (Figure 4.3 left) were not found useable or meaningful to most. It was also mentioned during the interview that the rest durations occur according to the tachograph limitations, and nearly all drivers would not prefer to give rest stops beyond. Instead, recommendations were made for additional screen contents that were believed to be more useful. Participants suggested the inclusion of an assistance screen to find truck parking areas especially in Europe, a data entrance screen for the load tonnage and load size, preferred start time of the journey, and display of weather forecast.

> P170102: "Time is my priority. We eventually get used to continuous driving of 4.5 hours and only stop if there is an emergency. I would rather

have the system ask me to enter cargo load weight and size, my preference for day or nighttime driving and show me weather conditions.”

Figure 4.3: Left: Welcoming screens (Middle: Navigation set screen. Right: Navigation screen)

With regard to navigation screens in the middle and right of Figure 4.3, drivers said being able to see at which course autonomous drive option will be offered would allow them to plan their non-driving activities, such as placing phone calls. The two-color definition, blue for autonomous drive and white for manual drive road courses displayed on the map was clear to all drivers and well received. Participants consistently stated that estimated arrival time, or drive hand over time estimations to and from autonomous system in the form of hours and minutes does not work precisely today due to traffic, custom clearance or ferry wait times, so they would prefer information display of these features in kilometers. Inclusion of tachograph drive time records into navigation screens were also suggested. One participant stated he had difficultly to understand the acronyms used for manual and autonomous driving descriptions at the bottom of the screen and would prefer a full text display.

4.2.2.2 Drive Handover Screens to Autonomous System

Participants said the graphics clearly describe how to hand over the drive to the autonomous system however they emphasized the need to be assured when they become free to take hands off form the steering wheel and that the system assessed the road conditions extensively prior to offering any driver take over requests. Participants verbalized their need to check that autonomous drive system is able to see traffic signs, side barriers, speed limit signs, etc. at all times including the moment of the drive hand over (Figure 4.4).

> P40203: "At which speed and road condition would the system send take over requests? I would not like the idea to hand over the drive on a downhill path or when approaching a curvy road course."

Figure 4.4: Drive handover screens (Left: Drive handover to autonomous system Right: Drive handover completed)

5 participants communicated their preference to see all information in kilometers rather than hours and minutes and 3 participants would like both kilometer and time information display. Participant P170102 stated he would expect to hear an audio chime 5-10 minutes before this screen comes up and see a color change animation on the steering wheel so that full driver attraction is created.

4.2.2.3 Straight Ahead Autonomous Drive Screen

Many participants stated that this screen has critical importance. In general, the enhanced vision capability of the autonomous system is very well received, and participants associated the green radar wave rings around the truck as autonomous system radar coverage zone and stated that this provided assurance in system being fully aware of its surround. Participant P120101 said he would use this screen in manual drive mode as well (Figure 4.5).

> P120101: “The green ring graphics around my truck in the screen is assuring, they show what the truck sees.”

Figure 4.5: Straight ahead autonomous drive screen

Further recommendations were provided for improvement particularly for this screen in Figure 4.5, such as an addition of radar coverage zone information in meters, screen to show a full ring around the truck, meaning 360 degrees of vision is provided by autonomous drive technology even including back of the trailer – an area desired to be seen by drivers for improved safety feeling. Another suggestion was a color change feature on the screen with a warning chime if other vehicles get too close.

Speed information display of the vehicles in the left lane was not deemed as necessary for most, but one participant stated he would need this information, to see if the vehicle on the left lane was fast enough to over-take the front vehicle. With the help of this information, he would feel comfortable and would not need to consider a possibility for emergency braking. He also added the desire to see the safe stop distance for the vehicle in the front, as he may consider leaving extra driving distance in case the emergency breaking need arises due to other vehicles in front. Safe driving distance feature was liked but proposed to be changed with a tracking distance information displayed in meters instead of a green band to eliminate reflection issue at night. If this distance is not maintained, a red distance band appearance was proposed as a warning feature.

Continuous display of weather conditions and speed limits were liked. One driver verbalized his expectation to receive a warning chime when sudden changes about to occur, such as approaching to a curvy road course, rain or temperature drop.

> P40203: “We are too used to the conventional graphic of 0ºC with a snowflake sign, this is not creating attention. We experience severe temperature drops due to elevation change during the journeys and would like warning audio chimes just to be aware.”

Another participant was not sure if vehicles in the next lane were moving in the same direction with his truck or coming from the opposite direction, suggesting a need to add a vehicle move direction indicator graphic to the screen.

Participant P40203 had slightly different comments from rest of the participants. He stated that he trusts the engineers developing autonomous drive, but not to the system due to unexpected instances that might happen during the journeys. He explained how his life was endangered once by the load he was carrying in an emergency break situation but added if all vehicles were running with autonomous drive, things would be different. He also suggested that until all trucks are running in full autonomous more, that it would be good for other vehicles to see his truck is operating in autonomous mode.

4.2.2.4 Maneuvering Screens in Autonomous Mode

When the screen proposals in Figure 4.6 are interviewed, results indicated that drivers were not totally comfortable with the idea of autonomous drive system to perform drive maneuvers. Two participants said they would not use autonomous drive system to perform a vehicle take-over maneuver regardless of suggested screen designs but continued the interview to provide recommendations for further improvement of these screens. Regarding the take-over maneuver screen on the left in Figure 4.6, participants informed that they would like to see additional information such as – a red indicator if the truck is getting too close to the vehicle at front, the active and working mode of the vehicle sensors including trailer sensors, and a full view of the back of the trailer. They stated that an audio chime was necessary as well prior to maneuver start or in case of a necessary breaking to keep safe drive distance with the vehicle at front.

Some of the participants could not put a meaning to the speeding up from 100 to 110 km/h icon on the left upper corner and thought this is cruise control symbol due to round design of the graphic with a speed indicator.

It was seen that participants were more comfortable with middle screen in Figure 4.6, a decelerating straight ahead driving scenario screen. One participant said he would like to use these screens in manual driving mode as well.

Nearly all participants repeated the wish to see the safe driving distance in meters, have a full view of back of the trailer, a need to have a vehicle move direction indicator, display of traffic and other signs to be assured that system is able see them as well, and the screen to clearly show if autonomous drive is or is not intending to overtake the front vehicle. Some participants thought continuous display of vehicle speeds in the next lane was too much information during a steady course, and maybe shown selectively when needed.

When the highway exit maneuver screen on the right in Figure 4.6 is reviewed, four of the participants stated that they would not feel comfortable with the autonomous drive system performing a highway exit maneuver, regardless of screen designs since conditions of the road surface, load tonnage, load dimensions and the way it is positioned in the trailer are safety critical.

> P170102: “I cannot trust autonomous system to make a highway exit. If I have a bulky cargo load, even 50 km/h exit speed would be too much or exit bridges may have frost on the road.”

Figure 4.6: Maneuver screens (Left: Take-over maneuver Middle: A decelerating straight ahead drive Right: Highway exit maneuver)

Other participants informed that they would like to see the planned speed during exit maneuver, and speed of other vehicles if any, and additional graphic showing the vehicle's intention to exit, and receive an audio chime at least 2 kilometers before the maneuver.

> P40202: "I would try highway exit in autonomous drive mode, but I would stay alert. The load that I am carrying becomes very important during this maneuver and I want the system to inform any possibility of a vehicle cutting in front and its speed."

All of participants said they would like to be notified before the autonomous drive system performs any maneuvers (takeover, exit, etc.) both through HMI screen as well as audio chimes.

4.2.2.5 Changing Weather Condition Screens in Autonomous Mode

Three of the participants explained that they would not feel comfortable with the autonomous drive system performing a straight ahead drive under rainy weather conditions due to unexpected road surface performance mishaps and the likelihood of radar and camera visions blockages with splashes. Others stated that they would continue to drive in autonomous mode and use changing weather screen on the left in Figure 4.7 to monitor. Participant P50101 said his expectation would be autonomous drive system to slow down under rain. He informed he would use such a screen during manual drive mode under rainy conditions as support and recommended addition of road surface condition, presence of fog, if any. He also recommended replacement of x2 icon and green band graphic in the left screen in Figure 4.7 with safe driving distance in meters. P170102 explained that safe driving distance depends on the season of the year and loading conditions, therefore it varies under rain.

Some participants recommended to remove the deceleration graphic on the upper left corner as speed drops can be felt directly by the driver and graphic was deemed as unnecessary.

Some participants thought vehicle sensor graphic was a good feature to have in the screen. Participants thought warning screen in the middle and drive take over screen on the right in Figure 4.7 were sufficient with no further recommendations.

Figure 4.7: Change in weather conditions screen (Left: Changing weather screen Middle: Warning screen Right: Drive take over screen)

4.2.3 Trust to System After Reviewing Autonomous Drive HMI Screen Elements Design

Two closure questions were raised to understand if HMI screen design proposals created a feeling of trust at the end of interview. In the first closure question, participants were asked whether they would trust a Level 4 autonomous drive system to hand over the drive and take a rest or sleep during the journey. The responses indicated that 33% of participants agreed or in conditionally agreed to trust the system and hand over the drive to take a rest (Figure 4.8). Only 17% of the participants said they would trust the system to consider sleeping during autonomous drive journey.

In the second question, participants were asked if there was anything they could advise from HMI screen design perspective to achieve or improve trust to autonomous drive system. Participants stated that trust build up was rather related with autonomous drive system competency and they would need to experience this competence to build in confidence.

During the interviews it was seen that participants were continuously stating the big responsibility they have while operating long haulage trucks, and how a mistake can have fatal consequences both for themselves and for others on the road. It was seen as a common pattern that they all have zero risk drive characteristics, and continuously consider all possibilities that that may go wrong, including other vehicles’ mistakes. In general, we can say that in a way participants see their profession as a mastery, such that each driver has unique personal experience build up, accumulating through drive practicing so a personal experience with autonomous drive system is deemed important.

With regard to environmental factors, participants made a point about the need for road infrastructure enhancements to support autonomous drive technology, legal rearrangements to recognize autonomous driving and city planning changes such as logistics warehouse centers moving outside city centers.

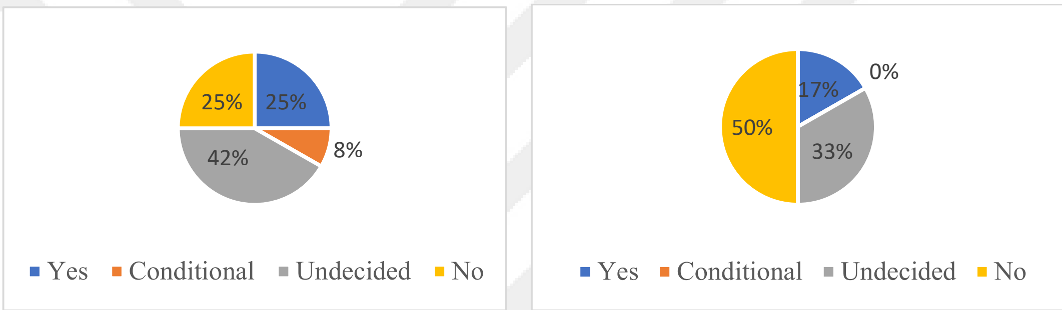


Figure 4.8: Responses to closure question (Left: “I can trust autonomous drive to take a rest break”. Right: “I can trust autonomous drive to take a sleep”)

CHAPTER 5
DISCUSSION AND CONCLUSIONS

5.1 Discussion

The goal in this research was to collect data and analyze how HMI screen element designs can contribute to driver trust for Level 4 autonomous drive long haulage trucks though semi-structured interviews. It also created contribution to literature by expanding trust parameters to autonomous drive systems for long haulage trucks as well as proposing HMI content feature grouping methodology and tries to link these groupings, through the way system status and information is exchanged, with trust to autonomous drive system.

Through this truck specific research, discovery and understanding of long haulage truck driving profession and operating conditions, as well as the way drivers interact with their current technology truck screens, identification of trust critical drive maneuver instances and the related potential information flow needs for trust build up support for driving in autonomous mode are captured.

During the study, it was seen autonomous drive technology is still considered to be new and unknown to many long haulage truck drivers, as well as lacking a general awareness whether this technology is trustworthy. This outcome can be seen with the scattered results of the trust questionnaire. Trust factor questions like 10: Reliability for changing road conditions, 11: Entrust, 14: Intention, 2: Sneaky,5: Harm, 3: Suspicion and 1: Deception do not display a predominant ranking order, indicating a confusion among drivers regarding their belief in autonomous drive technologies trustworthiness. However, after participants became more informed about fundamentals of the Level 4 autonomous drive technology, majority of the drivers considered Level 4 autonomous drive opportunities with favor, such as autonomous system providing extra resting opportunity in the long journeys and assisting to plan a shorter trip in total and offering a potential solution to the top issues listed in ATRI (2019). These findings indicate the importance of impression of technology, as being one of the proposed trust factors, as well as a potential change of driver assessments in future with increasing familiarization with autonomous drive.

While the participants were initially excited about such opportunities with autonomous drive technology, their answers to further questions indicate a lack of trust to system to make advantage of these opportunities.

In this respect, the outcome of this study is important. Findings provide a current status of drivers' belief to Level 4 autonomous system's competency in successful handling of straight-ahead driving tasks on the highways under normal conditions and describe the desired features from HMI screens for this autonomous drive scenario. On the other hand, findings also show lack of trust to Level 4 autonomous drive system under changing weather conditions and drive maneuvering instances. These drive maneuvers, which can be called as safety critical, have crucial importance for the drivers and significantly increase their need to monitor road and other vehicles and receive transparent information about system status and environment on a continuous basis.

Drivers give critical decisions such as increasing safe tracking distance, choose the speed they will exit the highway or to take a curve, and to or not to perform a takeover maneuver based on their personal drive experiences. Participants explicitly commented about themselves as masters in driving trucks, referring to years of accumulated experience. They perform their profession with a zero risk driving characteristics, continuously considering what could go wrong, such as mistakes of other vehicles, changing weather and road surface conditions. In an environment where there is no real time experience with Level 4 autonomous drive to test and get assurance on its technical competence, whether it is equivalent or better than a truck driver and lack of knowledge on AI, such as how the system will take and apply maneuver decisions or act under rain or snow, prohibits the drivers to consider drive hand over to autonomous system for the extended duration of the journey. These findings are in support of Choi and Yong (2015) study, in which they identified three subdivision dimensions for trust to autonomous driving technology: technical competence, system transparency, and situation management. The results of this research study also shows that accessible, explainable and transparent AI has influences on trust build up to autonomous systems, including autonomous long haulage trucks.

These findings indicate that HMI screen designs provide transparent information sharing between driver and autonomous drive system, its intention, as well as its limits, and support trust creation (Debernard et al., 2016). In return an acceleration of transitional period from current truck technology to autonomous drive trucks can be achieved and society can benefit increased road safety, driver comfort, transportation time efficiency in the near future.

This research provided further outcomes with regard to HMI screen design considerations for Level 4 autonomous drive trucks. Research results indicate that

drivers’ expectances from a Level 4 autonomous driver truck is still to include the content from current technology screen elements, but road and other vehicles monitoring screens and audio-visual warning chimes are highly prioritized.
The increased significance of these HMI elements might be related to driver’s need to be assured that the autonomous system sees and is aware of what drivers’ see and are aware. The road and other vehicles might be assessed as two of the major components that the AI system of the truck and the driver can have equal information and evaluation access (in comparison to elements such as oil level, speed). Thus, these can help assuring the driver that the system is trustable.
Regarding the road monitoring screen focused interview outcomes, the study brought to light the drivers’ needs to monitor the road, other vehicles - including the ones that are behind of the trailer – for the full duration of autonomous drive journey, be informed and warned to stay alert. Drivers would like to be assured that autonomous system sees and fully complies with traffic and speed limit signs, provides continuous information on road surface conditions, safe driving distance, system intention – explicitly to state it will or will not perform a maneuver -and warnings through audio visual chimes before a change happens in the steady drive course or in case of a potential violation. These outcomes are in coherence with Debernard et al.’s (2016) study with particular attention to system transparency on what autonomous drive can perform, how and why, as well as with Krupenia and Selmarker’s (2014) findings, where they reported drivers’ preference for sound and visual interfaces together so that they have a comfortable level of situation awareness during autonomous drive mode.

With regard to HMI screen layouts, the study showed that design layouts in support of prioritization of road and other vehicles monitoring are preferred when changing from traditional long haulage trucks to Level 4 autonomous long haulage trucks, with HMI screen layout preferences that position monitoring screens to central locations and move other screen elements to periphery locations.

Considering all above, it can be concluded that HMI screen designs can provide a positive impact with regard to trust towards Level 4 autonomous drive long haulage trucks up to the point where drivers develop a complete trust to system and consider getting extended rests, even sleeping during autonomous drive journeys. The learnings from this research put forward a user-centric design development need for Level 4 autonomous drive truck HMI screens to provide mainly transparency and intention of autonomous drive AI algorithms that are to be developed based on drivers' driving characteristics, decision makings and situation management, especially for changing weather, road surface conditions and maneuvering instances. The findings would be useful to define the type of information as well as how and when it should be displayed in HMI screens.

This research also created learnings to myself, working as an engineer in transportation product development industry as well as conducting this academic study as a graduate school student. My experience in heavy commercials segment directed me to conduct this research with fleet drivers initially, with the knowledge that most long haulage trucks are fleet owned and truck fleet owners prefer to keep their vehicles up to date with recent technologies to continuously improve their business. During the study, I had a chance to be able to fully understand how truck drivers value of experience above all, mostly personal experience with new systems and features and how strong of an attitude they possess to avoid any kind of risk during their journeys. It was challenging for me, to design proposals for HMI screen probes, which included all the necessary visual information to achieve a zero-risk autonomous drive system impression but at the same avoid unnecessary mental load for the drivers.

5.2 Limitations

There were couple limitations during this thesis study. The first one is with the data collection environment. Participant assessments of HMI screen proposals were collected in a static environment with use of paper prototypes. If it had been possible to assess the screen proposals installed in a running Level 4 autonomous truck prototype or with use of Wizard of Oz technique, it would have been possible to immerse the drivers more into an autonomous drive environment and collect more rich feedback, with inclusion of behavioral and experience-oriented observations (Frison et al., 2019). The second limitation is with the number of participants and the fact that they are all fleet drivers. It is recommended to repeat the preliminary trust questionnaire study with more drivers, and include drivers who work independently, to be able to make a more comprehensive assertion about drivers trust towards Level 4 autonomous drive systems.

5.3 Recommendations for Future Work

Considering the dynamic and complex world of truck driving, and the way how critical drive decisions heavily rely on drivers' experiences, it may be a suggestion to conduct future research studies on long haulage truck drivers' decision-making processes for maneuvers and driving characteristics under changing weather and road surface conditions. The findings would be useful to define drive competency concept in a detailed extend, and support machine learning algorithms for AI. Performing behavioral observations on drivers' interactions with proposed HMI elements during the drives are also recommended for a better immersed understanding of driver experiences. In return, these early interactions with enhanced HMI screens, even on current technology trucks, would enable early driver familiarization and it is believed to support trust towards Level 4 autonomous drive technology in the long run.

The findings in this research are also indicating the importance of familiarization and experience with technology. The study reflects the current trust state of participants and their expectations from autonomous drive technology at the time of study. As drivers increase their familiarity with this technology, trust factor definitions and participant opinions are expected to be subject to change. Therefore, it is recommended to perform similar studies as future work to monitor changes and consider continuous design updates to ensure continuation of trust support as required.

This research study focuses on the visual modality of HMI screens in trust build up. It is rational expectation that after trust build up occurs and extended duration of autonomous drive journeys are achieved, other interaction modalities between the driver and the truck will need be considered. Situation awareness of the driver for drive incidents, presence and use of audio chimes, as well as haptic information exchange modalities (e.g., Ekman et al., 2018a) are important. Design implications of these modalities without creating unnecessary mental load for the drivers are potential areas of study for future work for long haulage trucks.

With the outcomes of this research, I hope to be able to provide an inspiration for autonomous drive HMI screen design development studies for long haulage trucks from trust support perspective through giving information about system status. It is key to achieve driver trust for acceptance of autonomous driving systems so that both the driver and the truck can work as a team and collaborate to complete a safe, efficient, and comfortable journey together, and only from that moment on the expected benefits of autonomous driving technology for the society can flourish.

APPENDIX 1

CRASH STATICS

(The analysis is up to 2020 due to Covid19 outbreak)

Table A1.1: Number of crashes, by crash severity, 2010-2019 (NHTSA, 2022)

Year	Crash Severity			
	Fatal	Injury	Property Damage Only	Total Crashes
2010	30.296	1.542.000	3.847.000	5.419.000
2011	29.867	1.530.000	3.778.000	5.338.000
2012	31.006	1.634.000	3.950.000	5.615.000
2013	30.202	1.591.000	4.066.000	5.687.000
2014	30.056	1.648.000	4.387.000	6.064.000
2015	32.538	1.715.000	4.548.000	6.296.000
2016	34.748	2.116.000	4.670.000	6.821.000
2017	34.560	1.889.000	4.530.000	6.453.000
2018	33.654	1.894.000	4.807.000	6.735.000
2019	33.244	1.916.000	486.000	6.756.000
	32.044	Annual average of crashes between 2010-2019		

Table A1.2: Drivers (all ages) involved in crashes 2010-2019 (NHTSA, 2022)

Year	Crash Severity			
	Fatal	Injury	Property Damage Only	Total Crashes
2010	44.599	2.781.000	6.717.000	9.543.000
2011	43.840	2.750.000	6.596.000	9.390.000
2012	45.664	2.949.000	6.887.000	9.882.000
2013	44.803	2.915.000	7.083.000	10.043.000
2014	44.671	3.011.000	7.718.000	10.773.000
2015	49.163	3.171.000	8.032.000	11.252.000

2016	52.399	3.876.000	8.145.000	12.074.000
2017	52.752	3.496.000	7.974.000	11.523.000
2018	51.905	3.482.000	8.492.000	12.025.000
2019	50.930	3.549.000	8.519.000	12.119.000
	48.073	Annual average of driver involvement per year in fatal crashes between 2010-2019		

Table A1.3: Related factors for drivers involved in fatal crashes drivers 2010-2019 (NHTSA, 2022)

		2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Driver Behavior related Factors	Driving too fast for conditions or in excess of posted limit or racing	9.634	9.130	9.420	8.938	8.380	8.931	9.385	9.073	8.788	8.746
	Under the influence of alcohol, drugs, or medication	6.933	6.096	6.396	6.028	5.412	5.587	5.788	5.761	5.405	5.164
	Failure to keep in proper lane	3.482	3.997	3.404	3.747	3.792	3.531	3.966	3.885	3.729	3.381
	Failure to yield right of way	3.227	3.158	3.240	3.178	3.106	3.414	3.703	3.785	3.640	3.728
	Operating vehicle in a careless manner			2.062	2.121	2.133	2.632	2.757	3.066	2.889	3.302
	Distracted (phone, talking, eating, object, etc.)	3.064	3.111	3.167	2.972	3.018	3.313	3.252	3.065	2.704	3.008

	Operating vehicle in erratic, reckless or negligent manner	2.574	2.631	1.671	1.524	1.556	1.778	2.026	2.039	2.016	1.880
	Overcorrecting/oversteering	2.096	2.095	2.257	2.000	1.816	1.858	1.995	1.866	1.632	1.569
	Failure to obey traffic signs, signals, or officer	1.933	1.844	1.838	1.793	1.805	1.945	2.092	2.146	2.036	2.054
	Swerving or avoiding due to wind, slippery surface, ...	1.712	1.754	1.588	1.635	1.520	1.469	1.315	1.117	1.173	1.148
	Vision obscured (rain, snow, glare, lights, building, trees, etc.)	1.440	1.316	1.306	1.510	1.246	1.565	1.590	1.605	1.550	1.543
	Driving wrong way on one-way traffic or wrong side of road	1.392	1.088	997	850	879	1.074	1.187	1.214	1.254	1.223
	Drowsy, asleep, fatigued, ill, or blackout	1.234	1.173	1.262	1.234	1.306	1.275	1.332	1.319	1.229	1.240
	Making improper turn	990	1.016	953	704	768	983	363	505	652	419
1	Driver Behavior factor related fatal crashes total	39.711	38.409	39.561	38.234	36.737	39.355	40.751	40.446	38.697	38.405
Other related	Other factors	6.362	6.622	5.357	5.235	5.172	5.761	6.219	6.254	5.505	5.549

	None reported	12.763	13.211	14.264	13.757	13.625	15.019	15.603	11.430	9.240	9.196
	Unknown	5.086	4.416	5.078	5.452	6.082	7.135	8.965	13.699	15.933	15.423
2	Other factors related fatal crashes total	24.211	24.249	24.699	24.444	24.879	27.915	30.787	31.383	30.678	30.168
	Ratio of Driver related to Other Factors (1/2)	**1,6**	**1,6**	**1,6**	**1,6**	**1,5**	**1,4**	**1,3**	**1,3**	**1,3**	**1,3**

Table A1.4: Fatality rates in crashes involving long haulage trucks 2010-2019 (NHTSA, 2022)

Year	Crash Severity			
	Fatal	Injury	Property Damage Only	Total Crashes
2010	3.494	58.000	214.000	276.000
2011	3.633	63.000	221.000	287.000
2012	3.825	77.000	253.000	333.000
2013	3.921	73.000	265.000	342.000
2014	3.749	88.000	346.000	438.000
2015	4.075	87.000	342.000	433.000
2016	4.562	102.000	351.000	458.000
2017	4.805	107.000	363.000	475.000
2018	4.909	112.000	414.000	531.000
2019	5.005	119.000	414.000	538.000
	4.198	Average fatal crashes involving large trucks per year between 2010-2019		

Table A1.5: Large truck (heavier than 15 tons) involvement in fatal crashes 2010 2019 (NHTSA, 2022)

Year	Total Crash	Large Truck Involved	Percentage
2010	30.296	3.494	12%
2011	29.867	3.633	12%
2012	31.006	3.825	12%
2013	30.202	3.921	13%
2014	30.056	3.749	12%
2015	32.538	4.075	13%
2016	34.748	4.562	13%
2017	34.560	4.805	14%
2018	33.919	4.909	14%
2019	33.244	5.005	15%

APPENDIX 2

TRUST QUESTIONNARE

<table>
<tr><td colspan="2">Otonom sürüş teknolojisi hakkında fikirler</td></tr>
<tr><td colspan="2">Otonom araç şoför müdahalesine ihtiyaç duymadan uygun altyapısı olan yollarda yolu, trafik durumunu ve çevre şartlarını algılayarak kendi kendine gidebilen araçtır. Üst düzey sensörler ile donanmış bu araçlarda otonom sürüş esnasında sürücü olarak direksiyonu tutmak veya yolu izlemek sorumluluğunuz bulunmamaktadır.</td></tr>
<tr><td colspan="2">Lütfen “Katılımcı Numaranızı” yazınız</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Çekiciler için geliştirilmekte olan otonom sürüş sistemlerinin güvenilir olduğunu düşünüyor musunuz?</td></tr>
<tr><td></td><td>Evet, derinlemesine bilgim var</td></tr>
<tr><td></td><td>Evet, ne olduğunu duymuşluğum var</td></tr>
<tr><td></td><td>Hayır</td></tr>
<tr><td colspan="2">Yanıtınz Evet ise otonom sürüş sistemleri hakkında bilgiyi nerelerden edindiniz?</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">C ya da CE sınıf ehliyetiniz bulunuyor mu?</td></tr>
<tr><td></td><td>Evet</td></tr>
<tr><td></td><td>Hayır</td></tr>
<tr><td colspan="2">Çekiciler için geliştirilmekte olan otonom sürüş sistemlerinin güvenilir olduğunu düşünüyor musunuz?</td></tr>
<tr><td></td><td>Evet</td></tr>
<tr><td></td><td>Hayır</td></tr>
<tr><td></td><td>Fikrim yok</td></tr>
<tr><td colspan="2">Çekiciler için geliştirilmekte olan otonom sürüş sistemine güvenmeniz için neleri sağlaması gerekir?</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Otonom sürüşün uzun yol taşımacılığında kullanım amacı sizce ne olmalı?	
Otonom sürüşün uzun yol taşımacılığında sizin sistemden ana beklentiniz neler olur?	
Bundan sonraki ifadelere katılıp katılmadığınızı otonom bir çekici kullandığınızı hayal ederek cevaplayınız.	
Otonom çekiciler otobanlarda otomatik sürüş işlevini başarılı şekilde yerine getirebilir.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken kendimi emniyette hissederim.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otobanlarda otonom sürüş devredeyken ben de dinlenme molası alabileceğim için toplamda daha kısa sürecek bir yolculuk planlaması yapabilirim.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş bana destek olacağı için uzun yolda daha az yorulurum.	
	Katılıyorum

	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş yollarda sürüş güvenliğini arttıracaktır.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken sistem doğru manevra kararları alacaktır.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken sistemin yapacağı manevraları öngörebilirim	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş değişen yol koşullarında istikrarlı bir sürüş performansı sergileyecektir.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum

Otonom sürüş değişen hava koşullarında istikrarlı bir sürüş performansı sergileyecektir.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüşün bazı manevraları ne amaçla yaptığını anlamlandırabilirim.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüşe güvenerek otobanda sürüşü emanet ederim.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken yolu gözetlememe gerek olmaz	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken sistemin manevralarını gözetlememe gerek olmaz.	
	Katılıyorum
	Kısmen katılıyorum

	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom bir çekici kullandığınızı hayal etmeye devam edin ve aşağıdaki soruları cevaplayın;	
Otonom sürüşü kullanmanın beni yanıltacağını düşünüyorum	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş arka planda çalışacağı için aktif olmasa bile beni takip ettiği izlenimine kapılırım.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüşe güvenemem.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken ben de tetikte olurum.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum

	Katılmıyorum
Otonom sürüş devredeyken sistemin manevraları tehlikeli sonuçlar doğurabilir.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken sistemin manevraları hasara yol açan sonuçlar doğurabilir.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Otonom sürüş devredeyken sistemin ne amaçla nasıl davranacağına şüphe ile yaklaşırım.	
	Katılıyorum
	Kısmen katılıyorum
	Tarafsızım
	Kısmen katılıyorum
	Katılmıyorum
Cinsiyetiniz	
	Erkek
	Kadın
Yaşınız	
Eğitim durumunuzu belirtiniz	
	Herhangi bir öğretim kurmundan mezun değilim

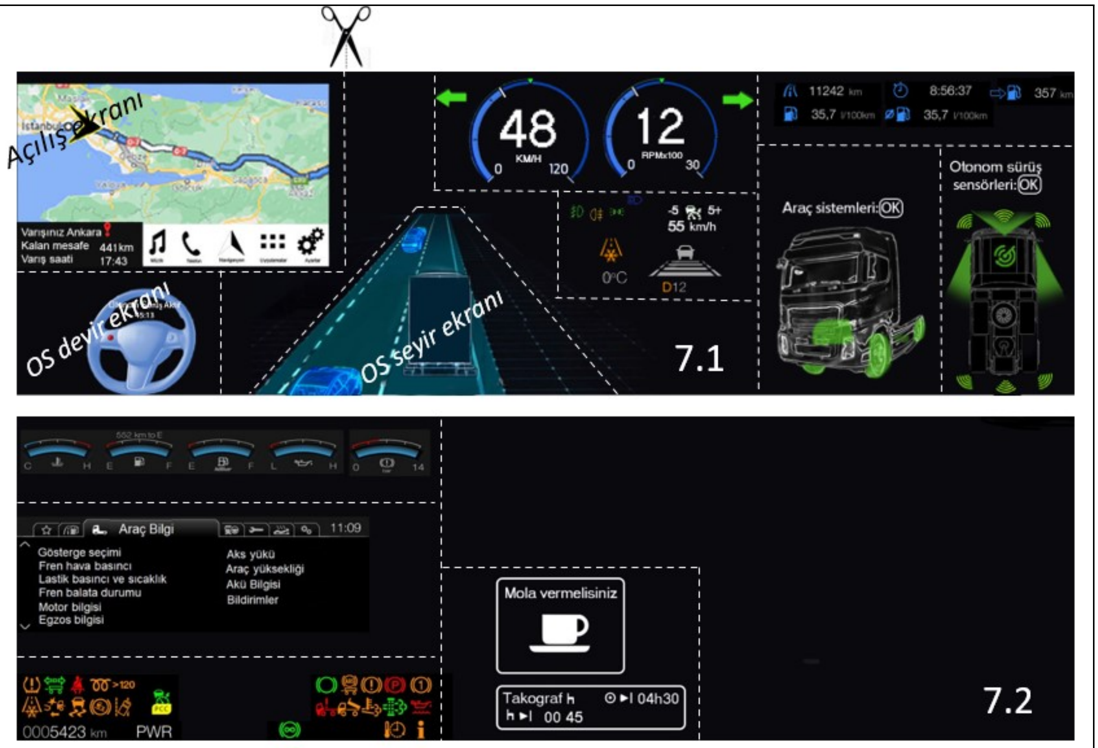
	İlkokul mezunuyum
	Ortaokula devam ediyorum
	Ortaokul mezunuyum
	Liseye devam ediyorum
	Lise ve dengi okul mezunuyum
	Yüksekokul/üniversiteye devam ediyorum
	Yüksekokul/üniversite mezunuyum
	Diğer
Bir yılda yaklaşık kaç kilometre çekici sürüyorsunuz?	
	0-15bin
	15-50bin
	50-100bin
	100bin'den fazla
Çekiciyi çoğunlukla hangi yollarda sürüyorsunuz?	
	Şehiriçi
	Şehirler arası, çğunlukla otoban dışında
	Şehirler arası, çoğunlukla otobanda
	Ülkeler arası
Günde ortalama kaç saat çekici sürersiniz?	
	9-10 saat
	9-10 saaatten az
Günlük aralıksız sürüş zamanınız ne kadardır?	
	Aralıksız 4-5 saat
	Şe4-5 saatten daha az

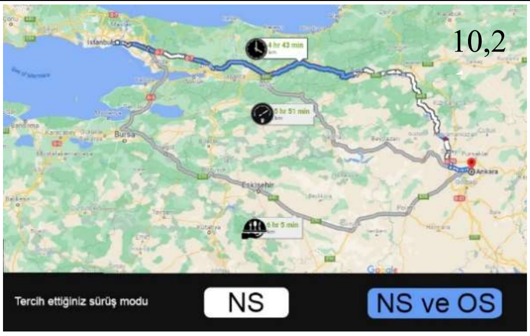
APPENDIX 3

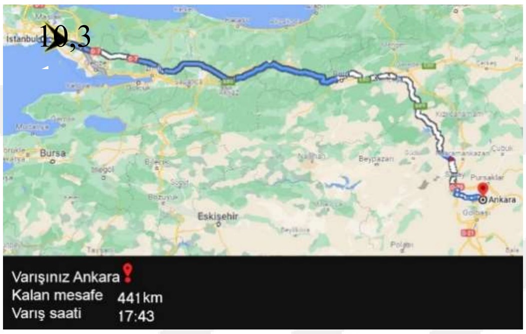
SEMI-STRUCTURED INTERVIEW PROTOCOL

Otonom sürüş teknolojisine sahip aracın ne olduğunu biliyor musunuz? Bana tanımlayabilir misiniz?
Bu araştırma kapsamındaki Seviye 4 otonom sürüş teknolojsine sahip çekiciler belirlenmiş parkurlar ve hava koşullarında tüm sürüşü kendi başına yapabilecek donanımda araçlar. Sürüş esnasında da ekranlar aracılığı ile sürücü ile iletişim kurup durum bilgisi paylaşıyorlar. Parkur veya hava koşulları uygun değil ise otonom yazılımı şoförün seyir esnasında sürüşü devralmasını ister, bu gerçekleşmez ise yol kenarında emniyetli bir duruş gerçekleştirir. Bundan sonraki soruları otononom sürüş teknolojisini bu şekilde dusunerek cevaplayabilirseniz memnun olurum. Ama öncesinde;
C ya da CE sınıfı ehliyetiniz bulunuyor mu?
Evet ise ne kadar süredir bu ehliyete sahipsiniz?
Herhangi bir otonom sürüş simulatörü deneyiminiz var mı?
GRUP 0: MEVCUT DURUM

4.1 
Şu an kullanıdığınız çekicinin panelinde en çok baktığınız ve sizin için en önemli gösterge hangisi? Niye bunu veya bunları daha sık kullanıyorsunuz?
Çekicide herşeyin yolunda gittiğini anlamak için öncelikle kontrol ettiğiniz göstergeler hangileri?
GRUP 1: BEKLENTİLER
Bir çekicinin otonom sürüş teknolojisine sahip olduğunu düşündüğümüzde, karşındaki ekranda neleri görmeyi beklersin?
Varolan ekran çözümlerinden daha çok aşağıdakiler yer alıyor. Sizce bunların arasında gereksiz olan var mı? Eklenmesi gerektiğini düşündüğünüz var mı?


Bunları siz olsanız ekrana ne şekilde yerleştirirdiniz? Niye bunu buraya yerleştirdiniz, bunu tepeye koydunuz, bu önem sırasını mı ifade ediyor?
Sisteme güvenmen, herşeyin yolunda gittiğini anlaman için en önemlileri hangileri olur sence? Ya da bu bilgiyi ekranda başka şekilde mi görmek istersin?
GRUP 2: AÇILIŞ EKRANI
Şimdi bizim tasarladığımız aşağıdaki bazı ekranlar üzerine yorumlarını merak ediyoruz.

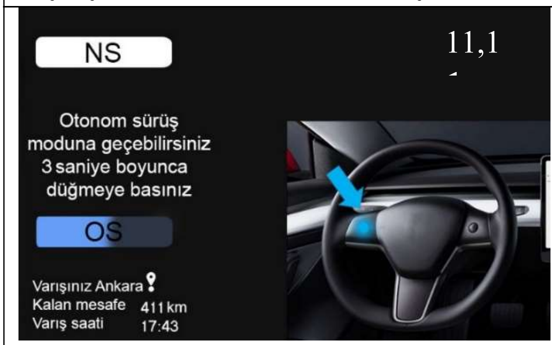




Açılış ekranları sana ne anlatıyor? Bunları nasıl yorumluyorsun?

GRUP 3: OTONOM SÜRÜŞE DEVRETME EKRANI

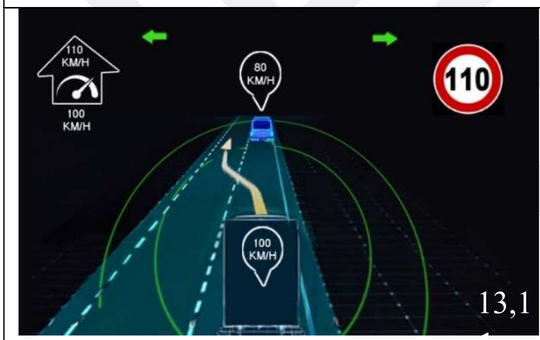
Otonom sürüş sistemine uygun olan yolda sürüşü devrebileceğine dair bir mesaj geldi diyelim, aşağıdaki ekranı sana bunu anlatmakta yeterli mi? Güvenerek sisteme sürüşü devretmek için bu ekranda görmek isteyeceğin başka bilgiler veya yönlendirmeler olur muydu?

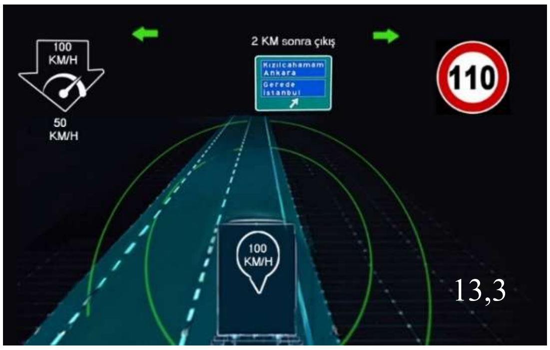


GRUP 4: OTONOM SÜRÜŞTE SEYİR EKRANI

Sürüşü devrettikten sonra aşağıdaki ekranda hangi bilgileri, hangi uyarıları görmek seni rahatladırdı?

Otonom sürüş esnasında sistemin hangi manevraları haber vermesini isterdin? Aşağıdaki ekranlara bir bakalım, bunları anlatmakta yeterli oluyorlar mı? Daha iyi nasıl yapabiliriz?

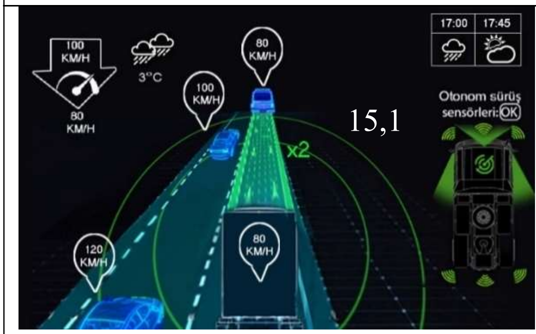


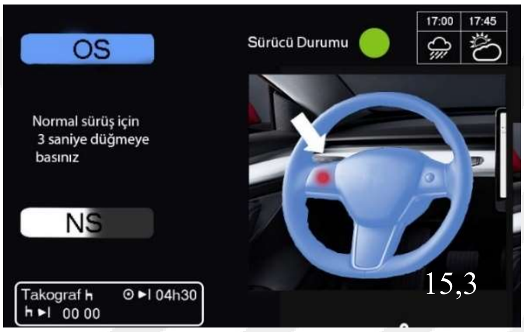


Otonom sürüş esnasında sistemin yapacağı manveraları sana ne zaman haber vermesini isterdin?

GRUP 5: DEĞİŞEN HAVA KOŞULLARI

Otonom sürüş esnasında hava koşullarında bir değişiklik olduğunda aşağıdaki ekranda hangi bilgileri, hangi uyarıları görmek seni rahatladırdı?





GRUP 6: KAPANIŞ SORULARI

Son olarak, uzun yolda dinlenebilmek, uyuyabilmek vs için otonom araca güvenebilir misin? Bu güveni sağlayabilmek veya arttırabilmek için aracın ekranında bize önerebileceğin başka bir konu olur mu?

GRUP 7: DEMOGRAFIK KAPANIŞ SORULARI

Eğitim durumunuzu belirtiniz

	Herhangi bir öğretim kurmundan mezun değilim
	İlkokul mezunuyum
	Ortaokula devam ediyorum
	Ortaokul mezunuyum
	Liseye devam ediyorum
	Lise ve dengi okul mezunuyum
	Yüksekokul/üniversiteye devam ediyorum
	Yüksekokul/üniversite mezunuyum
	Diğer

Bir yılda yaklaşık kaç kilometre çekici sürüyorsunuz?	
	0-15bin
	15-50bin
	50-100bin
	100bin'den fazla
Çekiciyi çoğunlukla hangi yollarda sürüyorsunuz?	
	Şehiriçi
	Şehirler arası, çğunlukla otoban dışında
	Şehirler arası, çoğunlukla otobanda
	Ülkeler arası
Günde ortalama kaç saat çekici sürersiniz?	
	9-10 saat
	9-10 saaatten az
Günlük aralıksız sürüş zamanınız ne kadardır?	
	Aralıksız 4-5 saat
	Şe4-5 saatten daha az
Cinsiyetiniz	
	Erkek
	Kadın
Yaşınız	

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