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User-Centered Approaches in Conventional and Autonomous Truck Design and Future Effects on Environmental Design

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Abstract

Meeting the world's increasing need for transportation today soon requires the development of autonomous vehicle systems. User-centered approaches in industrial design are crucial to advance technological, mechanical, and equipment specifications and provide effective driving experiences. This study analyzes conventional and new generation autonomous vehicles through user-centered design (UCD) and drivers' experiences. Turkish company BMC and the new truck series "Tuğra" are selected. Participants are truck drivers, designers, engineers, and specialists. Observations and face-to-face interviews investigated comfort, usefulness, usability, desirability, accessibility, credibility, findability, and value from the elements of user experience design within the truck, as well as users' awareness of UCD. Credibility and usability were among the highest-ranked principles. The participants provided valuable information for the design development of trucks, and ideas for future problems and solutions. Further multidisciplinary research that focuses on technical, as well as social and ethical issues is essential in this new and emerging area.

Keywords: *Industrial design, user-centered design (UCD), autonomous vehicles, truck design, truck interiors*

Geleneksel ve Otonom Kamyon Tasarımında Kullanıcı Odaklı Yaklaşımlar ile Çevrenin ve Tasarımının Geleceği Üzerindeki Değiştirici Etkileri

Öz

Dünyanın her gün artan ulaşım ihtiyacını bugün ve yakın gelecekte karşılaması için, otonom araç sistemlerinin geliştirilmesi hız kazanmıştır. Bu bağlamda, kamyon sürücüleri için endüstriyel tasarımda kullanıcı odaklı yaklaşımların, teknolojik, mekanik, ekipman spesifikasyonlarını geliştirebilmek için önemi büyüktür. Bu çalışmada geleneksel ve yeni nesil otonom araçlar kullanıcı odaklı tasarım ve sürücü deneyimleri anlamında incelenmektedir. Durum incelemesi olarak Türk BMC şirketi ve yeni kamyon serisi "Tuğra" seçilmiştir. Araştırmanın katılımcıları, kamyon sürücüleri, tasarımcılar, mühendisler ve uzmanlardır. Kamyon iç mekânına yönelik kullanıcı deneyimi tasarım özelliklerinden, yararlılık, kullanım kolaylığı, çekicilik, ulaşılabilirlik, güvenilirlik, bulunabilirlik ve değer kıstasları ve kullanıcıların kullanıcı odaklı tasarım kıstasları konusundaki farkındalığı, gözlemler ve yüz yüze röportajlar ile incelenmiştir. Kıstaslardan, güvenilirlik ve kullanılabilirlik en yüksek çıkan değerlerden olmuştur. Katılımcılar, kamyonların tasarımsal gelişimine yönelik değerli bilgiler ve geleceğe dönük sorunların çözümleri hakkında ipuçları vermiştir. Bu yeni ve gelişen alanda, ileriye yönelik, teknik konulara ek olarak, sosyal ve etik konulara odaklanması gereken multidisipliner çalışmalar yapılması önemlidir.

Anahtar Kelimeler: *Endüstriyel tasarım, kullanıcı odaklı tasarım, otonom araç, kamyon tasarımı, kamyon iç mekânı*

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1. Introduction

This study aims to reveal the transformation of a conventional transportation vehicle to not only a modern but also a technological and innovative vehicle in the light of the user-centered design philosophy. While many sources are covering UCD, and also UX and usability, which are UCD's supportive comrades, the concept of automotive design, even down to the basic distinction of what constitutes a commercial vehicle, does not have sufficient and qualified sources in the existing literature (Gladkiy, 2018). One of the complementary purposes of this study is being a source to the researchers who want to find comprehensive information about automotive history that is focused on commercial vehicles and their user-centered development of it.

The initial stage of the study started with questioning the differences between conventional and modern commercial trucks; will future changes only be limited to these vehicles being autonomous? Will this large-scale change involving the redesign of roads and the environment, the vehicle interior, the characteristics and qualities of future drivers, be only bound to autonomous system technologies? How will the education of designers and technical staff who will answer these numerous changes and provide real solutions be? Regarding the future of education appropriate for these problems and solutions, which research studies should be carried out in the automotive industry and academic fields? The specifications of conventional trucks and their missing or open to improvement points were the crucial enlightening indicators while comparing them with today's new technological autonomous trucks with the focus on UCD. Other criteria included psychological, ergonomic, and aesthetic design criteria that demand careful research and investigation, which can readily be comprehended through feedback from users. There is a lack of research regarding a comprehensive and multidisciplinary approach to truck design. A user-centered approach was the main approach for these analyses, which is focused on presenting what are the design essentials for conventional and autonomous trucks as well as their development process (IDEO.org, 2015). Existing literature and applications are a significant starting point and guide for this research together with analyzing and interpreting the processes of these sources thanks to professional knowledge and field research according to the user-centered design approach.

Transportation design, industrial design, user-centered design (UCD), autonomous vehicles, truck design, truck interiors are the main focal points in this study. The main research question is: What can be learned from a user-centered design assessment of autonomous truck interior design concerning conventional truck design? Sub-research question 1 is; what are the main differences and similarities between conventional and autonomous truck design in terms of user-centered design? Sub-research question 2 is; what are the role and effects of design for the transformation of conventional trucks to autonomous structures in the context of user-centered design? Sub-research question 3 is; what is the feasibility of a relationship between existing sectoral factors and planned truck transportation development in the future? The aim is to attempt to answer the questions within the context of the study.

1.1. Research Background

The automotive sector of today's world's existing circumstances is one of the most demonstrable examples of how technology plays an important role in our lives (Holweg, 2008). Moreover, it also shows us that we are not only dependent on it but also accept it as part of our daily lives (Jaafarnia and Bass, 2011). When it is taken into account, the speed of improvement of automotive technology, which started with the discovery of the wheel and has continued to today's autonomous vehicles in terms of user-centered design, it is not ignorable that the close and far future is going to experience this improvement acceleration more than the standard expectation of the whole world.

The definition of transportation style and solutions has changed from demand-driven to necessity, also product-based to user-based in the light of user-centered design throughout the previous centuries (Pillkahn, 2011). This study aims to put forth how this historical evolution and the human-centered process has taken place, where the commercial vehicles stand in this process, and how this technological development process affects positively or negatively the design, creation, and production periods. The final aim is to reveal how the truck design changing period and UX

adaptation to this process is applied to new products systematically, thanks to every discovery from the past to today (Quesenbery and Brooks, 2010). In addition, how will this transformation process develop in the future, and what are the expectations would be the supplementary questions that will ensure the integrity of this process.

1.2. Research Objective

First, it is aimed to make clear existing conventional truck design essentials for this study, after giving the necessary and detailed information about automotive history and its developmental progress from the past until today. UCD, user experience design, and usability are the crucial investigative tools for this process. Discussing existing commercial truck brands' autonomously designed vehicles and their concept vehicles in the light of user-centered design becomes another focused subject for this study. Revealing a design proposal for the transformation from the past to today of truck interior design, based on user-centered design, is the last and major aim of this research. These aims can be further elaborated as; To show the differences between existing conventional and autonomous truck design history and development process in the light of the user-centered design. Finding out the design essentials of existing autonomous truck interiors in the context of user-centered design. To collect user feedback from direct users of trucks for a more user-focused design. Creating a design proposal for the transformation of a conventional truck to an autonomous truck in regards to the vehicle interior in the light of the user-centered design.

2. Method

To clarify and reveal the development of the automotive industry and commercial vehicles' division, the study starts with a summary of the main developments in automotive history. The subject's details are researched specifically for commercial vehicle and truck design requirements. Truck design is examined with its structural details such as exterior and interior design features, with the focus on user experience design (Maccoby, and Maccoby, 1954). Moreover, the homologation criterion, which is decisive for the vehicle's main design volume to driver's use area's ratio, is examined. To better understand the effect of the contributions made by user-centered design, user experience, and usability to the whole development process of transportation and as the main subject of the study, they are explained in separate parts (Lumsden, 2004).

The design of autonomous vehicles and questioning its contribution to transportation systems in general as well as to truck-specific examination is detailed in the ongoing process of the study. Market research of existing companies is analyzed in the light of UCD and UX, to discover the main strategies and criteria for the transformation of a conventional truck structure to an autonomous one. While creating this deduction the first users of trucks are get involved in the subject. The critical points for truck design, truck accidents, and homologation requirements were analyzed. Finally, further implications regarding how the study can be advanced for researchers as well as designers are offered.

2.1. User-Centered Design, User Experience Design, and Usability

The essential aim of UCD is to research for better design, not only for a few people but also for the extensive determined community (Gasson, 2003), and a philosophy that puts the user in the center of the design and development process (Kirstin, 2013). UX Design is a comprehensive discipline that aims to create more beneficial and value-added products. It also aims to contribute not only to the final products or services but also to the creation and improvement process as well. Having an interdisciplinary method in addition to a multicultural point of view would be supportive of a developmentally oriented UX Design, as seen in Figure 1 and Figure 2, while it would not cause focus diffraction (Ferreira, 2017). Usability is the extent to which a system, product, or service can be used by specified users to achieve specified goals, with effectiveness, efficiency, and satisfaction in a specified context of use (ISO, 2014).

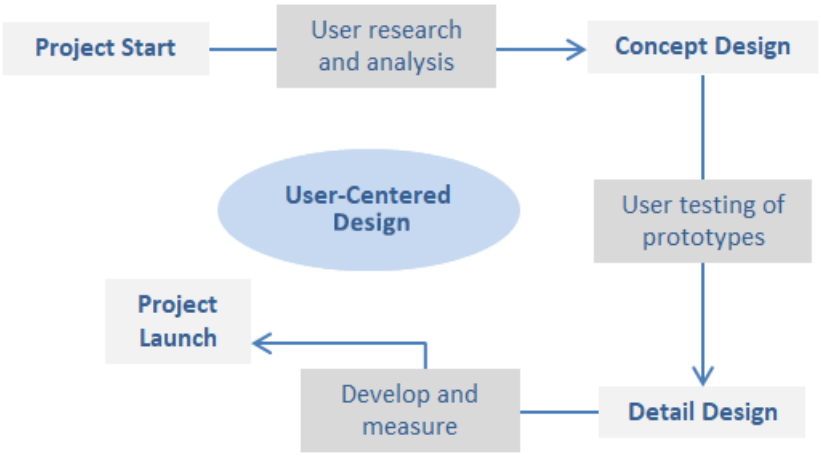

Figure 1. UCD Development Structure (Drawn by authors, adapted from Gladkiy, 2018)

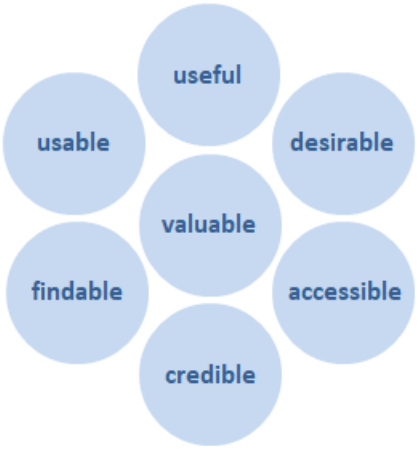

Figure 2. The UX Honeycomb (Drawn by authors, adapted from Morville, 2014)

2.2. What is Autonomous Technology?

To answer these requirements and also changing world conditions, there are many technical, systematic, engineering, and designing developments that have been implemented thanks to the technological development of the automotive industry. Advanced Driver Assistance Systems (ADAS), is one of the most important comprehensive developments for today's automotive industry. The primary aim of these systems is to guide the driver and provide usage ease during the driving time (Frost and Sullivan, 2016). Furthermore, providing a pleasurable and comfortable driving experience is another essential target for it. Before moving on and getting more details about ADAS, it should be known that ADAS took place thanks to Driver Assistant System (DAS) (Lewis, 2017). Autonomous Mobility is concerned about: safety, efficiency, environmental objectives, comfort, social inclusion, accessibility (ERTRAC, 2017).

2.3. Method

Interviews were considered to be the most suitable instrument for the consistency of this study. Not only collecting qualitative data was aimed at doing these interviews for the study but also collecting quantitative findings was believed to be the best method for giving clear expression. The qualitative data, which mostly relied on face-to-face interviewing with the drivers, produced unexpected contributions to the research's course of events. A Likert Scale was used to collect and assess data more readily. In addition to the experienced drivers as participants, other educated profiles such as industrial designers, engineers, design specialists were also included in other participant groups to collect various perspectives for the research. The main aim was to reveal their expectations about the sector and their harmonizing approach in line with their personal professional backgrounds and their ideas on future trends (Walker and Stanton, 2015).

Interviews with BMC Truck users, who used both the old and more recent "Tuğra" models, along with company experts, who are working as Industrial Designers, Engineers, Design Specialists, Department Managers, and the General Manager, were applied to collect data for the study's method chapter. Due to the continuing COVID-19 Pandemic, while all the interviews with truck drivers were conducted face to face, the other experts' interviews were conducted using e-mail sharing and face-to-face group explanations to prevent any health risk. After taking the required permission from the company's related departments and authorities, the interviews with drivers were conducted in January 2021 on three separate occasions. Each session with a participant took between 40 minutes to one hour. According to the final calculation, the interviews were carried out on a total of 20 truck drivers; In addition to this number, 46 experts completed the interviews.

2.3.1. Case: BMC Automative

BMC was established in 1964 in Izmir, Turkey. The company has a remarkable history in the nation's automotive industry. As Küçükerman (2008) mentioned in his book the company produced its first licensed vehicle the "TM 135" in 1966. Light commercial vehicles constituted most of the product range of the company for a defined period. Later, during the "Leland 30's" vehicle family production period, the "TM 100 and TM 140" vehicles were produced. The company developed itself after the initial development period by arranging productive investments and co-operations. After the Land-Rover production agreement, the "Volvo-Yavuz" production gained speed at the Company. Thanks to the joint work with Cummins, the legendary trucks called "Fatih" started to be produced. After some time and changing dynamics, some administrative alterations happened in the company. Later, Çukurova Holding became shareholders in the company, and as a result, new vehicle models were included in the production plans. After a long time, today the company has a new managerial structure and product range (Küçükerman, 2008). BMC serves both the commercial vehicles sector and the defense industry nowadays. Commercial vehicles consist of city buses and heavy trucks. A design study was conducted together with designers and engineers who created the company's new family of trucks which is called "Tuğra".

BMC's previous trucks, the "Professional Series", were designed by the Italian design team Pininfarina. The new truck family which is called "Tuğra" shown in Figure 3, is a product of a co-operative study with BMC's in-house industrial design and engineering teams with outsourced design and engineering teams such as Design-um and Infotron. The exterior design of the truck preserves some characteristic features from the previous truck models of the company. A variety of user feedback was collected to present better-equipped vehicles to the market throughout the designing process of Tuğra.

Figure 3. BMC New Tuğra Truck, 2021 (BMC Otomotiv Sanayii ve Ticaret A.Ş., 2021)

3. Results

It would be correct to say according to answers to interview questions; the primary user of the trucks are aware of the importance of UCD essentials integration to their vehicle design even they do not know the academic terminology within the approach. At the same time, while the majority of the engineers and design specialists are informed about UCD principles and their importance for designing a new vehicle, most of the time they could not make sufficient research also apply its required factors to the vehicles because of the project's budgets or deadlines. The results can be examined in Figures 4-13.

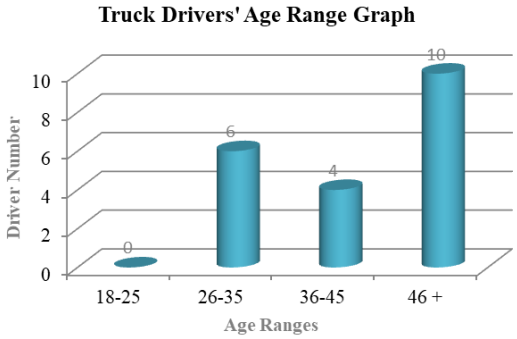

Figure 4. Truck Drivers' Age Range

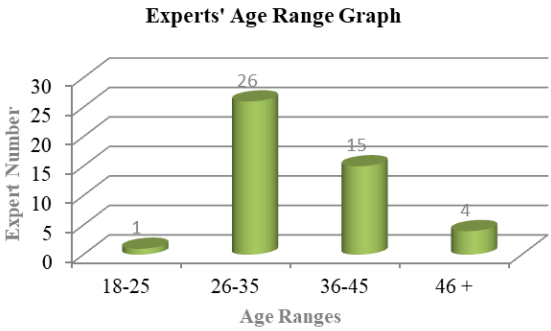

Figure 5. Experts' Age Range

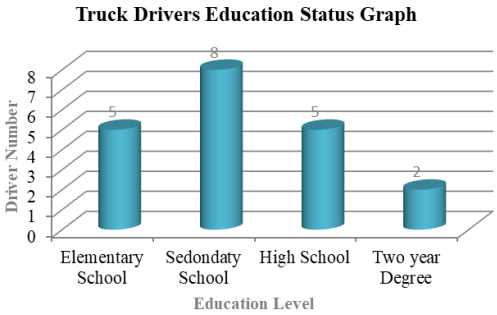

Figure 6. Truck Drivers Education Level

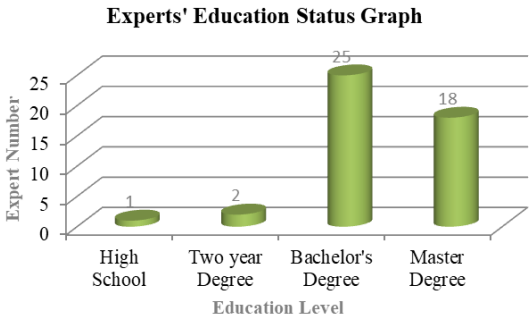

Figure 7. Experts' Education Level

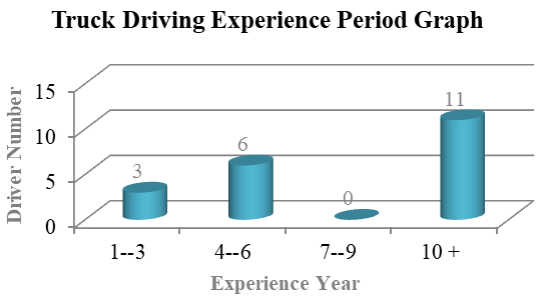

Figure 8. Truck Driving Experience of Drivers

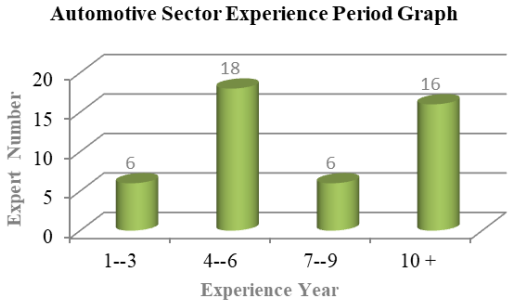

Figure 9. Automotive Sector Experience of Experts

What is the UCD relation between truck users and drivers according to the interview results? What are the key findings of the interviews?

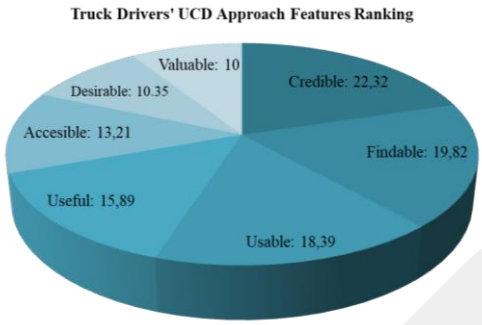

Figure 10. Truck Drivers' UCD Approach Features

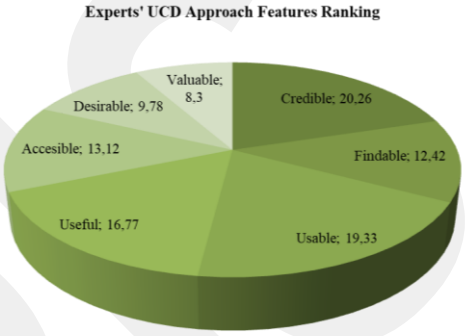

Figure 11. Experts' UCD Approach Features

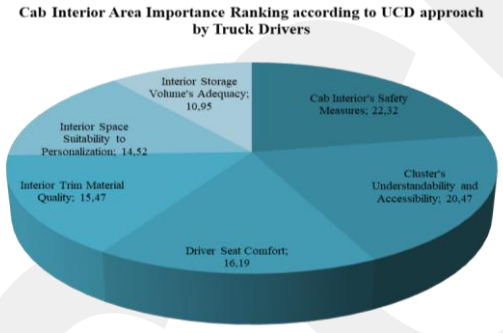

Figure 12. Cab Interior Importance Ranking according to UCD Approach by Truck Drivers

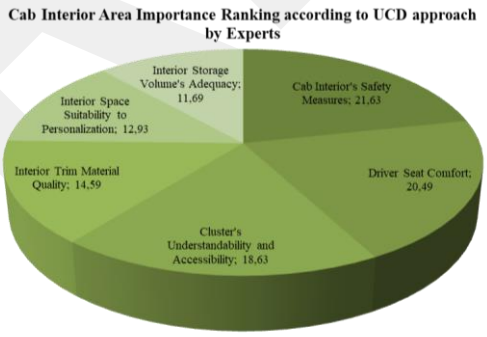

Figure 13. Cab Interior Importance Ranking according to UCD Approach by Experts

It was proposed to take direct and indirect findings to contribute to collecting logical answers to the question of "What can be learned from a user-centered design assessment of autonomous truck interior design in comparison to conventional truck design?". Truck drivers were chosen as prior-direct users of the trucks, which is the production under examination, to indicate user-product relationships as a basis of collecting information about the UCD approach. The interviews helped interactively give efficient information.

4. Findings

According to this research, one can state that the user-centered design approach and its integration into the trucks, is one of the most effective tools for achieving innovative, beneficial, and promising trucks for the future. These essentials are collected first from the user, the truck driver in this study, and compared with experts' opinions. The users' desires, needs, and habits are crucial factors for being reference points to the designers, regardless of the vehicle is conventional or autonomous. It would be easily said that the truck driver's experiences and comments reveal and contribute to design essentials for autonomous trucks as the user. Understandability, perceptibility, acceptability

were found to be some of the effective essentials for truck design, especially throughout the transformation period for conventional to autonomous trucks.

4.1. Findings on the Main Research Question

The main research question asked what could be learned from a user-centered design assessment of autonomous truck interior design referred from conventional truck design. For truck drivers, the interior design of a truck is equally significant to the design of a house and must be as efficient. UCD essentials directly serve how this volume would be designed effectively for drivers. While conventional trucks are today's vehicles, autonomous trucks would define our future mobility. The important point is to catch their common design essentials based on UCD. The design of usable, useful, desirable, accessible, credible, findable spaces would be a direct and beneficial source for reaching consistent design and technology transformation between conventional and autonomous trucks. Putting the user at the core of design research requirements needs to be at the core, for both conventional and autonomous trucks.

4.2. Findings on the Sub-Research Questions

What are the main differences and similarities between conventional and autonomous truck design with a focus on user-centered design? Digitalization is the main factor for differences between conventional and autonomous trucks. While in conventional trucks, nearly whole instruments and commands like steering, braking, mirror control, or menu navigation are controlled by drivers thanks to the physical equipment; in autonomous trucks, these features are managed by the brain of the vehicle, according to autonomy level. For drivers, the effectiveness of the used area is the most important factor to be considered both for conventional and autonomous trucks. The user's requirements, desires, and evaluations for better vehicles are the common consideration for both truck types.

What is the role of design in the transformation of the conventional truck to autonomous structure in the context of user-centered design? Questioning which design is better and how the design would be more effective are the major considerations of design to provide and present innovative vehicles to its users. These inquiries are a prior supporter of the transformation of the conventional truck to autonomous truck. Finding a path for presenting the new technology to its user necessitates understanding the user while acknowledging the needs of the business. With regards to the realistic predictions for the future, according to the literature review, evaluation of the sect, and the interview results, one could state that the autonomy integration to today's existing transportation organization requires more time. Naturally, this interpretation directly depends on the geographical and cultural context. Technical features and abilities of autonomy, environmental factors, regulations, and sector adaptation research continue to develop. Autonomy is expected to be the new approach to mobility, but at the same time, it should be accepted that the time is required to ask and answer several questions related to design, as well as social, political, and ethical issues.

While approaching the topic, because of usage habit variations, each driver has an individual interpretation method even if the results are the same. This can be noted as a beneficial contribution for further studies. The truck's interior is the living space for a truck driver while acting as an office. The office needs to be safe as well as being comfortable. Moreover, the volume should allow for ease of access to any function while also making the driver feel special in it. As a user and an owner, a driver contends that he or she has the right to desire these factors. At this level of the evaluation; industrial designers, together with engineers should be responsible for answering these user-centered requirements.

5. Conclusion

Even though a few factors' percentages showed some variations, according to the interview results, safety and comfort-related items are becoming a topic of more concern for experts and drivers. The foreign branded trucks' strengths are accepted by both of the participant groups, according to the interviews. Drivers and experts determined that the common brand "Volvo" was the most successful in terms of its trucks. Safety of both the exterior and interior of the truck, driver usage ease, interior

volume efficiency, clean and understandable style design, advanced technological features are the most important factors according to all participants.

Thanks to the autonomous driving and technology-related questions in the interview, it can be stated that existing truck users could not establish a bond with today's driving environment and habits, while experts have not yet accepted that these systems are inevitable for our future mobility. From the perspective of truck drivers, a truck's interior should answer the users' wishes with utmost usability and pleasure. Long distanced roads, environmental problems, negative external factors already have sufficient power to make their job more difficult, and therefore, a truck should be comfortable, both if it is conventional or autonomous.

This research aimed to provide more concrete evidence for industrial designers, engineers, or any other discipline researchers who wish to collect and evaluate truck industry facts and information on autonomous trucks and their interaction with traditional ones, thanks to the UCD approach. Further implications may be to study; "Autonomous technology integration according to geographical location", "Users' perception and approach to the transformation from conventional to autonomous mobility" or "Differences and similarities between autonomous truck designers' working methods in comparison to conventional truck designers' methods". There is still much to learn regarding how user-centered approaches can contribute to the truck design. Not only are these technical issues, but also social and ethical ones that will need to be studied using multidisciplinary methodologies due to their complexity.

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Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article. There is no conflict of interest.

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