

The Impact of Integrating Human and Organizational Factors (HOF) on Transportation Safety*

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Abstract

As transport technologies evolve, cities expand, and traffic volumes grow, transportation systems are becoming increasingly complex. These developments create opportunities to enhance safety, but they also introduce new risks. This paper examines the combined influence of human and organizational factors (HOF) on transportation safety and system resilience. Human elements such as decision-making, fatigue management, and human-machine interaction remain central, while organizational dimensions—including leadership, safety culture, and management systems—shape the environment in which operators work.

The study adopts a mixed-methods approach, combining analysis of safety data with interviews conducted among industry professionals. The findings suggest that considering human and organizational aspects separately does not capture how they interact in practice. Case examples from aviation, rail, road, and maritime sectors indicate that integrated approaches can lower accident rates and improve system adaptability in the face of digitalization and automation.

The paper emphasizes the value of interdisciplinary collaboration, user-centered technology design, and robust safety cultures as key drivers of improvement. It also highlights the need for further research into how emerging technologies—particularly artificial intelligence and autonomous systems—interact with human and organizational dimensions of safety.

Keywords: accident prevention, human factors, organizational factors, risk assessment, safety management, system resilience, transportation safety.

Introduction

Transportation safety has emerged as a pressing global issue as systems grow in scale and complexity, driven by technological progress and increasing traffic across all modes of travel. While innovations such as automation and artificial intelligence have the potential to reduce certain categories of risk, they also bring new challenges that require careful management. According to the International Transport Forum (ITF), road traffic accidents alone cause approximately 1.3 million deaths every year worldwide. Similar concerns persist in aviation, rail, and maritime sectors, underscoring that technology on its own cannot guarantee safety. Human and organizational factors remain decisive in shaping outcomes.

Human and organizational factors (HOF) represent two distinct but interrelated dimensions of safety. On the one hand, human factors refer to the cognitive, physical, and psychological capabilities that determine how individuals make decisions, maintain vigilance, and respond under pressure. On the other hand, organizational factors—such as leadership style, institutional culture, and safety management systems—create the broader conditions in which individuals operate. Although both dimensions are critical, they are often examined or managed in isolation. This separation limits our understanding of how accidents occur and how they might be prevented more effectively.

This study addresses that gap by focusing on three guiding questions:

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1. How do human factors influence safety within transportation systems?
2. What role do organizational factors play in shaping safety outcomes?
3. In what ways can integration of these perspectives contribute to safer and more resilient systems?

Drawing on insights from human factors research, organizational psychology, and systems engineering, the paper argues that integrated frameworks are necessary to strengthen safety. Such approaches combine operator training, human-centered technology design, and a strong culture of safety, thereby supporting both individual performance and organizational resilience. The ultimate aim is to provide evidence and recommendations that can assist policymakers, researchers, and practitioners in reducing accidents, improving operational performance, and ensuring that transportation systems remain sustainable and adaptable in times of rapid change.

Literature Review

Human factors in transportation safety

Human factors encompass the cognitive, physical, and psychological dimensions of performance that directly affect safety in transport operations. Extensive research has shown that errors linked to fatigue, stress, or miscommunication remain among the leading causes of accidents (Reason, 1990). For example, pilot fatigue is estimated to contribute to around 20% of aviation incidents (Caldwell, 2012), while distracted driving continues to be one of the strongest predictors of road collisions worldwide (WHO, 2023).

One important theme is cognitive load. When operators face excessive information or stressful conditions, the quality of their decision-making deteriorates (Sweller, 1988). Structured training programs have been shown to reduce this effect; in aviation and rail transport, simulation-based training can improve performance under pressure by up to 40% (Kanki, Helmreich, & Anca, 2010). Similarly, virtual reality exercises in maritime and rail settings have proven effective in enhancing situational awareness and preparedness for emergencies.

Human-machine interaction (HMI) is another critical area. Poorly designed systems can increase the risk of operator error, as illustrated by navigational system failures in maritime transport (Hetherington, Flin, & Mearns, 2006). In contrast, aviation has invested heavily in cockpit designs that integrate tactile and visual cues to support situational awareness (Dekker, 2014). In road transport, advanced driver assistance systems (ADAS) reduce driver workload but also create risks of complacency and overreliance (Endsley, 2017).

Recent work has also examined the growing role of artificial intelligence in safety-critical industries. Bach, Kristiansen, Babic, and Jacovi (2023), in a systematic review, emphasize that while AI can enhance decision-making and reduce workload, it also introduces challenges such as automation bias, loss of situational awareness, and reduced operator vigilance. Their findings highlight the importance of designing AI systems that are transparent, interpretable, and trustworthy so that they complement rather than undermine human judgment. These insights are particularly relevant to transportation, where partially automated systems are already changing the role of human operators.

Finally, physiological and psychological states such as fatigue, stress, and misplaced trust in automation remain influential. Fatigue can impair performance to a degree comparable to alcohol consumption (Dawson & Reid, 1997), which has led to stricter duty-time regulations and the adoption of wearable monitoring devices. Addressing these challenges effectively requires not only technical solutions but also organizational support and a culture that prioritizes operator well-being.

Organizational factors in transportation safety

Organizational conditions define the environment in which human operators perform their tasks. Strong safety cultures are consistently linked to lower accident rates (Guldenmund, 2000). Leadership commitment, open communication, and clear safety policies play a decisive role. Aviation's Crew Resource Management (CRM) programs demonstrate how leadership-driven initiatives can foster teamwork and collective responsibility for safety (Helmreich & Merritt, 2000). Similarly, mandatory drills in maritime transport have reduced fatalities during capsizing accidents (Hetherington et al., 2006).

Reporting and learning systems are another crucial element. European rail operators, for instance, reported a 40% increase in hazard detection after introducing anonymous reporting systems (Antonsen, 2009). Such practices promote psychological safety, encouraging employees to report near misses without fear of reprisal. Together,

leadership, training, and transparent reporting systems shape how organizations prevent, respond to, and learn from incidents.

The need for integration

Despite advances in both fields, human and organizational factors are still too often studied in isolation. This separation does not reflect the realities of modern transport systems, where people, organizations, and technologies interact continuously (Reason, 1997). Evidence from Scandinavian aviation demonstrates the value of integration: the implementation of Safety Management Systems (SMS) that combine human and organizational perspectives reduced incident rates by about 30% in a single decade (European Aviation Safety Agency, 2018).

The emerging literature on human–AI interaction reinforces this need. As automation and AI increasingly influence decision-making, integrating human capabilities with supportive organizational practices becomes even more important. Aligning these dimensions not only reduces the likelihood of accidents but also strengthens resilience in the face of growing complexity, digitalization, and automation.

Methodology

This study employed a mixed-methods design to examine how human and organizational factors (HOF) interact in shaping transportation safety. The rationale for this approach was to capture both measurable patterns and contextual insights, which cannot be obtained through a single method alone.

The quantitative component drew on accident databases, safety reports, and industry statistics covering the past decade across aviation, rail, maritime, and road transport. These data sets were used to identify trends in incident rates, fatigue-related accidents, and audit outcomes.

The qualitative component consisted of 20 semi-structured interviews with industry professionals, including pilots, drivers, maritime officers, rail operators, and safety managers. The interviews were designed to explore how HOF influence decision-making, operational practice, and longer-term safety strategies. Questions focused on day-to-day challenges, the effectiveness of safety measures, and perceptions of organizational culture.

All participants gave informed consent, and anonymity was ensured. The study followed the ethical guidelines of the host institution. Data from both components were analyzed separately and then compared, allowing for triangulation and the identification of recurring themes. This process made it possible to link statistical evidence with practitioners' lived experiences, thereby providing a more comprehensive understanding of the interaction between human and organizational factors.

Results and Discussion

Human factors as the foundation of safety

The findings confirm that human factors remain a cornerstone of transportation safety. In aviation, the introduction of Crew Resource Management (CRM) has reduced accident rates by encouraging teamwork, communication, and shared decision-making (Helmreich & Merritt, 2000). In road transport, the implementation of electronic logging devices (ELDs) to monitor driver rest periods has contributed to measurable reductions in fatigue-related crashes.

Simulation-based training emerged as another area of progress. Rail and maritime organizations reported improvements in situational awareness and emergency preparedness following the adoption of virtual reality and other experiential learning tools. These results align with earlier studies suggesting that structured training, improved decision-making under pressure, and human-centered system design play an essential role in reducing the likelihood of human error.

Organizational influence on safety practices

The results also highlight the importance of organizational factors. Companies that promote open reporting and emphasize regular safety drills tend to experience fewer incidents and demonstrate stronger responses to unexpected situations. A comparative case from the maritime sector illustrated that a firm with structured reporting systems and consistent drills reported approximately one-third fewer accidents than its counterpart without such practices.

Interview data reinforced the role of leadership. Participants consistently described leadership commitment as a decisive influence on safety outcomes. Organizations where leaders treated safety as a strategic priority demonstrated stronger reporting cultures and more resilient responses to operational stressors. These observations support earlier research linking organizational culture with safety performance (Guldenmund, 2000).

Synergizing HOF for comprehensive safety

Perhaps the most important insight is that human and organizational factors are most effective when they are aligned. Sectors that focused exclusively on training or solely on culture-building achieved less progress than those that pursued integrated strategies. The Scandinavian aviation sector provides a telling example: the introduction of Safety Management Systems (SMS) that combined human and organizational perspectives reduced incident rates by around 30% within a decade (EASA, 2018).

The interviewees echoed this point. Operators who received training on fatigue and stress management reported much better outcomes when organizational measures—such as flexible scheduling, accessible reporting channels, and visible leadership support—were in place. Conversely, advanced technologies alone were insufficient if organizational backing was weak.

Theoretical and practical implications

Overall, the findings reinforce the socio-technical perspective, which conceptualizes safety as the result of interactions between people, organizations, and technology (Reason, 1997). From a practical standpoint, integrated approaches appear to reduce accidents, enhance efficiency, and strengthen adaptability. These advantages are becoming increasingly relevant as transport systems face the combined pressures of automation, digitalization, and rising demand.

Recommendations

The results of this study point to several directions for enhancing transportation safety and resilience. They suggest that progress depends less on isolated initiatives and more on integrated strategies that connect human performance, organizational practices, and technological innovation.

Develop integrated safety frameworks

Policies and management strategies should explicitly link human and organizational dimensions. Rather than treating training, technology, and culture as separate domains, they should be designed to reinforce one another. Cross-sector learning—drawing lessons from aviation, rail, road, and maritime transport—can accelerate improvement.

Strengthen training and education

Training programs need to address more than technical competence. They should prepare operators to manage stress, make decisions under pressure, and maintain situational awareness. At the same time, training should help shape organizational culture by promoting open communication and shared responsibility. Collaboration with universities and research institutions can ensure that training remains evidence-based and up to date.

Encourage interdisciplinary collaboration

Transportation safety challenges are too complex to be addressed by a single discipline. Human factors specialists, engineers, organizational psychologists, and policymakers should work together to design integrated solutions. Interdisciplinary councils or working groups could provide a platform for such collaboration.

Use emerging technologies wisely

Artificial intelligence, machine learning, and the Internet of Things (IoT) offer new opportunities for risk prediction and prevention. However, these technologies should be viewed as supportive tools rather than replacements for human judgment. Designing systems with users in mind is essential to prevent overreliance or misuse.

Build and sustain a culture of safety

Finally, organizational culture remains a central driver of resilience. Leaders must set the tone by treating safety as a non-negotiable value. Practices such as anonymous reporting, regular feedback, and recognition of safe behaviors can foster openness and accountability. Over time, these practices contribute to a culture in which resilience is embedded, rather than dependent on individual initiatives.

These recommendations are especially relevant for policymakers and industry leaders as they navigate post-pandemic recovery and the accelerating digital transformation of mobility.

Conclusion

This study examined how human and organizational factors (HOF) interact to shape safety and resilience in transportation systems. The evidence suggests that while human elements such as training, decision-making, and fatigue management are essential, they reach their full potential only when supported by organizational measures such as strong leadership, a positive safety culture, and continuous learning opportunities.

An integrated perspective allows safety to be understood not as the product of isolated measures but as the outcome of people, organizations, and technology working together as a system. Case examples from aviation, rail, road, and maritime transport illustrate that this alignment not only reduces accident rates but also enhances adaptability in the face of digitalization and automation.

The contribution of this paper lies in reinforcing a socio-technical view of safety while also offering practical guidance for policymakers, industry practitioners, and researchers. At the same time, several limitations must be acknowledged, including the relatively small interview sample and the focus on four transport sectors. Future research should explore how rapidly developing technologies—such as artificial intelligence, automation, and digital twins—interact with human and organizational dimensions across different contexts.

Ultimately, integrating human and organizational factors should not be considered optional. It is a strategic necessity for building transportation systems that are safer, more resilient, and better prepared for the challenges of the future.

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