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The Impact of Integrating Human and Organizational Factors on Transportation Safety: A Cross-Sector Qualitative Study*

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Abstract

The increasing complexity of modern transportation systems reinforces the critical role of human and organizational factors (HOF) in shaping safety outcomes. While extensive research has examined human performance, safety culture, and organizational systems separately, the literature offers limited cross-sector evidence on how these dimensions interact to influence operational resilience. This gap restricts the development of integrated safety strategies applicable across diverse transport domains.

This study addresses this gap by investigating the integration of HOF across four sectors—aviation, rail, road, and water transport. A qualitative research design was adopted, involving twenty semi-structured interviews with industry professionals representing operational, supervisory, and safety-management roles. Interview data were analyzed using a hybrid inductive–deductive coding approach, and factor salience was quantified using a five-point importance scale to enable cross-sector comparison.

The findings show substantial variation in HOF integration across sectors. Aviation demonstrated the highest level of integration, supported by strong leadership engagement, mature reporting systems, and structured training practices. Rail and water transport exhibited moderate but uneven integration, with communication and situational awareness emerging as core strengths. In contrast, road transport revealed high human-factor salience—particularly fatigue management and decision-making—yet weaker organizational support mechanisms. Across all sectors, the most influential factors included situational awareness, teamwork and communication, leadership commitment, and non-punitive reporting systems.

The study contributes a cross-sector perspective on how integrated human–organizational approaches enhance safety resilience. The findings provide actionable implications for regulators and industry leaders seeking to design targeted, sector-appropriate interventions that strengthen both human performance and organizational safety systems.

Keywords: human factors; organizational factors; qualitative research; transportation safety; resilience; leadership; automation; system integration

Introduction

Transportation systems are undergoing profound transformation driven by automation, digitalization, and globalization. These developments have generated unprecedented efficiency gains but also new categories of risk that cannot be managed through technical solutions alone. Despite technological sophistication, human behavior and organizational dynamics remain decisive in determining safety outcomes. As Reason (1997) argued, accidents rarely arise from isolated operator errors but from systemic interactions among individuals, organizations, and

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technologies. This socio-technical perspective underscores the need to understand not only the human element—cognition, fatigue, decision-making—but also the organizational conditions that shape how humans perform.

In recent years, international safety bodies such as the European Union Aviation Safety Agency (EASA, 2018) and the International Transport Forum (ITF, 2021) have emphasized the integration of human and organizational factors (HOF) as a prerequisite for sustainable safety management. Human factors research traditionally focuses on the micro-level of performance—attention, workload, situational awareness—whereas organizational studies address the macro-level influences of culture, leadership, and structure. However, empirical evidence increasingly demonstrates that treating these domains separately fails to capture the interdependencies that produce either resilience or vulnerability in complex systems (Dekker, 2014; Hollnagel, 2017). For instance, highly skilled operators can still make poor decisions in environments where management practices discourage reporting or learning from errors.

Although quantitative analyses of accident databases and safety indicators are common, qualitative inquiry remains essential for revealing the contextual subtleties of human–organizational interactions. Interview-based approaches provide insight into the lived experiences of practitioners who navigate trade-offs between operational efficiency and safety on a daily basis (Patton, 2021; Braun & Clarke, 2021). Such insights are critical as transportation sectors face converging challenges: increasing automation, multi-national workforces, and complex supply chains. Understanding how these pressures influence human and organizational behavior can inform the design of more adaptive safety management systems.

Building on prior conceptual work that highlighted the need for integration (Reason, 1997; Guldenmund, 2000), this paper extends the discussion with empirical evidence from twenty semi-structured interviews across four transport sectors—aviation, rail, road, and water transport. The study aims to explore how HOF integration manifests in diverse operational contexts and to identify sector-specific enablers and barriers. The research questions are therefore as follows:

- How do human factors influence safety within each transportation sector?
- What organizational factors most strongly shape safety outcomes?
- In what ways are these perspectives integrated to foster safer and more resilient systems?

The paper contributes a comparative cross-sector understanding of HOF integration. The findings not only validate the socio-technical model of safety but also provide actionable insights for policymakers, regulators, and industry leaders seeking to strengthen transportation safety in an era of accelerating technological change.

Methodology

This study employed a qualitative research design to explore how human and organizational factors (HOF) interact in shaping transportation safety across different modes of transport. A qualitative approach was chosen because it allows researchers to capture in-depth insights into experiences, perceptions, and the socio-technical contexts in which safety is produced and managed. Such an approach is particularly appropriate for understanding complex human–organizational interactions that are not easily quantifiable (Patton, 2021; Braun & Clarke, 2021).

Sample and data collection

Twenty semi-structured interviews were conducted between April and July 2024 with professionals representing four transport sectors: aviation, rail, road, and water transport (five participants from each sector). Participants were selected through purposive sampling to ensure diversity of experience and role. The sample included frontline operators (pilots, drivers, ship officers, train drivers), safety managers, dispatchers, and training personnel. All participants had a minimum of five years and an average of fifteen years of professional experience, ensuring a mature understanding of safety processes within their organizations.
Interviews were conducted either in person or via encrypted online platforms, depending on participant availability. The interview protocol included open-ended questions exploring human and organizational influences on safety, communication practices, fatigue and stress management, leadership style, safety culture, and experiences with automation or human–machine interaction.

Data analysis

The initial phase of analysis involved open coding to identify recurring themes, followed by axial coding to group related concepts under broader categories such as “communication,” “leadership commitment,” and “training

effectiveness." This process was guided by the literature on HOF integration (Reason, 1997; Guldenmund, 2000; Hollnagel, 2017).

To provide analytical transparency and enable comparison across sectors, the relative importance of each identified factor was quantified using a five-point Likert-type scale (1 = low importance, 5 = very high importance). The combination of qualitative coding and numeric scoring allowed the construction of comparative tables and visual representations across sectors.

While the sample size (n = 20) limits statistical generalization, the goal of qualitative inquiry is to achieve analytical—not numerical—generalization. The findings therefore highlight patterns of meaning and interaction rather than population-level inferences. Nevertheless, the balanced representation across four transport sectors provides a strong comparative foundation for understanding how human and organizational factors shape safety within different operational environments.

Participant Profile

A total of 20 professionals participated in the study, distributed evenly across four transport sectors. As shown in Table 1, participants represented a balanced mix of operational and managerial roles—including captains, drivers, dispatchers, safety officers, and trainers—with an average of 14.6 years of professional experience (ranging from 5 to 25 years). This diversity ensured that the perspectives captured reflected both frontline operational realities and organizational-level safety practices. The even distribution across sectors also provided a consistent basis for comparing differences in the integration of human and organizational factors.

Table 1. Participant demographics by sector

Participant	Sector	Role	Years of experience
P01 – P05	Aviation	captains, safety mgrs	8-22
P06 – P10	Rail	drivers, dispatchers	6-20
P11 – P15	Road	fleet drivers, HSE mgrs	5-18
P16 – P20	Water Transport	officers, trainers	7-25

Results

The results of this study present both thematic and quantitative findings derived from coded interview data. Sector-specific patterns demonstrate that while the relative salience of human and organizational factors varies across transport modes, the most effective safety systems emerge when these factors are mutually reinforcing. Numerical ratings represent the mean importance (1–5) assigned by coders to each identified factor.

Overview of sectoral differences

Across all sectors, the average importance score for human factors was 4.38, while organizational factors averaged 4.15. Aviation achieved the highest integration score (4.59), followed by water transport (42,6), rail (4.23), and road (3.96). Figure 1 illustrates the mean ratings of human versus organizational factors by sector. Aviation consistently demonstrated the strongest balance between human competence and organizational maturity, whereas road transport showed the greatest disparity—high human-factor relevance but weaker organizational structure and leadership consistency.

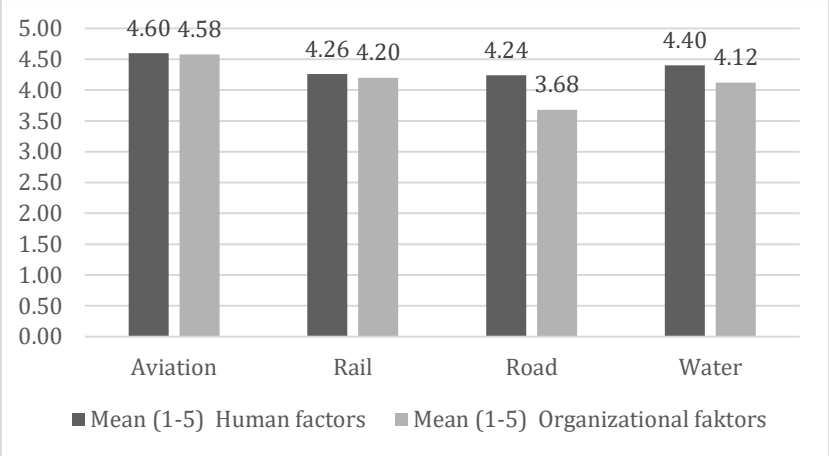

Figure 1. Relative importance of human vs. organizational factors by sector

Aviation sector

Respondents from the aviation sector described a highly institutionalized safety environment characterized by mature safety management systems (SMS), continuous simulation-based training, and strong leadership engagement. Key human factors: situational awareness, decision-making under pressure, and communication/teamwork - were reinforced by organizational supports such as leadership commitment and reporting systems. Aviation's long-standing CRM (Crew Resource Management) programs were identified as critical for embedding psychological safety and team learning. The combination of standardized reporting, leadership culture, and scenario-based training produced the highest integration rating among sectors.

Rail sector

Rail participants emphasized procedural reliability and the importance of structured communication between drivers, dispatchers, and control centers. Human factors such as attention management, fatigue control, and team communication ranked high. Organizational elements: particularly reporting systems and training consistency - were viewed as improving but still uneven across operators. Several respondents highlighted that anonymous reporting mechanisms encouraged learning from near-misses. Rail's integration score (4.23) indicates substantial maturity, though participants noted the need for broader inter-company knowledge sharing and more

Road sector

The road transport sector revealed the greatest gap between human and organizational dimensions. Human factors such as fatigue management and decision-making under time pressure received high importance scores, but organizational supports: leadership commitment, training programs, and safety culture maturity - lagged behind. Small and medium-sized enterprises often lacked formal safety management systems, relying instead on individual responsibility and experience. Overall, road transport's average integration score (3.96) reflects strong human performance but weaker systemic supports—indicating that individual competence alone cannot compensate for structural deficiencies.

Water transport sector

In the water transport sector, respondents described a mixed environment combining formal procedures with high demands on situational awareness and teamwork.

Human factors such as communication, situational awareness, and emergency response readiness were supported by organizational mechanisms like safety drills, leadership engagement, and training integration. Water transport showed moderate-to-high integration (4.26), reflecting a stable safety culture but variability between multinational crews and company-specific practices.

Figure 2 presents the radar chart comparing key factors across all four sectors.

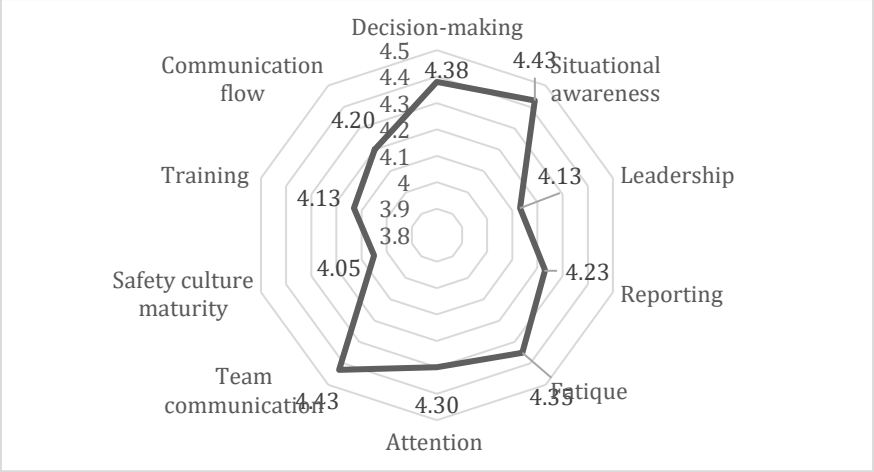

Figure 2. Overall importance profile of human and organizational factors

Cross-sector comparison

To summarize the quantitative data, Table 2 presents the mean importance ratings (1–5 scale) for the most frequently mentioned human and organizational factors across all sectors. The results reveal a consistent hierarchy of factors: situational awareness, decision-making under pressure, and fatigue management emerged as the most influential human dimensions, whereas leadership commitment and reporting and learning systems were the leading organizational drivers.

Notably, aviation and rail sectors show relatively balanced human–organizational integration, whereas the road sector demonstrates a pronounced gap between high individual competence and weaker structural support mechanisms. Water transport, while generally stable, displays moderate scores reflecting variability in safety culture and training consistency across companies.

Table 2. Mean importance of human and organizational factors by sector

Factor type	Key factor	Aviation	Rail	Road	Water Transport	Mean (All)
Human	Fatigue management	4,5	4,1	4,5	4,3	4,35
Human	Decision-making under pressure	4,6	4,2	4,4	4,3	4,38
Human	Situational awareness	4,8	4,3	4,0	4,6	4,43
Human	Attention management	4,4	4,3	4,2	4,3	4,30
Human	Team communication & coordination	4,7	4,4	4,1	4,5	4,43
Organizational	Leadership commitment	4,7	4,2	3,5	4,1	4,13
Organizational	Safety culture maturity	4,5	4,1	3,6	4,0	4,05
Organizational	Reporting & learning systems	4,6	4,2	3,8	4,3	4,23
Organizational	Training effectiveness	4,5	4,3	3,7	4,0	4,13
Organizational	Organizational communication low	4,6	4,2	3,8	4,2	4,20

These results indicate that human and organizational dimensions co-evolve. Strong human awareness and communication are reinforced when leadership and reporting practices are mature.

Figure 3 visualizes the top three factors for each sector, highlighting that situational awareness, communication, and leadership commitment dominate across all transport modes. The cross-sector similarities indicate that despite

contextual differences, effective safety management consistently depends on communication flow, informed decision-making, and proactive leadership.

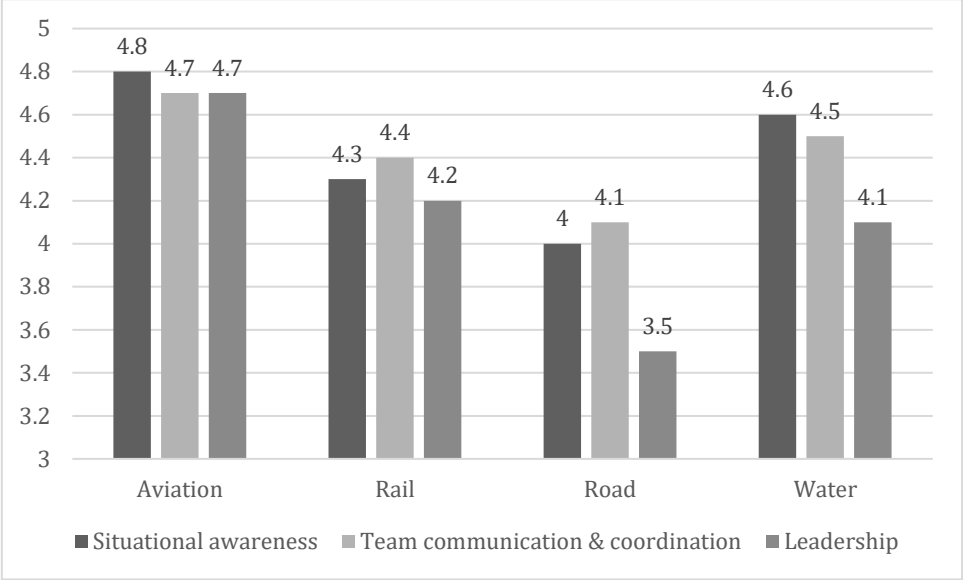

Figure 3. Top three factors by sector

Finally, Figure 4 presents the composite HOF integration score calculated as the mean of human and organizational factors in each sector. This visualization demonstrates that aviation achieves the highest level of HOF integration (4.59), followed by water transport (4.26), rail (4.23), and road transport (3.96). The steady gradient across sectors reflects how organizational maturity amplifies the benefits of individual expertise, reinforcing the need for system-level integration of human and organizational factors.

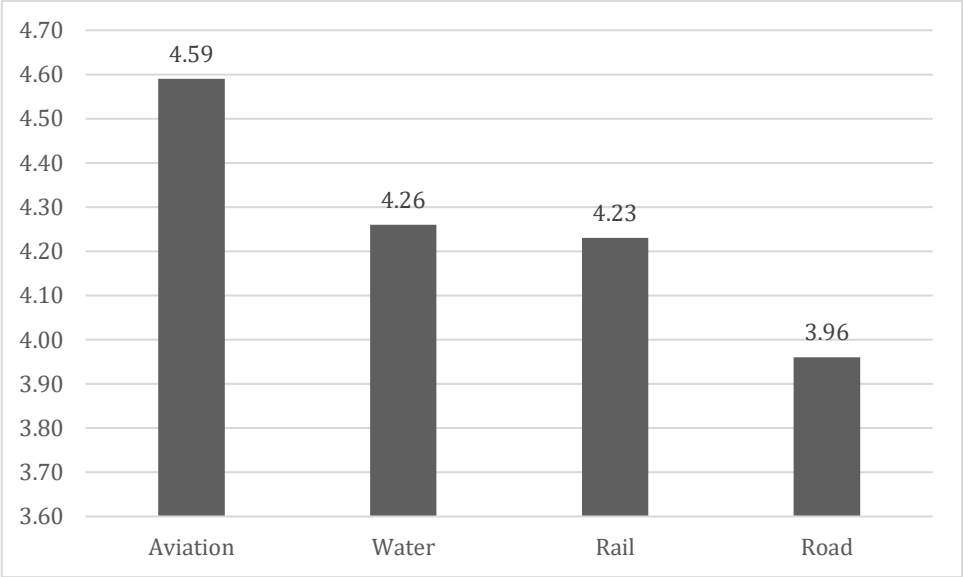

Figure 4. Cross-sector HOF integration score

Discussion

The findings of this study reinforce the socio-technical view that safety in transportation is the outcome of continuous interaction between human behavior and organizational systems rather than a function of either domain in isolation (Reason, 1997; Hollnagel, 2017). Three cross-sectoral insights emerge from the comparative analysis.

First, sectors with strong organizational leadership and formalized safety structures—such as aviation and rail—demonstrate higher integration of HOF. The consistent presence of leadership engagement, structured training programs, and open reporting mechanisms directly correlates with elevated human performance indicators such as situational awareness and decision-making accuracy. These findings align with existing evidence that

organizational commitment is a key enabler of human reliability and resilience (Guldenmund, 2000; Dekker, 2014).
Second, the results highlight a significant organizational gap within the road transport sector. While individual competence, vigilance, and adaptive decision-making remain high, these strengths are undermined by insufficient managerial support and fragmented safety systems. The prevalence of small and medium-sized enterprises (SMEs) in this sector contributes to the lack of formal safety management frameworks comparable to those seen in aviation or rail. This suggests that interventions should prioritize scalable organizational practices—lightweight reporting tools, leadership training, and fatigue risk management systems—tailored to smaller companies.

Third, the water transport sector, though generally mature in procedural compliance, reflects challenges of cultural diversity and variable training quality. This echoes earlier findings by Hetherington et al. (2006) on the "human element" in shipping, where mixed national crews and hierarchical structures sometimes limit open communication. The present study's respondents indicated that safety drills and leadership engagement help mitigate these barriers, but maintaining consistency across fleets remains an ongoing challenge.

Overall, the findings reinforce that integration, rather than isolation, represents the cornerstone of sustainable safety performance. The co-existence of strong human capabilities and robust organizational systems fosters adaptability and learning—key attributes of resilient transport operations. Furthermore, the quantification of qualitative data provided here demonstrates that combining thematic analysis with numerical scoring can produce actionable, evidence-based insights suitable for policy and managerial application.

Conclusions And Recommendations

This qualitative study explored the integration of human and organizational factors (HOF) across four transportation sectors: aviation, rail, road, and water transport. Using coded interview data and importance scoring, the analysis revealed distinct sectoral patterns. Aviation demonstrated the most advanced integration of HOF due to strong leadership and mature reporting systems. Rail showed consistent progress supported by procedural discipline and structured communication. Water transport maintained moderate integration but faced variability across multinational crews, while road transport exhibited the lowest organizational maturity despite strong individual competencies.

The findings reinforce that sustainable safety performance arises from the alignment of human and organizational systems rather than isolated improvements in either domain. Sectors that embed leadership commitment, training, and open reporting within their operational culture achieve higher reliability and resilience.

Based on the comparative results, three concise recommendations are proposed:

1. Strengthen systemic integration of HOF.
   Organizations should treat human and organizational elements as interconnected, embedding both in safety management frameworks and operational practices.
2. Invest in communication and learning mechanisms.
   Encouraging open dialogue, cross-sector learning, and consistent feedback systems enhances situational awareness and error recovery.
3. Tailor organizational practices to sector scale.
   Particularly in the road transport sector, adaptable and proportionate safety tools are needed to extend HOF integration to smaller operators.

Future research should continue to examine how digitalization and automation reshape the relationship between human and organizational factors in complex transport ecosystems.

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