

Humans at the center!? Analyzing digital workplace characteristics and their impact on truck drivers' perceived workload

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Abstract

Purpose – The aim of this study is to examine the relationship between job characteristics such as mental job requirements, decision-making authorities, variety of skills, (social) interactions, and perceived workload using the example of truck drivers from a work humanization perspective.

Design/methodology/approach – A questionnaire was conducted with 221 truck drivers in Germany.

Findings – This study makes strong theoretical and empirical contributions to the existing body of knowledge. First, it enhances the understanding of perceived workload in the digital work environments of truck drivers. Second, it augments the theoretical approach of human-centered work design in the context of digital transformation and especially in digital road freight transport by emphasizing the critical role of worker empowerment and technology commitment for the successful implementation of digital technologies. Lastly, it helps to understand the importance of the human factor in ensuring robust supply chains.

Originality/value – The transportation sector, particularly road freight, plays a pivotal role in maintaining robust supply chains and economic stability. Concurrently, the sector is undergoing substantial transformations driven by digitalization, which is fundamentally altering the work environment of truck drivers. Existing research underscores the importance of the human factor for successful use of digital technologies thereby ensuring high performance. However, a comprehensive analysis of human needs in digital work environments in relation to perceived workload remains an unresolved issue.

Keywords Truck drivers, Job characteristics, Technology commitment, Perceived workload, Humanization of work, Workplace design

Paper type Research article

1. Introduction

The transportation sector plays a critical role in maintaining robust supply chains and economic stability. Efficient and resilient supply chains are able to cope with external disruptions quickly and overcome the associated risks in a short time (Ambulkar *et al.*, 2015; Maharjan and Kato, 2022; Sawyerr and Harrison, 2019). Digitalization enables organizations to navigate disruptions, and to respond to changes with enhanced agility and precision, thereby transforming supply chains to become more efficient and resilient (Sharma *et al.*, 2024; Tortorella *et al.*, 2024). In this context, digitalization involves an intensified collaboration between humans and digital technology. In such work settings, the human factor is essential for the successful implementation and effective use of digital technologies since human expertise is crucial for interpreting data, making informed decisions, and ensuring that digital systems align with broader business objectives (Kaasinen *et al.*, 2020; Koreis *et al.*, 2023). Thus, the effectiveness of digital technologies is fundamentally linked to human involvement (Bottalico *et al.*, 2022; Klumpp and Ruiner, 2022). While automation increasingly offers the potential to replace routine tasks along the



supply chain, studies indicate that the human factor will continue to play a vital role in digital work settings (Gabler *et al.*, 2023; Kadir and Broberg, 2020). While much of the existing research has concentrated on optimizing human-technology performance, workers' perspectives on the consequences of digital technology use remain notably underexplored (Jena and Ghadge, 2021). Furthermore, the humanization of work approach has often been applied to study working conditions in digitalized settings such as order picking, warehousing, and manufacturing (Grosse, 2024; Grosse *et al.*, 2023; Winkelhaus *et al.*, 2022a, b). Yet, one group remains largely neglected: truck drivers, whose working conditions and environments are profoundly reshaped by digital transformation but rarely examined in scholarly discourse. This study addresses this gap by applying a human-centered work design perspective to the digitalization of road freight transport (Berg *et al.*, 2023).

Truck drivers constitute a critical element of the supply chain, ensuring service continuity while sustaining both efficiency and resilience (Montoya-Torres *et al.*, 2023; Schollmeier and Scott, 2023). Their unique working conditions encompass workplace isolation, stringent driver control, monotony, safety concerns, and substantial mental and physical job demands (Mayerle *et al.*, 2020; Sekkay *et al.*, 2021). Rising digitalization and automation intensify these challenging conditions, heightening workload perceptions while simultaneously affording support in daily operations. Such a digitalized work environment typically entails continuous GPS tracking, facilitating driver monitoring and seamless control of work steps (Klump and Ruiner, 2022; Levy, 2015, 2022). Furthermore, the use of digital technologies is associated with increased complexity, high work intensity, and other risks that augment or even increase perceived workload (Gagné *et al.*, 2022; Hartwig *et al.*, 2020; Marsh *et al.*, 2024). In response to the growing demands of the digital workplace, increasing attention has been directed toward human-centered design principles (Longo *et al.*, 2020; Paschek *et al.*, 2022). Against this backdrop, this study examines how specific job characteristics influence truck drivers' perceptions of workload through the lens of work humanization. By identifying the determinants of perceived workload, it aims to inform digitalization strategies that address the challenges of digital transformation while advancing a genuinely human-centered approach (Guest *et al.*, 2022; Winkelhaus *et al.*, 2022a, b). This study seeks to address the research question:

RQ. How do job characteristics in a digital workplace determine truck drivers' perceived workload?

The remainder of this paper is structured as follows: Section 2 provides an overview of the relevant literature regarding human-centered digital work environments and perceived workload. Section 3 introduces conceptual background and hypotheses development. Data analysis is conducted in Section 4, which is followed by the presentation of results (Section 5) and a discussion of the results in Section 6. The paper closes with a brief conclusion in Section 7.

2. Literature review

2.1 Humanization of work

Current research related to work in Industry 5.0 underscores the importance of adopting a human-centered perspective that considers both physical and cognitive capabilities of workers to address associated challenges of digital transformation (Kolade and Owoseni, 2022; Sgarbossa *et al.*, 2020). The concept of work humanization emerged as a response to adverse working conditions, seeking to promote work that is humane, safe, and free from excessive strain (Blustein *et al.*, 2023). Indicators of good work, such as physical strain, psychological monotony, and social isolation were already identified in the 1970s (Fricke, 2000). The demand for work to be engaging, fulfilling, and meaningful marked the inception of the humanization of work approach, advocating for the consideration of social factors even prioritized over economic objectives (Leviton and Johnston, 1973; Westley, 1979). This marked a foundational

shift toward greater attention to organizational control mechanisms and the fulfillment of human needs (Wool, 1973). Even today, centering humans in the workplace and exploring how personal and job characteristics interact remain essential for tackling the challenges of contemporary work (Hackman and Oldham, 1976). To this day, guidelines aim to advocate for a human-centric approach in the design of work systems (DIN894, 2008; DIN6385, 2016; DIN9241, 2017). Human labor and task execution involve structuring activities and disseminating information—processes that presuppose human engagement. As tasks grow in complexity, an equivalent level of resources is needed for their completion. In the manufacturing industry, digital technologies increasingly take over routine tasks, enabling humans to concentrate on more creative activities while simultaneously minimizing errors. Creating a humane work environment, however, depends on striking the right balance between human contribution and decisions delegated to digital systems (Bubb, 2006). The humanization of work in the digital era arises from a critical awareness of its human costs, emphasizing worker well-being to guard against a technocentric future where decision-making is delegated to machines (Cotta and Breque, 2021; German Federal Ministry of Labour and Social Affairs, 2017). Concepts such as “fair work”, “good jobs” and “decent work” are the key points of new initiatives aimed at addressing digitalization (Alberti *et al.*, 2022). The rise of Industry 5.0 places renewed emphasis on the human dimension, highlighting the imperative to align digital technologies with human values and ethics across sectors such as manufacturing, industrial automation, and electronics (Grosse *et al.*, 2023). In this context, Ulmer *et al.* (2023) demonstrate how assistance systems in manufacturing can only be used effectively when they integrate human needs into their design. Similarly, Vijayakumar and Sobhani (2023) show that fully automated pick-and-transport robots not only enhance system performance but also have the potential to improve workers’ productivity, well-being, and overall quality of work. Specifically, aspects such as social interaction, autonomy, well-being, problem solving, and task diversity are deemed essential for supporting a human-centered use of digital technologies in the workplace (Longo *et al.*, 2020). Kadir and Broberg (2021) developed a framework for the human-centered design of industrial work systems, integrating human and ergonomic factors—such as well-being and system performance—with work system modeling and strategic structures. The authors highlight that successful transformation relies on additional elements, including effective change management. In shaping the use of digital technologies at work, empowerment stands as a defining principle of a human-centered workplace, calling for the transfer of power, responsibility, authority, and control over resources to employees (Spreitzer, 2007). Spreitzer (2007) argues that empowerment can be experienced by employees across all levels of an organization when they are encouraged to participate in decision-making, have access to information, and are supported through the provision of adequate resources. Empowerment encompasses a sense of meaning through alignment with workers’ roles and values, confidence in possessing the necessary skills, autonomy in decision-making, and the ability to influence organizational outcomes. When any of these dimensions are absent, empowerment can only be experienced in a limited form (Spreitzer, 1995). In digital work environments, empowerment is realized when technology enhances work processes, supports skill development, and deepens employees’ understanding of their responsibilities, rather than serving merely as a tool for surveillance (Heikkilä *et al.*, 2018; Kaasinen *et al.*, 2020). From a work humanization perspective, Widodo (2024) finds that digitalization is viewed as employee-friendly when it fosters empowerment and tangible support, shifting attention from replacing workers with technology to enhancing their independence and capability. This human-centered approach not only boosts organizational performance but also promotes employee well-being and motivation. Moreover, automated systems can play a crucial role in this process by offering sustained physical and mental relief to workers (Romero *et al.*, 2016). In the pursuit of work humanization, the emphasis is on advancing qualifications and skills to facilitate the successful and human-centered implementation of digital technologies (Romero *et al.*, 2020). In the manufacturing sector, the use of cobots has shown diverse workforce effects, ranging from

deskilling to retraining or upskilling, depending on the nature of the tasks (Dornelles *et al.*, 2023).

2.2 Perceived workload

As part of the humanization of work approach, there is a pursuit for reduction in perceived workload. Fundamentally, workload emanates from “the interaction among the requirements of a task, the circumstances under which the task is performed, and the skills, behaviors, and perceptions of an operator” (Hart and Staveland, 1988, p. 140). Perceived workload is a multidimensional construct reflecting an individual’s subjective evaluation of the cognitive and physical demands of a given task or activity. It captures the combined influence of external factors and workplace conditions that impose physical or psychological strain on employees (Hart, 1986). It includes cognitive demands, such as concentration and decision-making, physical demands related to task execution, temporal demands involving perceived time pressure, self-evaluated performance, required effort, and experienced frustration. Additionally, perceived workload extends to contextual factors like social interactions with colleagues and superiors, environmental conditions, and task complexity (Castro *et al.*, 2019; Hart, 2006; Hart and Staveland, 1988). The use of digital technologies introduces novel challenges for both workers and organizations, as it significantly alters various aspects of the work environment. Information overload, technological complexity, and system malfunctions associated with digital technologies can significantly increase perceived workload (Ayyagari *et al.*, 2011; Marsh *et al.*, 2024; Tarafdar *et al.*, 2010). Frequently, digital technologies involve divided cognitive attention across multiple tasks, heightening the risk of delayed responses and errors (DiDomenico and Nussbaum, 2011). Moreover, complex requirements, excessive information, and the constant division of attention across multiple tasks compress work processes and intensify the overall cognitive and physical strain on workers (Hooey *et al.*, 2018; Lager *et al.*, 2021).

In the logistics sector, and most notably among truck drivers, work strain originates from multiple sources. Cognitive distractions from secondary tasks, such as route planning, together with the complexities of interacting with other road users, substantially heighten mental demands (Seitz *et al.*, 2013; Yang *et al.*, 2020). Concurrently, excessive workload contribute to fatigue and drowsiness, compounding the pressures drivers experience (Giroto *et al.*, 2019; Zhang *et al.*, 2024). Additional stressors include social isolation, job dissatisfaction, disrespectful treatment by customers, the challenge of meeting tight delivery schedules, and the burden of regulatory compliance (Utomo *et al.*, 2020; Williams *et al.*, 2017). This interplay of cognitive, emotional, and organizational pressures illustrates the complexity of truck driving as an occupation and underscores the urgency of developing comprehensive strategies within logistics to mitigate these challenges. Prolonged exposure to such conditions can lead to exhaustion, declining job satisfaction, and adverse health outcomes (Ahuja *et al.*, 2007; Aryal *et al.*, 2023). To counterbalance these risks, adequate job resources are essential, as they buffer the negative effects of excessive demands (Bakker and Demerouti, 2007). The framework of human-centered work thus offers a foundation for designing digital workplaces that address the diverse determinants of perceived workload and foster resilience.

3. Conceptual background and hypothesis development

3.1 Digitalization and job characteristics

Digitalization introduces new requirements and expectations that present both opportunities and risks for workers and organizations alike (Cichosz *et al.*, 2020; Grover and Ashraf, 2024). On the one hand, digital tools can streamline work processes by enhancing communication and improving time efficiency (Alasoini *et al.*, 2023; Mahlberg *et al.*, 2024). On the other, their implementation may also generate challenges such as excessive surveillance, heightened task pressure, and information overload (Gierlich-Joas *et al.*, 2024; Watson and Pengwang, 2024). The increasing complexity of work additionally requires continuous skill development and

knowledge acquisition to effectively navigate these systems (Lipis and Schislyaeva, 2022; Marsh *et al.*, 2022). Together, such factors shape workers' overall sense of strain (Parent-Rocheleau and Parker, 2022; Zorzenon *et al.*, 2022). In settings where human effort and digital systems interact closely, it becomes vital to understand how technology affects individuals and their job characteristics (Pessot *et al.*, 2023). This study therefore examines how specific job characteristics within digital work environments influence workers' perceived workload. Specifically, the four job characteristics—skill variety, decision latitude, mental job requirements, and interaction possibilities—are experiencing profound changes due to digitalization and thus constitute the focal point of this study (Winkelhaus *et al.*, 2022a, b).

3.1.1 Skill variety. It is hardly surprising that the adoption of digital technologies is transforming operational domains, requiring new qualifications and skills to meet evolving demands (Lagorio *et al.*, 2023). Overall, the simplification of tasks contrasts with the simultaneous upgrading of others that demand higher levels of qualification (Attewell, 1992; Braverman, 1974). Predominantly routine tasks (e.g. manual packaging, manual sealing) are being phased out for workers and supplanted by automated processes (Cimini *et al.*, 2019; Grosse *et al.*, 2015). In this context, uncertainty and monotony can often lead to a loss of focus, which may result in under-stimulation and act as a source of cognitive strain (Hartwig *et al.*, 2020; Iseland *et al.*, 2018). A compelling example of how digital technologies can ease drivers' workload is the use of driver assistance systems, such as automated distance control. However, comprehensive knowledge of their correct operation must be made transparent and readily accessible to ensure their effective and safe use (Cummings, 2018; Gierlich-Joas *et al.*, 2024; Gkinko and Elbanna, 2023). In terms of the perception of workload, this means that a wide variety of skills helps to meet new requirements and thus reduce perceived workload. At the same time, the broader skill variety creates a basis for taking on different tasks, which results in less monotony and therefore a lower perceived workload (Giroto *et al.*, 2019; Zhang *et al.*, 2024). Ideally, digital technologies should be utilized in a manner that fully harnesses the potential of the skills at hand (Klump *et al.*, 2019; Yang *et al.*, 2020). A great variety of skills (SKIVAR) can therefore assist in maintaining a low level of perceived workload. Consequently, the first hypothesis of the model is posited as follows:

H1a. A greater skill variety reduces perceived workload.

3.1.2 Decision latitude. Job decision latitude, as conceptualized by Karasek (1979), serves as a resource for managing strain and perceived workload, and can be considered as a component of work autonomy. It encompasses decision-making authority regarding work methods, task planning, and problem-solving, primarily focusing on freedom in task execution. Work autonomy, as defined by Breugh (1985, 1989), extends beyond decision latitude to include structural aspects of work organization, such as the flexibility to choose one's work location, working hours, and duration. This broader understanding of autonomy brings together decision-making for specific tasks and the ability to adapt within the organization. In logistics, the adoption of digital systems is often tied to GPS tracking, enabling the constant surveillance of workers' activities (Aloisi and De Stefano, 2022; Grisold *et al.*, 2024). Professions that are traditionally characterized by a high degree of autonomy are seeing this scope for independence increasingly restricted. In logistics, the ability to arrange working hours and tasks flexibly is a decisive factor shaping decision latitude and overall perceived workload (Bharatan *et al.*, 2022; Makridis and Han, 2021). While digital tools can enhance autonomy by enabling drivers to self-organize their day, they can equally become a source of strain when managerial control reduces decision latitude and monitoring is used as a means of pressure (Levy, 2015, 2022). The impact of control on perceived workload depends on its source: control from customers and colleagues is often seen as a burden, whereas oversight from algorithms and management generally has the potential to be helpful

(Ruiner and Klumpp, 2022). The hypothesis regarding the impact of decision latitude (DECISI) is formulated as follows:

H1b. Increased decision latitude diminishes perceived workload.

3.1.3 Mental job requirements. The logistics sector is defined by stringent demands such as tight deadlines, the necessity for rapid and flexible responses, and the ongoing management of personal and professional uncertainties (Caza *et al.*, 2022; Hege *et al.*, 2019). The integration of digital systems often compresses work, amplifying strain through excessive demands (Chesley, 2014; Ji-Hyland and Allen, 2022). While digital information sharing is intended to enhance efficiency, it can become overwhelming when the volume of data surpasses workers' capacity to cope (Abdulkareem *et al.*, 2024; Ayyagari, 2012). Although these technologies are designed to support workers, their benefits are not always perceived (Hartwig *et al.*, 2020). Process automation and interconnected systems enhance communication and self-monitoring, while the integration of artificial intelligence enables problem-solving and further diminishes human involvement (Estlund, 2023; Moore and Tambini, 2018). Operating in such hybrid environments involves increased complexity and a conscious division of tasks between humans and machines to ensure seamless interaction (Klumpp, 2018; Lane *et al.*, 2024; Ulmer *et al.*, 2023). Workers often find themselves in situations where they must respond quickly, which adds even more pressure to those already struggling with a high level of perceived workload and fast work pace (Marsh *et al.*, 2022, 2024). In such scenarios, insufficient transparency, especially regarding the division of responsibilities between humans and technologies, can intensify the strain of working with digital systems (Kadir and Broberg, 2020; Parent-Rocheleau and Parker, 2022). Consequently, the third hypothesis concerning the influence of mental job requirements (MJR) on perceived workload is:

H1c. Increased mental job requirements increase perceived workload.

3.1.4 Interaction possibilities. Digital transformation reshapes workplace interactions, encompassing both human-technology collaboration and social relations among coworkers. It is therefore essential to examine how digital tools alter interpersonal dynamics and collective collaboration as a social dimension of work. Communication and personal interaction remain central elements of a healthy work environment (Bellesia *et al.*, 2019; Jacobs *et al.*, 2016; Wuersch *et al.*, 2023). Literature distinguishes between interactions that trigger emotional overload and heightened strain (Badura, 1990; Ingram *et al.*, 2001) and those that ease demands by positively shaping the experience of work (Pooja *et al.*, 2016). In digital workplaces, communication through mobile devices, emails, and various applications has become omnipresent. On the one hand, such exchanges help maintain a social work environment, offering opportunities for interaction even across physically dispersed workplaces and thus alleviating occupational stressors (Chakraborty *et al.*, 2021; Eftimov *et al.*, 2025; Sen *et al.*, 2022; Shinn *et al.*, 1984). Substantive collaboration in digital form can further reduce strain and foster a sense of support (D'Oliveira and Persico, 2023). On the other hand, in professions marked by physical separation, the absence of face-to-face contact heightens the risk of workplace isolation and weakens social support at work (Hallin *et al.*, 2022; Sahai *et al.*, 2021). This diminished personal interaction, closely tied to social isolation, can itself become a source of mental strain (D'Oliveira and Persico, 2023). Thus, digital communication simultaneously mitigates isolation by enabling connection while also carrying the risk of eroding direct, in-person relationships. The influence of potential interactions (INTACT) on perceived workload warrants closer scrutiny, as delineated in the following hypothesis:

H1d. Greater interaction opportunities diminish perceived workload.

3.2 Technology commitment

To examine the use of digital technologies in the workplace more comprehensively, this study includes two moderating variables: technology commitment (TCOMMIT) and the duration of digital technology use (DUR) in the work context. Technology commitment emerges as a pivotal personal trait essential for the sustainable and efficient use of digital technologies (Wicki *et al.*, 2019). Technology acceptance, technology competence, and technology control conviction are the three factors that essentially determine technology commitment and thus predict successful utilization of technologies (Neyer *et al.*, 2012). The process of innovation adoption involves committing to their sustained use, contingent upon the individual decisions to either adopt or reject them (Rogers, 1985). According to Rogers (1985), the adoption process unfolds in several stages, beginning with awareness, followed by attitude formation, and culminating in the decision to embed new tools into daily practice. Successful implementation and sustained use, however, demand long-term commitment (Perotti *et al.*, 2022). Among the foremost theories explaining the relationship between attitudes towards technology and behavior is the theory of reasoned action by Ajzen and Fishbein (1977). According to this theory, individual attitudes toward technology reflect evaluative judgements that translate into corresponding behaviors (Ajzen and Fishbein, 1977). Venkatesh *et al.* (2003) argue that, beyond prior experience, effort and performance expectations, social influences, and facilitating conditions shape technology use. Adoption thus involves a deliberative process in which personal expectations are weighed against perceived benefits and feasibility. Facilitating conditions, which reflect the objective yet sometimes restrictive aspects of the work environment, also influence users' confidence in their technological skills and sense of control (Ajzen, 1991; Choi, 2021). Technology commitment, therefore, is pivotal in the human-technology interaction and warrants attention. Moreover, users continuously reassess and adjust their expectations and experiences with digital technologies in an ongoing, adaptive process—highlighting the temporal dimension embedded in the study's conceptual framework. The moderating roles of technology commitment and duration of technology use are examined through hypotheses formulated for each focal variable.

Hypotheses on technology commitment (H2a-d):

- H2a. Technology commitment moderates the relationship between skill variety (SKIVAR) and perceived workload.
- H2b. Technology commitment moderates the relationship between decision latitude (DECISI) and perceived workload.
- H2c. Technology commitment moderates the relationship between mental job requirements (MJR) and perceived workload.
- H2d. Technology commitment moderates the relationship between interaction possibilities (INTACT) and perceived workload.

Hypotheses on the joint moderating effect (TCOMMIT × DUR) (H3a-d):

- H3a. TCOMMIT × DUR moderates the relationship between skill variety (SKIVAR) and perceived workload.
- H3b. TCOMMIT × DUR moderates the relationship between decision latitude (DECISI) and perceived workload.
- H3c. TCOMMIT × DUR moderates the relationship between mental job requirements (MJR) and perceived workload.
- H3d. TCOMMIT × DUR moderates the relationship between interaction possibilities (INTACT) and perceived workload.

Figure 1 illustrates the interrelations among the factors comprising the conceptual framework of this study.

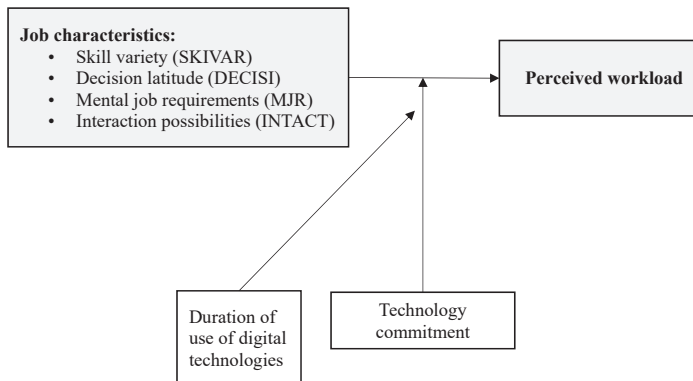


Figure 1. Relationship of the main factors. Source: Author's own work

4. Data and methods

This study examines the relationship between job characteristics in digital work environments and perceived workload, with workplace characteristics represented by the variables skill variety, decision latitude, mental job requirements, and interaction possibilities. In addition, technology commitment and the duration of digital tool usage are included as moderating variables. The measurement of all variables is based on a quantitative survey conducted among truck drivers in Germany.

4.1 Data collection

The survey was administered to truck drivers between July 2021 and November 2022 using a mixed-mode approach that combined online and paper-based questionnaires. This design accounted for varying levels of digital competence among participants and aimed to maximize response rates (Couper, 2011; Dillman *et al.*, 2014). To ensure broad coverage of the target group, multiple recruitment channels were employed (Couper, 2008; Kuckartz *et al.*, 2009). Logistics service providers across Germany were contacted directly, and survey links were distributed via company representatives, typically managing directors or dispatchers. For participants preferring a non-digital format, printed versions of the questionnaire were provided and returned anonymously. To further expand participation, additional truck drivers were reached through an external recruitment agency. In total, 688 drivers from various companies were invited to participate, yielding a response rate of 29.9%, which is consistent with response patterns in this occupational field (Döring, 2023; Prockl *et al.*, 2017). Eligibility for inclusion required formal qualification as a truck driver employed by a logistics service provider and active use of a digital transport management system. Ultimately, a total of 221 completed questionnaires were evaluated.

Alongside the established scales used to measure dependent and independent variables, the survey included questions on socio-demographic characteristics and the general conditions of daily working life. The study focused on the use of various digital devices in professional practice. A fundamental distinction can be made between technologies that substitute physical activities and those that augment or replace cognitive functions (Choe *et al.*, 2015; Endsley, 2017). The survey primarily examined the use of mobile devices as central elements of digital work. In the logistics sector, and particularly among truck drivers, response rates in surveys are typically low—a circumstance largely attributable to the demanding nature of everyday work, including high time pressure and limited opportunities for participation (Wagner and Kemmerling, 2010). To address potential non-response bias, respondents' characteristics were compared with those of the target population. The analysis of average digital technology use,

age, and professional experience revealed no substantial differences, suggesting that the sample is representative and the results are not biased (BALM, 2022; IRU, 2023; Prockl *et al.*, 2017). The final data set contained only a few isolated missing values, with no evidence of systematic patterns in item nonresponse. To preserve the completeness of the sample, missing data were imputed using multiple imputation in SPSS thereby allowing the inclusion of all corresponding cases in the analysis (Döring, 2023).

4.2 Sample characteristics

The sample comprised 204 male drivers and 17 female drivers, with women representing 7.9% of participants. The mean age of the drivers was 47.7 years, accompanied by an average of 18.4 years of professional experience and 12.1 years of tenure with the current employer. Most respondents were employed under permanent (60.2%) and full-time (70.9%) contracts. The analyzed data set thus represents the general demographics of truck drivers in Germany (BALM, 2023). With respect to educational attainment, 25.7% of respondents held a general secondary school certificate, 56.4% had completed an intermediate secondary education, and 17.9% reported a grammar school qualification. The average weekly working time amounted to 48.6 h, with more than 90% regularly exceeding their contractual hours. Regarding the use of digital technologies, mobile devices such as smartphones, handheld scanners, and tablets have not yet fully displaced manual, handwritten data entry—an overlap that initially places additional demands on drivers. Only 11.4% indicated that manual recording had been completely replaced by digital recording. Most truck drivers (46.5%) reported that most of the information is recorded digitally, but some details still need to be recorded on paper, while 39.9% of drivers have to record all information twice (digitally and on paper).

4.3 Scale items and reliability

The standardized scale by Benninghaus (2014) was utilized to record items pertaining to perceived job characteristics [1]. This scale comprises four subscales, each representing an independent variable: decision latitude, skill variety, mental job requirements and interaction with others. To enhance the generalizability of the findings, Breaugh's work autonomy scale was incorporated to measure decision latitude and further items were added to the subscale measuring interaction possibilities (Matthes *et al.*, 2014; Stegmann *et al.*, 2010). For each subscale, unweighted indices were created following the specific guidelines, representing the corresponding independent variables. Perceived workload was assessed using the scale devised by Weyer *et al.* (2014). Technology commitment was measured using the scale developed by Neyer *et al.* (2016), which captures three key dimensions: technology acceptance, technological competence, and perceived control over technology. These components were combined into a single composite index. All items were tested with Likert scales in different, predefined gradations Cronbach's alpha was employed to assess the internal consistency of each variable and to identify individual items whose removal would enhance the reliability of the respective index (Keller *et al.*, 2020).

Individual characteristics also shape how workers perceive their work environment. Accordingly, age (c1) and general work experience (c2) were included in the model as covariates. Neither variable, however, showed a statistically significant effect on perceived workload. Statistical significance was determined at the conventional 5% level. Yet, contemporary research increasingly advocates for a more nuanced interpretation of significance, incorporating factors such as prior evidence and theoretical plausibility (McShane *et al.*, 2019).

5. Results

To examine the hypotheses, moderated regression models were estimated using SPSS (version 27) using Hayes' PROCESS macro for moderated regression analysis, incorporating 95%

bias-corrected confidence intervals and a common seed for bootstrapping (10,000 samples) (Hayes, 2018). The PROCESS macro conducts a series of regression models to derive direct, indirect, and conditional effects in moderated models, a widely adopted method in logistics literature for exploring complex effects (Essuman *et al.*, 2023; Gabler *et al.*, 2023; Masorgo *et al.*, 2023; Ta *et al.*, 2023). Additionally, the Johnson-Neyman technique was employed to examine and visualize the magnitude and direction of the moderating effects (Hayes, 2018). To assess the moderating effects, interaction terms were created by multiplying the mean-centered independent and moderating variables (Aguinis *et al.*, 2017). Table 1 presents the results of moderated regression analyses predicting perceived workload. Each model estimates both the direct effects of the independent variables and the specific moderating influences of technology commitment, duration of use, and the focal predictor. In all models, perceived workload serves as the dependent variable, with the full set of independent and control variables included. Interaction terms were constructed solely for the focal predictor to isolate its conditional effects. Before interpreting the results, all necessary prerequisites for performing a regression were checked. Plotting the dependent variable against the independent variables demonstrated the fulfillment of the linearity assumption between the regression coefficients. Additionally, an assessment was made for any bias in terms of heteroscedasticity. For this purpose, the standardized residuals were plotted against the standardized predicted values, revealing a random distribution of the points with no funnel-shaped or curve-like arrangement. Furthermore, the model underwent testing for multicollinearity between the independent variables. The variance inflation factors (VIF) were all significantly lower than 2, and the tolerance levels were all greater than 0.50, indicating no multicollinearity (Belsley *et al.*, 1980; Tabachnick and Fidell, 2019).

In accordance with hypotheses H1a, H1c and H1d, the job characteristics skill variety, mental job requirements and interaction possibilities have a significant direct effect on the perception of workload. According to H1a, a greater skill variety (Model 1a) leads in all models to a direct reduction of perceived workload ($\beta = -0.064$, $p = 0.000$). This effect is also significantly strengthened by a high technology commitment ($\beta = 0.007$, $p = 0.000$) and increasing duration of use ($\beta = 0.003$, $p = 0.000$). The joint moderating effect of technology commitment and duration of use is not statistically significant. Accordingly, hypotheses H1a and H2a are supported, whereas hypothesis H3a must be rejected. The findings suggest that a broader range of skills in the digital workplace is associated with lower levels of perceived workload. This effect appears to be amplified by a strong commitment to using digital technologies. The direct effect of mental job requirements (Model 1c) on perceived workload is significantly positive, indicating that higher cognitive demands are associated with greater perceived workload. Unexpectedly, the interaction between mental job requirements and technology commitment also yielded a significant positive effect ($\beta = 0.006$, $p = 0.0007$). No significant moderating effect was observed for joint moderation. Consequently, only hypothesis H1c is supported regarding the influence of mental job requirements. Furthermore, a significant direct negative effect of interaction possibilities (Model 1d) on perceived workload was found, meaning that hypothesis H1d is supported and an increase in interaction possibilities reduces perceived workload ($\beta = -0.063$, $p = 0.001$). The joint interaction of both moderators also shows a significant effect ($\beta = 0.001$, $p = 0.001$). Hypotheses H1d, H2d and H3d can be accepted accordingly. The alleviating effect of interaction possibilities appears to be further enhanced when accompanied by a strong willingness to engage with digital technologies and sustained experience in their use. In contrast to the assumption of hypothesis H1b, none of the regression models revealed a significant direct impact of decision latitude (Model 1b) on perceived workload at the 5% significance level. The absence of a statistically significant main effect suggests that decision latitude does not influence perceived workload when the moderator is set to zero. Nonetheless, the interpretation of this finding should not be dismissed, as prior research highlights the relevance of decision latitude as a meaningful workplace characteristic (Bharatan *et al.*, 2022). While plausibility and prior evidence continue to play a secondary role compared to the

Table 1. Regression coefficients with interacting moderators M1*M2 = technology commitment $\times$ duration of use [2]

Independent variable	Model 1a: SKIVAR			Model 1b: DECISI			Model 1c: MJR			Model 1d: INTACT		
	Coeff	SE	<i>p</i>	Coeff	SE	<i>p</i>	Coeff	SE	<i>p</i>	Coeff	SE	<i>p</i>
SKIVAR	−0.064	0.012	0.000	−0.062	0.012	0.000	−0.056	0.012	0.000	−0.048	0.012	0.000
DECISI	0.001	0.007	0.861	−0.002	0.007	0.736	−0.002	0.007	0.752	0.000	0.007	0.951
MJR	0.239	0.021	0.000	0.227	0.021	0.000	0.248	0.022	0.000	0.232	0.021	0.000
INTACT	−0.043	0.019	0.027	−0.049	0.019	0.012	−0.049	0.020	0.014	−0.063	0.020	0.001
TCOMMIT	−0.069	0.010	0.000	−0.074	0.010	0.000	−0.066	0.010	0.000	−0.053	0.010	0.000
DUR	0.010	0.006	0.121	−0.002	0.007	0.738	0.010	0.006	0.117	0.007	0.006	0.293
TCOMMIT $\times$ DUR	0.002	0.001	0.098	0.001	0.001	0.427	−0.001	0.001	0.481	−0.001	0.001	0.553
SKIVAR $\times$ TCOMMIT	0.007	0.001	0.000									
SKIVAR $\times$ DUR	0.003	0.001	0.000									
SKIVAR $\times$ TCOMMIT*DUR	0.000	0.000	0.110									
DECISI $\times$ TCOMMIT				−0.002	0.001	0.005						
DECISI $\times$ DUR				0.002	0.001	0.001						
DECISI $\times$ TCOMMIT*DUR				0.000	0.000	0.001						
MJR $\times$ TCOMMIT							0.006	0.002	0.007			
MJR $\times$ DUR							0.000	0.002	0.834			
MJR $\times$ TCOMMIT*DUR							0.000	0.000	0.068			
INTACT $\times$ TCOMMIT										0.016	0.002	0.000
INTACT $\times$ DUR										0.005	0.001	0.000
INTACT $\times$ TCOMMIT*DUR										0.001	0.000	0.001
Age	−0.022	0.009	0.016	−0.014	0.009	0.116	−0.008	0.009	0.365	−0.009	0.009	0.300
Work Experience	0.015	0.010	0.112	0.008	0.010	0.405	0.007	0.010	0.494	0.011	0.010	0.254
R^2	0.196		0.000	0.181		0.000	0.164		0.000	0.199		0.000
ΔR^2	0.08			0.06			0.05			0.08		
f^2	0.10			0.08			0.05			0.10		
Source(s): Author's own work												

p-value, their importance is gaining traction in contemporary research debates (McShane *et al.*, 2019). Furthermore, there is an ongoing discussion advocating for lowering conventional significance thresholds (Andrade, 2019).

In contrast to the non-significant main effect, the interaction with technology commitment ($\beta = -0.002$, $p = 0.005$) and the joint interaction of both moderators ($\beta = 0.000$, $p = 0.001$) reached statistical significance. The results indicate that technology commitment diminishes the impact of decision latitude on perceived workload, whereas a longer duration of technology use amplifies it. Interestingly, the simultaneous interaction of both moderators shows a significant effect of zero, underscoring the distinct and opposing roles these moderators play in shaping the relationship between decision latitude and perceived workload. A possible interpretation is that decision latitude and technological commitment jointly exert a mitigating effect on perceived workload. High technological engagement combined with broad decision latitude appears to reduce perceived strain, suggesting a complementary relationship between autonomy and digital affinity. Conversely, the combination of extensive decision latitude and prolonged technology use tends to increase perceived workload, potentially reflecting the additional cognitive and temporal demands associated with sustained digital engagement. The regressions indicate a medium effect for the interactions based on the changes in R^2 . The moderating effect explained an additional 5–8% of the variance (ΔR^2), which corresponds to a medium effect (Cohen, 1992). The exact values and associated effect sizes can be found in Table 1.

6. Discussion

This study provides a holistic examination of the impact of job characteristics on perceived workload in the digital workplace of German truck drivers. The main results of this study help to quantitatively explain the emergence of perceived workload. This understanding forms a basis for designing the use of digital technologies according to the human-centered approach and can thus help to establish resilient supply chains (Dubey *et al.*, 2021; Sharma *et al.*, 2024). From the drivers' perspectives, their job necessitates rapid and intensive labor, coupled with the fulfillment of high demands within stringent time constraints, fostering the impression of high perceived workload. Digital technologies enable even swifter information dissemination, rendering work processes markedly dynamic and increasingly concentrated (Hartwig *et al.*, 2020; Ji-Hyland and Allen, 2022). The combined effect of mental job requirements and technology commitment produces a marginally positive association. A plausible explanation for this finding may lie in the increasing complexity of modern work environments: as cognitive demands intensify, even a strong commitment to technology offers only limited relief. In such contexts, technological engagement may facilitate task execution but cannot fully offset the mental effort required, resulting in only a modest attenuation—or even reinforcement—of perceived workload (Hooey *et al.*, 2018; Kadir and Broberg, 2020). Furthermore, it is conceivable that, although the control variable age did not yield a significant effect, the increasing complexity of digital work environments contributes to a heightened sense of strain and cognitive effort among older workers, irrespective of their willingness to engage with digital technologies. Given the dimensions of the technology commitment index—technology acceptance, technological competence, and perceived control over technology—it is plausible that fears of inadequate technical proficiency may weaken the overall influence of technology commitment. Conversely, a diverse range of tasks and required skills can alleviate strain, as they foster opportunities for developing expertise, expanding qualifications, and enhancing learning within the work process. The digitalized work environment of truck drivers spans a continuum from routine operations to complex problem-solving tasks, preventing the role from being characterized as monotonous. This variability necessitates specialized knowledge to effectively integrate new technological processes and avoid operational disruptions. When workers possess both high technology commitment and sustained experience, the resulting competence enables them to navigate this complexity more

efficiently, ultimately reducing the cognitive burden associated with their work (Lagorio *et al.*, 2023; Zorzenon *et al.*, 2022). Perceiving variety instead of monotony helps prevent underload over extended periods of technology use, thereby alleviating the overall strain experienced at work.

The opportunity for social interaction further reduces the perception of workload. Initially, this result may appear counterintuitive given that interaction stress is often cited in the literature (Badura, 1990). In particular, when the use of digital technologies leads to asymmetrical distribution of information, this results in excessive cognitive demands (Hallin *et al.*, 2022). However, the findings illustrate that interaction between individuals, both external stakeholders and colleagues across all hierarchical levels serve to mitigate the perceived workload in a digital workplace. Again, this effect is reinforced by a high level of technology commitment. Truck drivers spend much of their working time alone on the road, often with limited social interaction, particularly during long-haul trips. Digitalization helps counteract the adverse effects of occupational and social isolation by enabling communication and connection through mobile technologies, thereby easing mental strain and fostering a greater sense of balance in everyday work life. It is also possible that individuals with extensive professional experience may perceive their work as more socially isolating. In this context, the new avenues for communication and social interaction enabled by digital technologies could play an important role. At the same time, another noteworthy observation pertains to decision latitude. Several factors may account for the lack of statistically significant direct influence of autonomy on the perceived workload (Döring, 2023). Viewed in context, the findings on interaction opportunities highlight that truck drivers, as representatives of their organizations, play a crucial role in building strong professional relationships. Their knowledge of job content and accumulated experience can be effectively shared with newcomers, fostering meaningful connections and continuity within the profession (Gabler *et al.*, 2023; Hallin *et al.*, 2022; Rosenblat, 2016). Truck drivers are also entrusted with responsibility in their interpersonal dealings, which may outweigh the impact of autonomy (Kaasinen *et al.*, 2020; Spreitzer, 2007). The widely debated concept of autonomy appears to take on a new dimension, where individual decision-making authority within an organizational network, understood as empowerment, becomes a key factor shaping how workers experience and manage their work demands. Overall, high work strain appears to stem from increased cognitive demands, limited task diversity, and scarce opportunities for interpersonal exchange. In contrast, lower levels of perceived workload are associated with more manageable mental requirements, a varied range of responsibilities, and rich interaction possibilities. Technology commitment and the extent of use emerge as key factors in shaping these dynamics. Beyond their direct alleviating influence, a strong engagement with technology enhances indirect benefits across other job characteristics. In this context, the successful introduction of digital tools requires targeted support measures that foster acceptance, confidence in managing technology, and belief in one's technological competence.

7. Conclusion

The ongoing digital transformation is fundamentally reshaping the job characteristics inherent to truck drivers bearing the risk of additionally enhancing perceived workload (Klump and Ruiner, 2022; Pessot *et al.*, 2023; Winkelhaus *et al.*, 2022a, b). The study's findings offer significant theoretical and empirical contributions, highlighting the pivotal role of the human factor for the successful use of digital technologies (Lagorio *et al.*, 2023; Montoya-Torres *et al.*, 2023). The findings emphasize the importance of placing the human perspective at the center of digital workplace design to maintain manageable work demands. A human-centered approach is essential for the effective integration of digital systems, fostering a balanced interplay between workers and technology that strengthens both the resilience and efficiency of supply chains.

7.1 Contributions

The integration of digital technologies is fundamentally reshaping the nature of work. Yet, research often concentrates on enhancing human-technology performance while overlooking the underlying human needs that accompany digital engagement (Jena and Ghadge, 2021; Winkelhaus *et al.*, 2022a, b; Winkelhaus and Grosse, 2020). This study adopts a humanization of work approach to illustrate and underscore the necessity of a comprehensive and holistic examination of job characteristics, elucidating their impact on perceived workload and facilitating the derivation of pertinent and appropriate measures for enhancing working conditions (Blustein *et al.*, 2023; Longo *et al.*, 2020; Paschek *et al.*, 2022). In this regard, this study makes significant contributions.

First, the findings offer deeper insights into work experiences of truck drivers in digitalized environments, revealing that cognitive demands, skill variety, and opportunities for social interaction are key factors shaping their perception of workload. Truck drivers operate in a dynamic and complex environment shaped by diverse and demanding requirements (Hartwig *et al.*, 2020; Ji-Hyland and Allen, 2022; Lager *et al.*, 2021). The adoption of digital systems entails not only altering established workflows but also meeting new, demanding expectations. The pervasive use of digital devices facilitates continuous GPS tracking and organizational control, intensifying pressure and, alongside heightened cognitive demands, increasing the risk of driver exploitation. In contrast, promoting opportunities for social exchange and expanding task diversity can serve as effective means to ease work-related strain (D'Oliveira and Persico, 2023; Dornelles *et al.*, 2023; Wuersch *et al.*, 2023; Zhang *et al.*, 2024). With the ongoing advance of digitalization, the nature of interaction is undergoing a fundamental transformation, expanding beyond interpersonal exchanges to encompass dynamic collaboration between humans and technological systems. For truck drivers, whose work is characterized by prolonged social isolation, digital solutions can create new channels of communication that reduce solitude and ease psychological burden. At the same time, developing digital competencies strengthens their capacity to handle cognitive demands while diversifying the range of tasks they perform, thus preventing monotony and enhancing engagement. Equipping workers with advanced skills further reduce their vulnerability in the face of global competition, fostering resilience and stability in increasingly volatile labor environments.

Second, findings expand the theoretical framework of human-centered work design within the context of digital transformation, particularly in digital road freight transport, by highlighting the essential importance of worker empowerment and technology commitment for the effective integration of digital technologies. The humanization of work approach seeks to cultivate working conditions amidst digitalization that contribute to perceived workload reduction thereby counteracting conditions deemed inhumane (Cotta and Breque, 2021). The devolution of responsibility to workers and the opportunity to participate in decision-making processes improve working conditions vis-à-vis empowerment (Spreitzer, 1995, 2007). The findings on job characteristics in digital work environments reveal that opportunities for social interaction across all hierarchical levels are instrumental in fostering empowerment and humane working conditions. Likewise, the development and enhancement of competencies, comparable to a broad skill set for managing digital systems, represent a form of empowerment that enables workers to address challenges independently (Romero *et al.*, 2020). A deeper understanding of how digital technologies can reduce dependency on them, thereby preserving greater autonomy in decision-making processes. Moreover, the results highlight the pivotal role of technology commitment in ensuring the successful integration of digital tools. Effective workplace deployment demands not only user acceptance but also confidence in controlling the systems, and the necessary technological competence (Neyer *et al.*, 2012). The significance of empowerment and technology commitment becomes particularly evident in highly digitalized work environments that demand multifaceted skill sets. Such settings are characterized by constant dynamism and a high degree of uncertainty, placing substantial responsibility on individuals in pivotal roles. Occupations that combine advanced

digitalization with far-reaching accountability—such as air traffic controllers, pilots, or IT security specialists—require professionals to manage complex systems, make strategic decisions under pressure, and safeguard the stability and security of critical digital infrastructures.

Third, the results contribute to understanding the importance of considering truck drivers' perceptions in ensuring robust supply chains. It is undisputed that the human factor is crucial for the successful use of digital technologies in terms of efficiency (Bottalico *et al.*, 2022; Klumpp and Ruiner, 2022). Crafting resilient supply chains relies on the capacity to swiftly respond to unexpected disruptive events. An efficient supply chain forms the foundation of organizational resilience, enabling the system to absorb disruptions more effectively through optimized processes and strategic resource allocation (Ambulkar *et al.*, 2015; Sharma *et al.*, 2024; Tortorella *et al.*, 2024). While prior research on digitalization in logistics has predominantly focused on warehouse operatives or manufacturing workers, far less attention has been paid to jobs like truck driving. Yet, the inherently dispersed and often solitary nature of this occupation introduces distinctive challenges that digital technologies are rapidly transforming. Framed within the lens of work humanization, this perspective deepens our understanding of how job design and technological conditions jointly shape workers' well-being and performance. Truck drivers occupy a critical position within supply chains, safeguarding the continuity, adaptability, and efficiency of logistic networks. Operating in dynamic and frequently unpredictable environments, they confront disruptions that demand swift, informed, and autonomous decision-making. In such contexts, digital technologies act as enablers, strengthening the capacity to anticipate, respond to, and recover from unforeseen events. However, these advances can reach their full potential only when human capabilities and digital systems work in harmony, emphasizing that resilient supply chains rely not only on technological innovation but also on the empowerment and well-being of the people who sustain them (Gabler *et al.*, 2023; Grosse *et al.*, 2023; Kadir and Broberg, 2020). Adopting a human-centered approach to workplace design is therefore critical for facilitating human-technology collaboration. Consequently, a comprehensive understanding of perceived job characteristics is essential for sustaining efficient and resilient supply chains. Recognizing individual perspectives is increasingly essential, establishing the assessment of worker-relevant factors as a cornerstone of effective workplace design. Tailoring work environments to workers' specific abilities and needs promotes engagement, efficiency, and sustainable well-being.

7.2 Practical implications

The analysis advances understanding of how perceptions of workload arise in digital environments by exploring the influence of key job features. The results demonstrate how mental demands, variety of skills, autonomy, and opportunities for social exchange shape workers' perception of workload. These dimensions are investigated in relation to the integration of digital tools, which increases operational complexity, heightens task pressures, and ultimately intensifies the perception of workload (Castro *et al.*, 2019; Kaasinen *et al.*, 2020; Lager *et al.*, 2021). Possessing the requisite qualifications facilitates a diverse array of tasks and the resolution of any ensuing challenges. Furthermore, opportunities for exchanging experiences and fostering engagement within and beyond organizational boundaries can alleviate cognitive strain and enhance well-being. The perception of excessive workload, often stemming from inadequate working conditions, remains a primary source of turnover among truck drivers (Miller *et al.*, 2021; Prockl *et al.*, 2017). Adopting an integrative perspective on job design in digital work environments enables a nuanced appraisal of the factors shaping workers' sense of workload. Such an approach offers management a framework for developing proactive measures, such as targeted skill-building and training programs, that enhance working conditions and help reduce persistently high attrition rates. By equipping workers with the competencies to adapt to technological change, continuous professional

development not only strengthens their capacity to manage cognitive demands but also fosters resilience in an increasingly complex work landscape. Concrete implications for fair, digital work standards could involve establishing transparent criteria for workload assessment, ensuring equitable access to digital tools and training, and safeguarding workers' rights amidst automation and algorithmic management. For truck drivers, this could entail for example implementing digital tachographs and route planning systems that prioritize health and safety, as well as introducing flexible scheduling and rest periods that are digitally monitored and enforced. Lastly, research has shown that a strong commitment to technology is a key factor for the successful implementation and effective use of digital technologies, especially when aiming for a human-centered approach to workplace design. When workers are open to and engaged with digital technologies, they are more likely to use these tools efficiently and to their full potential. In this context, management can play a crucial role by taking active steps to involve workers throughout the process of introducing digital systems. For instance, actively involving workers in decision-making processes, offering targeted training opportunities, and fostering an open culture of feedback can cultivate trust and facilitate the acceptance of digital technologies. These initiatives not only strengthen workers' commitment to digital transformation but also nurture a constructive mindset toward organizational change. In doing so, they lay the foundation for integrating digital systems in a manner that harmonizes strategic objectives with the promotion of worker well-being. Figure 2 shows the relationships among all relevant factors fostering a human-centered design of the digital workplace, encapsulating theoretical and managerial implications. To foster human-centered work, initiatives could actively involve drivers in the design and implementation of digital systems. For example, co-creating digital tools through participatory workshops, offering tailored training on new technologies, and establishing regular feedback channels can help build acceptance and commitment. Additionally, organizations can set up digital well-being initiatives or appoint digital ambassadors among the workforce to ensure ongoing dialogue and support.

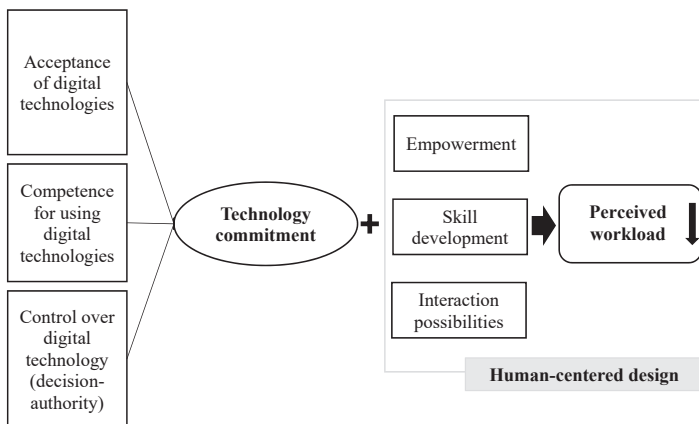


Figure 2. Illustration of relevant factors contributing to a human-centered workplace. Source: Author's own work

7.3 Limitations and future research

The study sheds light on the effects of job characteristics on the perceived workload within the digital work context of truck drivers in Germany. In the German truck driving profession, the average age is relatively high, with approximately one third of drivers aged 55 or older and only a small proportion under 25 years (BALM, 2023). Given these similarities, the sample

can be considered representative of the broader population of truck drivers in Germany. This enhances the generalizability of the study’s findings for this occupational group, as the results are likely to be applicable to truck drivers in Germany in general, supporting robust and valid conclusions about this profession. The results thus contribute to a better comprehension concerning perceived workload emergence of truck drivers in digital work contexts. Nevertheless, the results are subject to certain limitations. First, this study is limited to the German context. Workload of truck drivers is closely linked to their working conditions. In countries with similar conditions to Germany workload is also high but mitigated by higher wages, stronger social protection, and better working time regulations. A typical feature is a long weekly working time (often exceeding 40 h), which increases the risk of musculoskeletal disorders and workplace accidents. In Eastern and some Southern European countries, working conditions are often worse: despite comparable levels of workload (in terms of long hours, high physical strain), social protection, wages, and working time regulations are less favorable, further increasing strain. To enhance generalizability, future research could include additional countries such as Switzerland, Austria, Belgium, or the Netherlands, which exhibit similar occupational structures and legal frameworks for truck drivers. This would allow for the identification of commonalities across comparable contexts. Conversely, extending research to Eastern Europe or Asia—with different structural and regulatory conditions—could help to highlight cross-national differences and further contextualize the findings. Second, digitalization has advanced disparately across various industries and professions. Moreover, the pertinence of job characteristics may fluctuate contingent upon the job profile. Hence, when extrapolating the study to other occupations, it may be imperative to calibrate and prioritize such job attributes. Third, the degree of digitalization not only dictates the magnitude of impact but also poses challenges in measurement. Subsequent studies necessitate the selection of settings enabling a more precise assessment of digital technology utilization. Lastly, the analysis relies on subjective self-assessments of 221 respondents. It is also noteworthy that almost 8% of the sample consists of female respondents, which is rather high in this profession. Further research could build on this composition and examine more closely whether a gender difference can be identified. Moreover, future research could further broaden the scope of the sample, while the inclusion of objective data could enhance and fortify workload measurement. Additionally, a qualitative analysis could provide further insights into the causal relationships, offering great depth of understanding.

Appendix

Table A1. Regression model (without moderation effects): dependent variable = workload

	Coeff	se	Coeff (std)	t	<i>p</i>	
constant	13.447	0.569		23.628	0.000	
SKIVAR	−0.052	0.012	−0.142	−4.398	0.000	
DECISI	−0.005	0.007	−0.024	−0.784	0.433	
MJR	0.249	0.022	0.324	11.500	0.000	
INTACT	−0.064	0.019	−0.097	−3.326	0.001	
Model summary						
<i>R</i>	<i>R</i> -sq	MSE	F	df1	df2	<i>p</i>
0.345	0.119	1.131	42.132	4	1215	0.000
Source(s): Author’s own work						

Table A2. Model 1a: focal predictor = SKIVAR

	Coeff	se	t	p	LLCI	ULCI
constant	23.793	15.719	1.514	0.13	−7.046	54.633
SKIVAR	−0.064	0.012	−5.233	0.000	−0.089	−0.04
TCOMMIT	−0.069	0.01	−7.139	0.000	−0.088	−0.05
Int_1	0.007	0.001	5.744	0.000	0.004	0.009
DURATION	0.01	0.006	1.552	0.121	−0.003	0.022
Int_2	0.003	0.001	3.548	0.000	0.001	0.004
Int_3	0.002	0.001	1.657	0.098	0.000	0.004
Int_4	0.000	0.000	−1.601	0.11	−0.001	0.000
DECISI	0.001	0.007	0.175	0.861	−0.012	0.015
MJR	0.239	0.021	11.26	0.000	0.198	0.281
INTACT	−0.043	0.019	−2.211	0.027	−0.081	−0.005
MJR	0.239	0.021	11.26	0.000	0.198	0.281
INTACT	−0.43	0.019	−2.211	0.027	−0.081	−0.005
age	−0.022	0.009	−2.422	0.016	−0.04	−0.004
WorkExp	0.015	0.01	1.59	0.112	−0.004	0.034
Product terms key						
Int_1: SKIVAR × TCOMMIT						
Int_2: SKIVAR × DURATION						
Int_3: TCOMMIT × DURATION						
Int_4: SKIVAR × TCOMMIT*DURATION						
Model summary						
R	R-sq	MSE	F	df1	df2	p
0.443	0.196	1.131	24.561	12	1207	0.000

Source(s): Author's own work**Table A3.** Model 1b: focal predictor = DECISI

	Coeff	se	t	p	LLCI	ULCI
constant	25.665	15.837	1.621	0.105	−5.405	56.36
DECISI	−0.002	0.007	−0.337	0.736	−0.016	0.011
TCOMMIT	−0.074	0.01	−7.367	0.000	−0.093	−0.054
Int_1	−0.002	0.001	−2.798	0.005	−0.004	−0.001
DURATION	−0.002	0.007	−0.335	0.738	−0.015	0.011
Int_2	0.002	0.001	3.31	0.001	0.001	0.003
Int_3	0.001	0.001	0.795	0.427	−0.001	0.003
Int_4	0.000	0.000	−3.369	0.001	0.000	0.000
MJR	0.227	0.021	10.592	0.000	0.185	0.269
INTACT	−0.049	0.019	−2.519	0.012	−0.087	−0.011
SKIVAR	−0.062	0.012	−5.125	0.000	−0.086	−0.038
age	−0.014	0.009	−1.573	0.116	−0.032	0.004
WorkExp	0.008	0.01	0.833	0.405	−0.011	0.027
Product terms key						
Int_1: DECISI × TCOMMIT						
Int_2: DECISI × DURATION						
Int_3: TCOMMIT × DURATION						
Int_4: DECISI × TCOMMIT*DURATION						
Model summary						
R	R-sq	MSE	F	df1	df2	p
0.426	0.181	1.153	22.253	12	1207	0.000

Source(s): Author's own work

Table A4. Model 1c: focal predictor = MJR

	Coeff	se	t	p	LLCI	ULCI
constant	21.181	6.163	1.31	0.19	−10.529	52.891
MJR	0.248	0.022	11.149	0.000	0.204	0.291
TCOMMIT	−0.066	0.01	−6.644	0.000	−0.085	−0.046
Int_1	0.006	0.002	2.682	0.007	0.002	0.01
DURATION	0.01	0.006	1.57	0.117	−0.003	0.023
Int_2	0.000	0.002	0.21	0.834	−0.003	0.004
Int_3	−0.001	0.001	−0.706	0.481	−0.003	0.001
Int_4	0.000	0.000	1.824	0.068	0.000	0.001
INTACT	−0.049	0.02	−2.468	0.014	−0.089	−0.01
SKIVAR	−0.056	0.012	−4.506	0.000	−0.08	−0.031
DECISI	−0.002	0.007	−0.316	0.752	−0.016	0.011
age	−0.008	0.009	−0.907	0.365	−0.027	0.01
WorkExp	0.007	0.01	0.684	0.494	−0.013	0.026
Product terms key						
Int_1: MJR × TCOMMIT						
Int_2: MJR × DURATION						
Int_3: TCOMMIT × DURATION						
Int_4: MJR × TCOMMIT*DURATION						
Model summary						
R	R-sq	MSE	F	df1	df2	p
0.405	0.164	1.177	19.688	12	1207	0.000
Source(s): Author's own work						

Table A5. Model 1c: focal predictor = INTACT

	Coeff	se	t	p	LLCI	ULCI
constant	8.83	15.829	0.558	0.577	−22.225	39.885
INTACT	−0.063	0.02	−3.22	0.001	−0.102	−0.025
TCOMMIT	−0.053	0.01	−5.44	0.000	−0.072	−0.034
Int_1	0.016	0.002	6.779	0.000	0.011	0.021
DURATION	0.007	0.006	1.052	0.293	−0.006	0.019
Int_2	0.005	0.001	4.326	0.000	0.003	0.008
Int_3	−0.001	0.001	−0.593	0.553	−0.003	0.002
Int_4	0.001	0.000	3.479	0.001	0.000	0.001
SKIVAR	−0.048	0.012	−4.016	0.000	−0.072	−0.025
DECISI	0.000	0.007	0.061	0.951	−0.013	0.014
MJR	0.232	0.021	10.898	0.000	0.19	0.274
age	−0.009	0.009	−1,037	0.300	−0.027	0.008
WorkExp	0.011	0.01	1.14	0.254	−0.008	0.03
Product terms key						
Int_1: INTACT × TCOMMIT						
Int_2: INTACT × DURATION						
Int_3: TCOMMIT ×						
DURATION						
Int_4: INTACT × TCOMMIT*DURATION						
Model summary						
R	R-sq	MSE	F	df1	df2	p
0.446	0.199	1.128	24.977	12	1207	0.000
Source(s): Author's own work						

Table A6. List of items

Original item (in German)	Translation
<i>Scale: SKIVAR – Skill variety</i>	
In welchem Maße erfordert Ihre Tätigkeit gründliche Fachkenntnisse?	To what extent does your job require in-depth specialist knowledge?
In welchem Maße erfordert Ihre Tätigkeit besondere Fertigkeiten (handwerkliche oder sonstige)?	To what extent does your job require special skills (manual or otherwise)?
In welchem Maße erfordert Ihre Tätigkeit schöpferische Begabung und Ideenreichtum?	To what extent does your job require creative talent and inventiveness?
In welchem Maße erfordert Ihre Tätigkeit, stets neue Dinge kennenzulernen?	To what extent does your job require you to constantly learn new things?
In welchem Maße erfordert Ihre Tätigkeit neue Wege für die Lösung von Problemen zu finden?	To what extent does your work require you to find new ways of solving problems?
Wie vielseitig ist Ihre Tätigkeit? D.h. In welchem Maße erfordert und erlaubt Ihre Tätigkeit viele verschiedene Dinge zu tun und Kenntnisse oder Fähigkeiten anzuwenden?	How many things does your job involve? I.e. to what extent does your job require and allow you to do many different things and apply knowledge or skills?
Die Ausübung meiner Tätigkeit setzt umfangreiche Kenntnisse und eine hohe Qualifikation voraus	My work requires extensive knowledge and a high level of qualification
Bei meiner Tätigkeit kann ich meine Kenntnisse und Qualifikationen weiterentwickeln	My job allows me to further develop my knowledge and qualifications
Meine Tätigkeit ist durch eine große Aufgabenvielfalt gekennzeichnet	My work is characterized by a wide variety of tasks
Meine Tätigkeit ist sehr abwechslungsreich	My job is very wide-ranging
<i>Scale: DECISI – Decision latitude</i>	
Welches Maß an Selbstbestimmung (Autonomie) weist Ihre Tätigkeit auf? D.h. In welchem Maße können sie selbst bestimmen, wie und wann sie Ihre Arbeit erledigen?	What degree of self-determination (autonomy) do you have in your job? In other words, to what extent can you decide for yourself how and when you do your work?
Ich kann selbst entscheiden, mit welchen mitteln ich zum Ziel komme	I can decide for myself which means I use to reach my goal
Bei meiner Arbeit kann ich oft zwischen verschiedenen Herangehensweisen wählen	In my work, I can often choose between different approaches
Ich habe viele Freiheiten in der art und Weise wie ich meine Arbeit verrichte	I have a lot of freedom in the way I do my work
Meine Tätigkeit gibt mir viel Freiheit und Unabhängigkeit bei der Planung und Durchführung der Arbeit	My job gives me a lot of freedom and independence in planning and carrying out the work
Ich bin frei in der zeitlichen Einteilung meiner Arbeit	I am free to organize my work according to my schedule
Ich kann selbst entscheiden in welcher Reihenfolge ich meine Arbeit mache	I can decide for myself in which order I do my work
Ich kann meine Arbeit so planen wie ich es möchte	I can plan my work the way I want to
In welchem Maße können sie bei Ihrer Tätigkeit bestimmen, wie die Arbeit aufgeteilt wird?	To what extent can you determine how tasks are divided up in your job?
In welchem Maße können sie bei Ihrer Tätigkeit bestimmen, mit welchen Personen sie zusammenarbeiten, um die Arbeit zu erledigen?	In your job, to what extent can you determine which people you work with to get the job done?
In welchem Maße können sie bei Ihrer Tätigkeit bestimmen, wann sie eine Pause machen?	To what extent can you decide when to take a break in your job?
Ich kann bei meiner Arbeit viele Entscheidungen selbstständig treffen	I can make many decisions independently in my work
Meine Arbeit gewährt mir einen großen Handlungsspielraum	My work gives me a great deal of freedom

(continued)

Table A6. Continued

Original item (in German)	Translation
In welchem Maße sind Sie persönlich an wichtigen strategischen Entscheidungen Ihres Arbeitgebers beteiligt, z.B. hinsichtlich der hergestellten Produkte und Dienstleistungen, der Beschäftigtenzahl oder der Finanzen?	To what extent are you personally involved in important strategic decisions of your employer, e.g. regarding the products and services produced, the number of employees or the finances?
In welchem Maße haben Sie in Ihrer Arbeit die Möglichkeit, sich selbst immer wieder neue Aufgaben zu suchen?	To what extent do you have the opportunity to constantly look for new tasks in your work?
<i>Scale: MJR – Mental job requirements</i>	
In welchem Maße erfordert Ihre Tätigkeit sehr schnell zu arbeiten?	To what extent does your job require you to work very quickly?
In welchem Maße erfordert Ihre Tätigkeit sehr angestrengt zu arbeiten?	To what extent does your job require you to work very hard?
In welchem Maße erfordert Ihre Tätigkeit ein großes Arbeitspensum zu erledigen?	To what extent does your job require a large volume of work?
In welchem Maße erfordert Ihre Tätigkeit unter hohem Zeitdruck zu arbeiten?	To what extent does your job require you to work under time pressure?
In welchem Maße ist Ihre Arbeit psychisch (nervlich) beanspruchend?	To what extent is your work mentally (nervously) demanding?
In welchem Maße ist Ihre Arbeit hektisch?	To what extent is your work hectic?
In welchem Maße kommt es vor, dass Sie unter starkem Leistungsdruck arbeiten müssen?	To what extent do you have to work under pressure to perform?
<i>Scale: INTACT – Interaction possibilities</i>	
In welchem Maße erfordert Ihre Tätigkeit Umgang mit anderen Personen (nicht nur mit Kollegen × innen und Vorgesetzten, sondern auch mit Kunden × innen usw.)?	To what extent does your job require interaction with other people (not only with colleagues and superiors, but also with customers, etc.)?
Meine Tätigkeit bietet viele Gelegenheiten, andere Menschen kennenzulernen	My job offers many opportunities to get to know other people
Die Ausübung meiner Tätigkeit bringt es mit sich, dass ich mit vielen Menschen zusammentreffe	Doing my job means that I meet a lot of people
<i>Scale: Technology commitment</i>	
Hinsichtlich technischer Neuentwicklungen bin ich sehr neugierig	I am very curious about new technical developments
Ich finde schnell Gefallen an technischen Neuentwicklungen	I quickly take a liking to new technological developments
Ich bin stets daran interessiert, die neuesten technischen Geräte zu verwenden	I am always interested in using the latest technological equipment
Wenn ich Gelegenheit dazu hätte, würde ich noch viel häufiger technische Produkte nutzen als ich das gegenwärtig tue	If I had the opportunity, I would use technological products much more often than I currently do
Im Umgang mit moderner Technik habe ich oft Angst, zu versagen	I am often afraid of failing when dealing with modern technology
Für mich stellt der Umgang mit technischen Neuerungen zumeist eine Überforderung dar	For me, dealing with technical innovations is usually too much of a challenge
Ich habe Angst, technische Neuentwicklungen eher kaputt zu machen, als dass ich sie richtig benutze	I'm afraid of breaking new technological developments rather than using them properly
Den Umgang mit neuer Technik finde ich schwierig–ich kann das meistens einfach nicht	I find it difficult to deal with new technology–I just can't do it most of the time
Ob ich erfolgreich in der Anwendung moderner Technik bin, hängt im Wesentlichen von mir ab	Whether I am successful in using modern technology essentially depends on me
Es liegt in meiner Hand, ob mir die Nutzung technischer Neuentwicklungen gelingt–mit Zufall oder Glück hat das wenig zu tun	It is up to me whether I succeed in using new technological developments–it has little to do with chance or luck

(continued)

Table A6. Continued

Original item (in German)	Translation
Wenn ich im Umgang mit Technik Schwierigkeiten habe, hängt es schlussendlich alleine von mir ab, dass ich sie löse.	If I have difficulties with technology, it is ultimately up to me to solve them
Das, was passiert, wenn ich mich mit technischen Neuentwicklungen beschäftige, obliegt letztlich meiner Kontrolle	What happens when I deal with new technological developments is ultimately under my control
<i>Scale: Workload</i>	
Abends nach der Arbeit bin ich erschöpft	I'm exhausted in the evening after work
Bei meiner Arbeit tauchen häufig Probleme auf, die sehr schwer zu überwinden sind	Problems often arise in my work that are very difficult to overcome
Manchmal denke ich, dass ich mir mit meiner Arbeit zu viel zumute	Sometimes I think I'm taking on too much with my work
Ich habe manchmal das Gefühl, dass ich mit meiner Arbeit einfach nicht mehr fertig werde	I sometimes have the feeling that I simply can't cope with my work anymore
Bei meiner Arbeit fühle ich mich einem ständigen Druck ausgesetzt	I feel under constant pressure at work
Ich fühle mich oft etwas abgehetzt bei der Arbeit	I often feel a bit rushed at work
Man wird vom Berufsleben doch ziemlich mitgenommen	You do get quite carried away by professional life
Bei der Arbeit bin ich meist sehr angespannt	I'm usually very tense at work
Ich arbeite unter starkem Zeitdruck	I work under a lot of time pressure
Manchmal fühle ich mich den Anforderungen, die die Arbeit a mich stellt, nicht gewachsen	Sometimes I don't feel up to the demands that work places on me
Ich bräuchte mehr Verschnaufpausen bei der Arbeit	I would need more breaks at work
Source(s): Author's own work	

Notes

1. A comprehensive list of all items is provided as supplementary material.
2. A detailed description of the regression models can be found in the [appendix](#).

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