The Truck Buddy: Towards a Mood-Based Truck Driver Assistance System

Short Paper

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Abstract

Road freight transportation presents a vital element of our economies while heavy-duty truck drivers (HTDs) make use of emerging technologies for operations. However, the work environment of HTDs is yet characterized by time pressure, social isolation, and safety concerns. Surprisingly, scientific knowledge about driver's well-being and mood enhancement scarcely exists in the context of IS. This paper addresses the research gap by the exploration of a mood-based truck driver assistance system (MTDAS) – the "Truck Buddy". We establish a design science research (DSR) project to explore the requirements and design objectives of an MTDAS based on data from a comprehensive literature review and expert interviews. Our results indicate that a context-sensitive MTDAS can assist HTDs well-being by five design objectives enabling system integration, communication, mood-detection, automated driver support, and the provision of driver feedback. This first iteration step constitutes a foundation for further evaluations and developments within a continuous DSR process.

Keywords: Road freight transportation, heavy-duty truck driver, assistance system, design science research, context-sensitive system

Introduction

The International Road Transport Union has emphasized that a driver shortage is "a global issue" (International Road Transport Union 2021) that poses a serious risk to the supply of goods. Occupational heavy-duty truck drivers (HTDs) work in a challenging environment, performing complex tasks while facing pressure due to work hours, social isolation, safety requirements, and the increasing use of information systems (IS) to manage operations efficiently (Boyce 2016; Williams et al. 2017). Given the nature of their jobs, HTDs suffer from physical exhaustion, social recognition, and psychological stress, with serious negative effects to their health (e.g., depression), lifestyle, and long-term well-being (Crizzle et al. 2017;

Kemp et al. 2013; Shattell et al. 2010). Additionally, work-related stress leads to low motivation (Ji-Hyland and Allen 2020) and road safety concerns (Perttula et al. 2011). Therefore, to attract professional drivers, supporting HTDs' well-being should become a key objective in the course of digital transformation for the trucking industry. To address the situation of HTDs, we aim to explore the requirements and design objectives for the development of a mood-based truck driver assistance system (MTDAS), which has the potential to indirectly enable improvement of drivers' overall well-being by reducing stress in the work environment. Based on the design objectives, we believe an MTDAS can support HTDs on an individual and organizational level through mood detection capabilities, supporting the idea of a so-called "Truck Buddy".

Scholars have already discussed the improvements of driving experiences in private vehicles, for example, through the optimization of in-vehicle IS (e.g., Mihale-Wilson et al. 2019) or affective interaction by driver-assistance systems to enable autonomous driving (e.g., Kukkala et al. 2018). Assistance systems for professional truck drivers have been investigated, predominantly addressing driving behavior (e.g., Winlaw et al. 2019) and road safety aspects (e.g., Kirushanth and Kabaso 2018), with the objective to increase efficiency, while published research on mood-oriented assistance for truck drivers is sparse. Horberry et al. (2021) designed a human-centered in-vehicle system to detect fatigue and distraction in truck drivers based on real road situations. However, the system did not focus on the drivers' well-being as an overarching goal. To the best of our knowledge, despite the high potential of existing assistance systems for drivers, a context-sensitive assistance system that focuses on HTDs' moods while ensuring optimal transport operations does not currently exist. Given the enduring pace of digital transformation that continues to vastly reshape the traditional employment of drivers in the road freight industry, we think that such an approach is of high value to investigate innovative technologies for future work. Although insights about digital workplaces (Baumgartner et al. 2021) and mental health in future technology-driven workplaces (Johnson et al. 2020) are investigated in the mobility domain, specific design knowledge of a context-sensitive assistance system through the lens of IS research is yet unexplored in the context of commercial truck drivers.

Against this backdrop, our study constitutes the first effort to explore the requirements and design objectives for the development of an MTDAS. Consequently, developing a driver-centered approach to achieve mood optimization requires further detailed analysis due to the existing connections between HTDs' moods and their work environment. The MTDAS assists HTDs by recognizing emotions through speech, phonetics, and additional input parameters from relevant information and communication technologies (ICTs) to recommend actions, improve drivers' moods, and enhance their well-being. For this reason, this paper represents research in progress and addresses a novel approach by exploring the requirements and design objectives of an MTDAS using the following research question (RQ):

What are the requirements and design objectives for a mood-based truck driver assistance system for professional drivers of heavy-duty trucks in road freight transportation?

To answer this research question, we initiated a design science research (DSR) project to derive design objectives for the MTDAS based on a comprehensive literature review and expert interviews. Within the context of truck driver assistance systems, we explore an innovative research topic and define the most effective mood-based assistance system for HTDs. The MTDAS achieves optimal well-being while respecting the drivers' operational tasks, regulation and compliance boundaries, the IS in use, and other ICTs present in the truck driver's cabin. In Section 2, we establish the background related to the topic. Thereafter, in Section 3, we describe the research design related to the DSR paradigm applied in this paper. Subsequently, we derive the requirements and design objectives for the MTDAS in Section 4. Following our findings from the study, we discuss the results and provide an outlook for future research in Section 5.

Background

Professional demands of HTDs are variable, as drivers coordinate with dispatchers and fleet managers to ensure safe driving and smooth vehicle operation. During transport operations, drivers are responsible for vehicle maintenance, time management, and verbal communication, leading to a myriad of tasks related to customer service requirements and legal obligations (Ji-Hyland and Allen 2020). To manage truck fleets efficiently, trucking companies equip their fleets with telematics systems that assess driver performance regarding economic vehicle handling based on specific metrics (e.g., fuel consumed) (Winlaw et al. 2019). Furthermore, telematics systems obtain driver data to support road safety by providing drivers with feedback on their driving styles with the aim to improve their behavior (Kirushanth and Kabaso 2018). This data offers opportunities to manage vehicle profitability and ensures road safety by analyzing driving behavior. Moreover, mobile applications appear to enhance transport workflows between dispatchers, drivers, and customers. For instance, drivers receive customer order instructions, and mobile applications provide details for the next truck stop, including routing information.

Since HTDs are present with information to enable them to perform operational tasks in a complex work environment, advancements through the use of innovative technologies may support driver moods (Sweller 1988). However, considering HTDs' high cognitive load, the stress-inducing effects of the application of IS during operation may lead to technostress (Brod 1982). Hence, the level of technostress of individual HTDs is of interest in order to apply IS to their benefit. HTDs' well-being should be considered as a subjective factor and is affected by moods (Yardley and Rice 1991). Moods influence behaviors related to motivation and performance, which have been conceptualized as frames of mind (Morris 1989). Nevertheless, the primary purposes of the IS already in use are process efficiency and vehicle safety, they do not focus on the driver's emotional state or subjective well-being. A mood-detecting system may simplify operational tasks by instantly adjusting technologies within the truck driver's cabin to support transport operations in dynamic transport scenarios according to the driver's emotional state. Hence, research offers a wide range of possible sensor inputs (Dzedzickis et al. 2020) for mood detection based on artificial intelligence (AI). Auditory input seems rich in underlying emotional cues, as humans are able to recognize emotional states more accurately when limited to their sense of hearing in contrast to using all senses (Kraus 2017). To do this, speech- and phonetics-based approaches are promising for detecting underlying changes in the driver's mood via AI, which are taken into consideration for the design of the MTDAS proposed in this paper.

Research Design

To explore the design of MTDAS, we apply a DSR approach, which provides structured methods for the development of artifacts from the identification of a problem to the implementation and application. Our study follows the approach of Sonnenberg and Vom Brocke (2012), who frame the phases *Identify Problems*, *Design*, *Construct* and *Use* and suggest an evaluation between each phase. Currently, we have completed the steps to justify our research problem, explore the design requirements, and arrive at the design objectives for a dedicated MTDAS (Figure 1, colored gray). To this end, our contribution marks the first iteration in an ongoing design process that aims to (1) provide a solution relevant to our identified problem, described in the introductory section, (2) derive general design objectives to guide future projects, and (3) present a design foundation for validation in subsequent iterations. In essence, we have identified requirements and design objectives to answer the RQ and intend to continue our research according to the subsequent steps in the DSR process.

For the literature review, we queried the search term *(optimization OR optimize OR improvement OR improve) AND (mood or sentiment or happiness) AND 'truck driver'* in seven bibliographic databases: SpringerLink, AISeL, ScienceDirect, Wiley, IEEE, ACM, and JSTOR. We initially identified nine relevant articles that covered driver well-being or assistance systems. We employed forward and backward searches, leading to the inclusion of further articles that focused on professional drivers. Finally, we analyzed 17 papers using a concept matrix (Webster and Watson 2002) to identify requirements for the MTDAS from the scientific literature. To gather additional data from practice, we invited experts from various enterprises that operate in the road freight forwarding industry. The experts are associated with the profession of HTDs and their work environment. To facilitate the selection of experts, we contacted a regional network of around 80 enterprises in the logistics industry. We introduced our topic to all network members by sending letters and asked for their interview participation. In this way, we recruited 11 experts for our interviews. The experts had work experience ranging from 6 to 31 years in positions such as truck drivers (four experts), fleet managers (five experts), and road freight business managers (two experts). To collect qualitative data, we developed a semi-structured interview with 14 questions addressing five sections: (1) introduction to the topic, (2) relevance of the identified problem, (3) motivation to address the problem, (4) opportunities and actions for improvement, and (5) conditions for the application of driver-centered technologies. We conducted the interviews in German and recorded them via a web-based online conference system and by phone, with conversations lasting between 27 and 54 minutes. Based on the transcribed audio records, we performed a qualitative content analysis (Mayring 2014) and used the software MAXQDA to elicit requirements. To identify relevant requirements from the collected data related to our topic, we used deductive category formation (Mayring 2014) for the structured parts of the interview. Additionally, inductive category formation (Mayring 2014) was used for the unstructured parts of the interview. To obtain final design objectives, one researcher with expertise in technical implementation coded the entire data set and another researcher with professional experience in road freight transportation refined the identified categories. Overall, we arrive at the design objectives for a proposed MTDAS and the research design illustrated in Figure 1 guides us throughout the DSR process. We present our exploration of requirements for the development of an MTDAS in the next section.

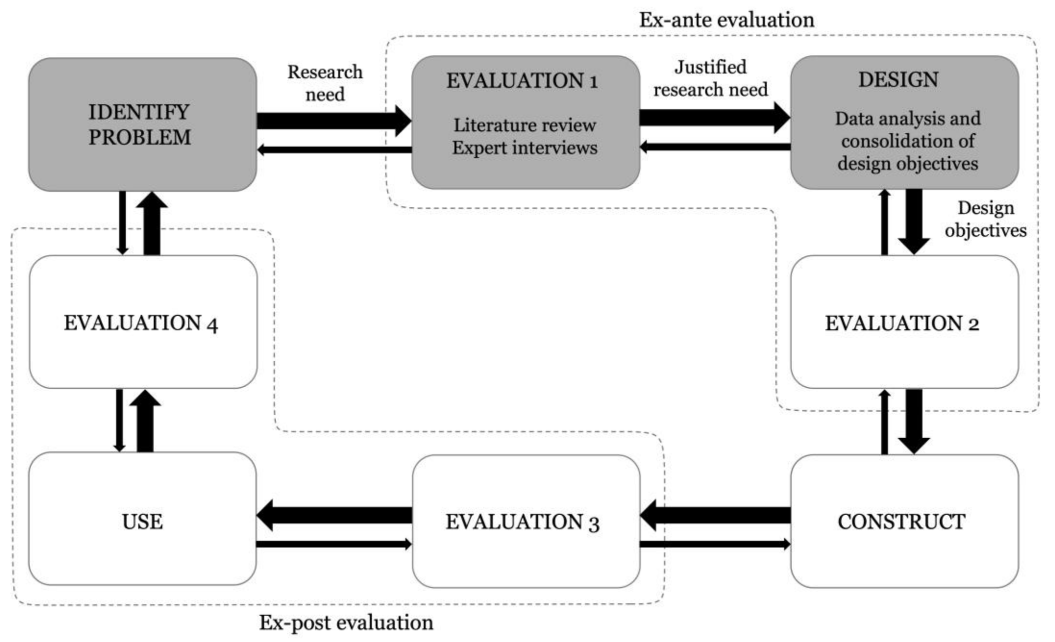

Figure 1. Research Design (based on Niemöller et al. 2016; Sonnenberg and Vom Brocke 2012)

Exploring the Design of a Mood-based Truck Driver Assistance System

Deriving Requirements from Literature Review and Truck Driver Experts

To explore the requirements for the design of an MTDAS, we present the results of our analysis from the collected qualitative data based on existing literature (L) and expert interviews (E). Overall, these requirements are focused on improving HTDs' moods while ensuring safe vehicle operation and seamless transport operations. Table 1 contains the concept matrix that maps the analyzed articles to the derived requirements for the MTDAS. The literature review reveals a need for improved means of communication for the driver as it specifies the need to *provide means for enhanced social support among colleagues or through social circles* (**L1**) and *facilitate enhanced communication between the driver, dispatchers, and fleet managers* (**L2**). In terms of the user interface for a driver assistance system, literature suggests fostering *context-sensitive interactions to fit driver state* (i.e., mood, fatigue, stress) (**L3**) and *providing an anthropomorphized conversational agent* (**L4**). Moreover, a call for smart recommendations, i.e., to *make context-sensitive action recommendations* (**L5**) *and provide context-sensitive recommendations for the driving and break schedule* (**L6**) in particular, can be inferred from existing research contributions. Furthermore, the MTDAS should *enable the integration of existing IS* (i.e., telematics, entertainment) (**L7**) *and provide the analysis of physiological and vehicle data to assess driver state* (**L8**).

The results from the expert interviews are presented in Table 2 and show the identified categories (E1 – E13). The numbers state how often a requirement was mentioned by the experts, and the range between 1 to 3 indicates an alignment to our topic of MTDAS. From the interviews, we derived that *communication with dispatchers and fleet managers* (**E1**) is a key activity for HTDs due to dynamic transport situations such as delays caused by traffic or vehicle issues. Moreover, *transport information* (e.g., order details) *and vehicle data* (e.g., fuel metrics) (**E2**) are required for driver assistance to improve driving performance and to support customer transport order handling. Furthermore, *driver-related health information* (e.g., fatigue, stress) (**E3**) need to be considered as an input for the MTDAS. *The integration of IS elements supporting digital transport management* (e.g., digital tachograph) (**E4**) is common practice to receive information from different ICTs used by drivers. Additionally, *driver-specific preferences for entertainment systems have a positive impact on their moods* (e.g., preferred music) (**E5**) to support subjective well-being. Since HTDs use a variety of mobile applications (e.g., order management apps), the need for a *direct connection to facilitate data exchange and notifications was identified* (**E6**). An MTDAS must *measure driver satisfaction on specific transport routes* (**E7**), which enables *the detection of driver issues and possible difficulties at customer sites* (**E8**) based on the driver's voice. *Improvements in the atmosphere within drivers' cabins can be achieved by controlling light* (e.g., specific colors) (**E9**) *and driver seat functions* (e.g., massager) (**E10**). To support obligatory vehicle checks and inspections (e.g., obligatory safety checks prior departure), *documentation can be recorded by voice to ensure operational safety* (**E11**). Moreover, *the system must be capable of informing drivers about details of the truck diagnostics and vehicle status* (**E12**). At all times, the MTDAS must facilitate *driver-controlled mood registration aligned to data privacy and compliance to control information exchange* (**E13**).

Specification	Du et al. (2020)	Ahmed et al. (2019)	Fank et al. (2019)	Fank and Lienkamp (2019)	Wijngaards et al. (2019)	Bennakhi et al. (2017)	Crizzle et al. (2017)	Williams et al. (2017)	Apostolopoulos et al. (2016)	Klemke et al. (2014)	Kemp et al. (2013)	Iqbal et al. (2011)	Perttula et al. (2011)	Shattell et al. (2010)	Liu et al. (2009)	De Croon et al. (2005)	Adams-Guppy and Guppy (2003)
L1				x	x			x	x	x		x		x			
L2								x			x						
L3		x				x	x										x
L4			x	x													
L5		x				x	x					x				x	
L6	x						x						x				x
L7						x				x							
L8		x				x									x		

Table 1. Results from the Literature Review

Based on our analysis, we further consolidated 11 meta-requirements (MRs). An MTDAS must *provide communication between transport operation stakeholders* (**MR1**, based on L2 and E1) and *provide support for social interaction* (**MR2**, based on L1 and E3). Since HTDs are hired internationally, the system must *operate in the driver's native language* to achieve smooth communication and avoid issues from languages (**MR3**, based on L3, L4, E2, E3, and E12). With a focus on driver's health, the *supervision of drivers' physical states* is relevant for the system (**MR4**, based on L3 and E3). Moreover, *driver recommendations for enhanced driving style should be provided to achieve economic and ecologic driving performance* (**MR5**, based on L5, L6, and E2). The detection of mood levels enables the *control of actuators according to individual driver preferences* (**MR6**, based on E5, E9, and E10). To consolidate information from other IS and in-vehicle ICTs, the *integration of technologies appears to be a crucial factor for drivers to effectively manage vehicles and transports through a "single point of access"* (**MR7** based on L7, E4, and E6). The experience of drivers in practice may reveal *valuable operational insights from individual ratings of transport situations* (**MR8**, based on E1, E7, and E8). Additionally, HTDs can *gather customer-specific information via voice records or incorporate compliance tasks* (**MR9**, based E1, E8, and E11). Besides, *the analysis of driver data and vehicle data* (e.g., work time, brake status) *create the basis for the assessment of driver mood by the MTDAS* (**MR10**, based L6, L8, E8, E7, and E12). To make the handling of mood-related data possible, *individual data privacy is to be ensured for truck drivers via personal control* (**MR11**, based on E13).

Expert	Expert Work Exper.	Expert Position (Title)	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
1	13 yrs	Fleet Manager	3	2	2	1	1		1	1	1	2	2	1	2
2	31 yrs	Truck Driver	2	2	1	2	1	1		2	2	2	1	1	3
3	8 yrs	Transp. Manager		1		1	1		1	1	1		1		1
4	9 yrs	Managing Director	1	2	1	1		1		1		1	1	1	1
5	36 yrs	Truck Driver	1	1			1	1		1	2		1		1
6	29 yrs	Truck Driver	1	2	1	1	1		1	1	1	1	2		1
7	20 yrs	Fleet Manager	2	1			1	1		1	1	1	1	1	1
8	6 yrs	Truck Driver	1	1		1	1	1			1	1		1	2
9	11 yrs	Managing Director	1	1						1	1	1	1	1	1
10	6 yrs	Truck Driver		1		1	1	1		1			1	1	1
11	27 yrs	Fleet Manager	2	1	1	2	1	1	1	1	2	2	2	1	2
Total Count			14	15	6	10	9	7	4	11	12	11	13	8	16

Table 2. Results from the Truck Driver Expert Interviews

Figure 2 presents a detailed overview of the relationships between requirements from the literature (L1 – L8), the truck driver expert interviews (E1 – E13), and the derived meta-requirements (MR1 – MR11). For each requirement from the literature and the interviews, the number shown indicates its frequency of occurrence in our analysis. The connections between the meta-requirements and the derived design objectives for the MTDAS are also illustrated. In the next section, we elaborate on the design objectives in more detail.

Deriving Design Objectives for a Mood-based Truck Driver Assistance System

Overall, we derived five design objectives (DOs) based on a series of workshops within the research team – relying on expertise in the fields of IS, psychology, industrial engineering, and cognitive science as well as professional experience in logistics and software engineering. The first DO is to create an *interface to enable the seamless integration of systems* (**DO1**). Based on the interface with telematics systems, the MTDAS can process data via a control area network (CAN) bus module to and from vehicle subsystems. To meet the first design objective, additional IS interfaces (e.g., for mobile applications) are necessary. To make use of the data for mood enhancements during transport operations, *support of communication in the driver's native language* is the second design objective (**DO2**). Consequently, HTDs are able to interact socially with driver colleagues, with back-office personnel, and with private contacts (MR2) to reduce emotional distress. The HTD can *release the phonetic-based mood value into the freight ecosystem via the interface, but only in accordance with data privacy principles* (**DO3**). Consequently, HTDs accept the MTDAS if individual data privacy and legally compliant data handling (e.g., adherence to data protection regulations) are ensured. Then, the determination of mood according to the driver's physical state can be realized (MR4). Based on the quantified mood value and the state of the vehicle and its environment, *automated driver support should be integrated into the MTDAS related to phonetic, freight transport, and vehicle data* (**DO4**). Hence, HTDs are capable of managing operational trucking efficiently by receiving assistance related to verbal communication (MR3). This comprises supervision of the HTDs' physical state (MR4), recommendations from driving operations (MR5), and direct control of actuators in the truck driver's cabin (MR6) associated with data analytics (e.g., vehicle performance metrics) for mood assessment (MR10). Furthermore, there is an opportunity *to provide voluntary feedback to stakeholders based on records* (e.g., voice texts from safety checks) *and the driver's experiences* (**DO5**). Individual HTDs are prompted proactively to inform fleet managers or dispatchers about circumstances they experience while they are driving, are parking in remote locations, or are being at the customer's site (un)loading freight. Thus, HTDs' experiences include incidents from operations, ideas for improvements, and any comment HTDs would like to give to managers in order to feel acknowledged and operationally encouraged while fostering drivers' commitment at work. In essence, this should have long-term positive effects on transport planning, vehicle operations, freight equipment, and infrastructure.

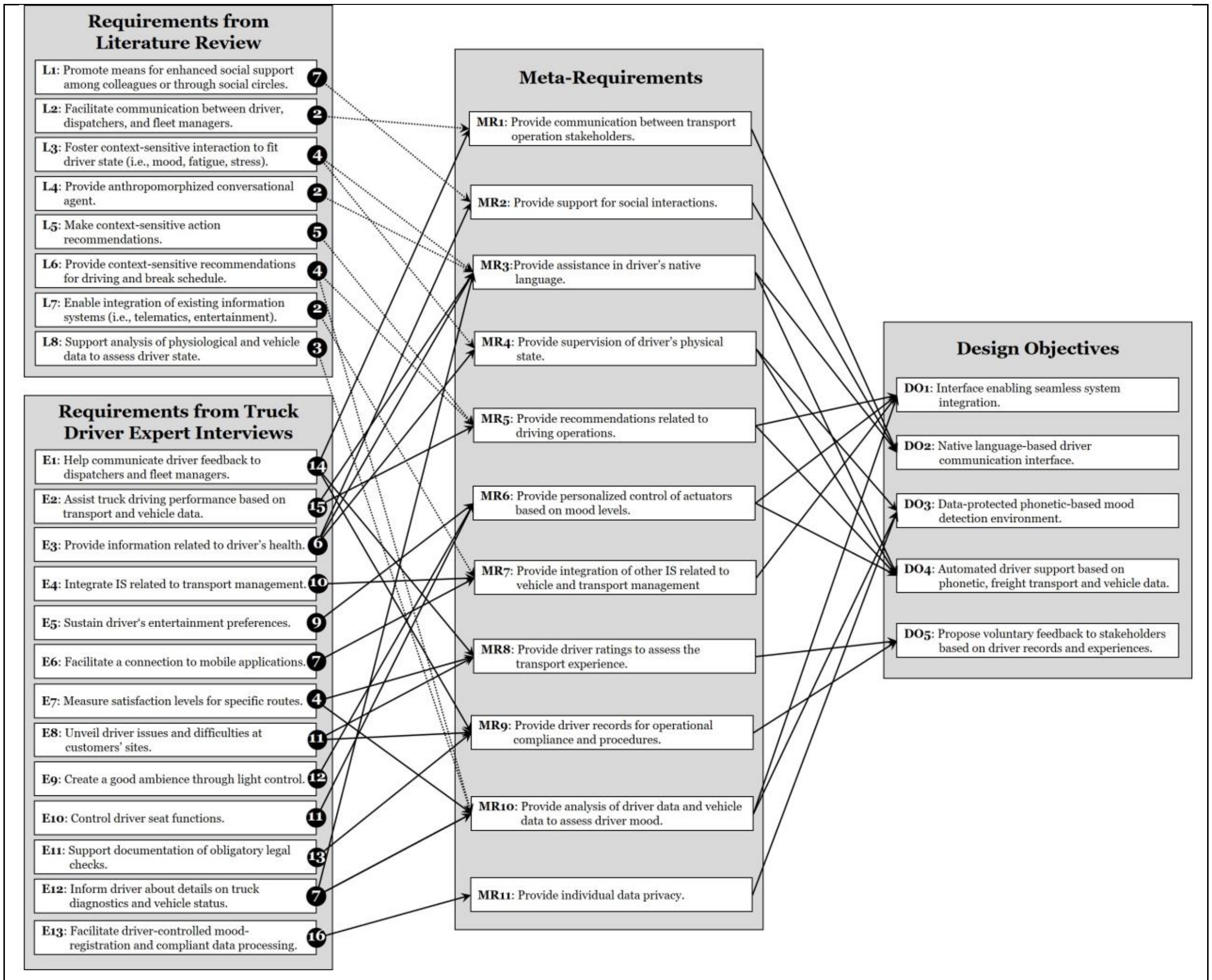

Figure 2. Derived Meta-Requirements and Design Objectives for the MTDAS

Discussion and Outlook

This contribution details our initial efforts in an ongoing DSR project to develop a driver-centered MTDAS that optimizes HTDs' moods. By reviewing the scientific literature and interviewing 11 experts, we studied the work environment of HTDs and confirmed the need for innovative IS to enhance driver mood. From the collected data, we derived 11 meta-requirements, further condensed them into five design objectives, and thereby answered our RQ. As the derivation process from meta-requirements to design objectives was based on the researchers' perspective, the next step is the evaluation of the design objectives (Evaluation 2 in the DSR process depicted in Figure 1), which is currently in conception. Here, not only practitioners and drivers but also experts in the field of industrial and health psychology may add valuable insights. Since we intend to complete the whole DSR process over the course of this project, the findings presented in this paper are the starting point for the future design and continuous evaluation of the MTDAS. Overall, practitioners recognized mood aspects as key factors to promote permanent employment of drivers and keep them healthy and motivated. IS literature predominantly discusses the technological nature of work environments and its effect on productivity and cognition, for example, by various modes of task-related information provision according to cognitive fit (e.g., Vessey 1991) or by managing cognitive load (Ortiz de Guinea 2018). However, few IS contributions focus on the link between technology and mental health and emotions, even though theories such as technostress underline the detrimental impact technology in the workplace can have on mental and physical health (Bondanini et al. 2020). Mood detection is at the heart of our derived design artifact as a guiding component for subsequent interventions. The theoretical implications of our contribution include the need to extend existing approaches by factoring in employees' emotional states and well-being more prominently while exploring the potential of IS and their positive influence in the road freight domain. Practical implications arise through the design objectives, which serve as a guide for the introduction of truck and driver technologies that focus on driver mood. As with any research contribution, there are limitations: First, the already applied methodology does not conclusively compile the perspectives of all scientific discourse and practitioners. For example, the interviewed experts from European countries are bound by specific regulations that differ to other countries (e.g., hours of service). Second, only the results from future implementation and evaluation of the envisioned MTDAS can demonstrate its effectiveness in solving the revealed problems for HTDs. Thus, a final solution is arguably comprised of various components ranging from process optimization to automation as indicated by DO4, that cannot be addressed by a single research project. Our ongoing research in progress will prioritize a context-sensitive mechanism to enhance the moods of HTDs in the future. To that end, we intend to (1) evaluate the design objectives in a focus group, (2) develop a concept and prototype accordingly, and (3) derive and validate design principles through additional iteration cycles.

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