Human Factors Integration in Digital Railway Transformation: A Call for Collaboration

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SUMMARY

A systematic literature review was conducted to synthesise research into Human Factors Integration and holistic risk management in the implementation of ETCS across Europe. The review highlights a lack of accessible literature in this field and makes several recommendations to bridge the gaps in knowledge and inform best practices in the UK. The importance of fostering collaboration within our discipline and developing new avenues for sharing lessons learned beyond traditional channels is highlighted throughout.

KEYWORDS

Human Factors Integration, Systems Ergonomics, Literature Review, Digital Railway, ETCS

Introduction

Britain's rail network is undergoing a digital transformation to generate capacity, performance, and safety benefits for passenger and freight users. Network Rail's long term plan for digital railway aims to bring "significant benefits to passengers and help suppliers to plan resources" (Long term plan for digital railway, 2024). Central to this transformation is the introduction of European Train Control System (ETCS), which enables track-to-train communication to provide in-cab signalling indications and control.

The implementation of ETCS introduces new technology, infrastructure, workflows, and processes which will influence the roles and responsibilities of many operators across the network (Young et al., 2006). While our rail industry possesses great expertise in navigating change across the network, the introduction of ETCS presents novel challenges for which the UK has limited experience.

The East Coast Digital Programme (ECDP) is a landmark scheme that will introduce in-cab digital signalling on the Southern part of the East Coast Main Line, between London Kings Cross and Grantham (East Coast Digital Programme, 2024). This will introduce ETCS to Britain's first intercity mainline. The incremental nature of its roll-out will create 'transition points' between signalling systems and instances where these systems are overlayed and interacted with differently between vehicles. As such, operators will be required to retain and selectively apply different knowledge and skillsets throughout their working day and across the implementation programme (Palumbo, 2014).

It is imperative that Human Factors (HF) are integrated from the start of this transformation to understand the impact on operators, manage associated risks across the programme, and ultimately ensure the system is optimised for end-user performance, safety, and efficiency.

Aims and Approach

To support and inform a strategic approach for Human Factors Integration (HFI) across ETCS deployment projects in the UK, a systematic literature review has been conducted to identify, analyse, and synthesise HF research into ETCS implementation across Europe. The aim of this activity was to:

- Understand the extent of HFI across ETCS projects to date;
- Determine best practice tools / techniques to integrate HF into ETCS projects;
- Identify gaps in the literature and opportunities for further work to address potential challenges and risks associated with end-user interactions with ETCS.

Method

A search was performed using the following search terms to identify relevant publications:

- **Constant search terms:** European Rail Traffic Management System (ERTMS), European Train Control System (ETCS);
- **Additional search terms:** Human Factors, Ergonomics, End User, Driver, Driveability, Signaller, Maintainer.

A title review was performed upon each search to exclude publications that were obviously not relevant to HFI in the implementation of ETCS. The abstract of each publication with a relevant title was then reviewed to confirm that the paper discussed the implementation of ETCS across a rail network, the (potential) impact on at least one operator, and at least one HF assessment method.

A full-text review was then conducted for all publications with abstracts that met these criteria. The bibliography of each paper was reviewed to identify relevant, related literature through a 'snowballing' approach. Publications identified through this process were subject to the same review process described above.

A total of 31 publications were subject to a full-text review. This dataset encompassed academic and industry research papers, conference proceedings, and accident investigation reports. Each publication was initially categorised based on metrics one to three in Table 1.

Table 1: Categorisation of relevant publications.

Item	Publications (N)
1. Operator(s) concerned	
Train Driver	26
Signaller	4
Maintainer	2
Other	1
2. System mode(s) / change(s) concerned	
ETCS Level 2	19
Level Transitions (NTC > Level 2)	11
Overlay Areas	8
Degraded Modes	5
3. Human Factors themes concerned	
Workload	13
Physical Design	13
Information Requirements	14

Automation	4
Operating Concept	7

The intention was to analyse groups of publications, based on the metrics outlined in Table 1, to compile insights into system and task changes, potential operator errors, performance shaping factors, and safety or performance-related consequences. Additionally, the methods employed to derive these findings, and steps taken to manage associated risks, would be documented as examples of best practice in HFI.

While such detailed analysis could be conducted for studies focusing on the train driver role, there was not sufficient evidence within published literature to construct a wider overview of HFI and holistic risk management in the implementation of ETCS across Europe. Nonetheless, this review has highlighted several notable gaps in the existing literature, which are discussed below.

Discussion

Considering Whole-System Risk

Most published literature focuses solely on the impact of ETCS on the roles, responsibilities, and performance of train drivers. This is understandable, given the introduction of in-cab digital signalling, driver interactions with the technology will directly influence system safety and performance. As such, regulatory requirements that prompt research often prioritize evaluating the train driver's ability to operate the system.

However, the performance of other operators is equally critical to the safe and efficient implementation of the ETCS system. Although some authors have proposed theories regarding the potential effects of ETCS on the performance of signallers, technicians, and maintenance personnel (e.g., Morrisroe, 2015), these are seldom assessed using rigorous Human Factors methods. Only one of the reviewed papers explicitly measured the impact of ETCS on train dispatcher and operational management staff performance, with limited focus around workload and human error probability (Zeilstra et al., 2016).

Despite some variability in the type of operator each paper focuses on, a common limitation is the focus on each type of operator in isolation. None of the reviewed papers considered the potential effects of ETCS on safety-critical communications between operators, such as train drivers and signallers, and/or the knock-on effects that each system and task change might have on other operator(s) across the system as a whole. Wilson (2013) notes that "the railway is a large, complex distributed system of many technical, organisational, economic and human components. This distributed system is spread across regional, national and cultural boundaries, giving additional problems of inter-operability." This highlights an opportunity for further work and research to consider the impacts of ETCS from a systems approach.

Establishing a System Definition of the Change

A clear, published 'system definition' may support and inform further HF approaches and research around the risks of implementing ETCS across the whole system and network of operators. According to the European Union Agency for Railways (2020) a 'system definition' is the most critical prerequisite for safe integration, delineating "all interfaces between the change/system under assessment and the human operators and the different parts, components, constituents or sub-systems to which it interfaces".

When establishing a system definition, it is best practice to engage HF specialists in collaboration with Systems Engineers to develop a comprehensive Concept of Operations (ConOps). This

describes the characteristics of the proposed ETCS system, across each phase of migration, from the perspective of all affected operators. Such an approach provides a framework for integrating HF across the system and transformation programme, such that a suite of user requirements can be developed to inform system and safety requirements. Shield and Thompson (2023) propose a compelling user-centred approach to the development of a ConOps in the context of digital signalling projects.

Sharing Best Practice in Human Factors Integration

ETCS systems have been in operation across Europe, in varying capacities, for over two decades. Despite the varying operational frameworks across European railways, it would be useful to leverage insights from system definitions, ConOps, and related efforts in integrating HF into ETCS deployment across the continent to inform best practices within the ECDP.

However, the scope of HF research in this field remains limited. Only 31 publications were identified in this review, predominantly found in academic journals, conference proceedings, and rail safety databases and authored by academic institutions (52%) or rail safety / regulatory organisations (19%). While these publications benefit from rigorous peer review processes, ensuring the credibility of their findings, they likely represent only a small proportion of the broader efforts to integrate HF within ETCS implementation across Europe. The lack of accessible grey literature and industry-developed case studies leaves a significant gap in knowledge of real-world examples and practical insights crucial for advancing HFI strategies across ETCS projects.

Recommendations

This paper highlights the lack of accessible literature concerning HFI and assessment of whole-system risk in ETCS implementation across Europe. While our focus has been on the unique topic of digital transformation in the rail industry, this finding will likely resonate with those working across a range of industries grappling with novel system integration.

As the findings of the literature review are limited, there is a need to 'cast the net wider' if projects/programmes are to benefit from a range of knowledge and experience. The following recommendations outline the next steps to identify and leverage existing forums to understand what other knowledge and experience exists in this field. New insights can then be drawn upon to inform a strategic HFI approach for a specific system definition, such as ECDP.

1: Opportunities for Collaboration on Special Interests

The Chartered Institute of Ergonomics and Human Factors (CIEHF, 2024) currently supports eight sector groups, fostering regular engagement and collaboration among key stakeholders to exchange best practices and insights on a shared interest. While a large proportion of the discipline's work revolves around the rail industry, and there has previously been an active network, there is currently a notable absence of a dedicated sector group. As a first step, it is therefore proposed that a Rail Sector Group is re-established.

HF professionals are involved in various, diverse facets of the rail industry and there is value in sharing best practice at a high level to provide a collective understanding of our work as a discipline. However, there is also a need for specialised interest groups within the overarching rail sector group. These groups should have a clearly defined focus, agenda, and objective to tackle a shared challenge. It is acknowledged that defining and establishing the key stakeholders of such groups can be challenging due to the fragmented nature of projects and contracting mechanisms within the industry, and the broad range of topics within the sector. To overcome this challenge, significant efforts are required amongst the CIEHF community to promote each special interest

group and cultivate an inclusive environment that encourages active participation and collaboration amongst industry, academia, and regulatory bodies.

2: Forums to Share Work in Progress, Best Practice, and Lessons Learned

Human Factors professionals have various avenues available to disseminate knowledge and best practice, including journals, conference papers, and magazine articles. While these platforms offer wide community reach, they often require a refined focus, robust methodologies, and well-defined novel insights. Due to project deadlines and priorities, industry professionals may struggle to develop such polished outputs. We therefore propose the development of a space where more frequent, practical case studies, lessons learned, and 'work on the table' can be shared. This forum could serve as an 'incubator' environment, fostering discussion, innovation, and the exchange of best practice within the field.

3: Connecting internationally

The existence of ETCS applications across Europe presents an opportunity for UK HF practitioners to learn from best practice, and inform approaches for HFI in the UK context. Avenues exist to connect internationally through conferences, such as The International Conference on Rail Human Factors, with the 7th event being the last held online in June 2021.

In addition, a relatively recent development presents opportunity to connect more regularly. In October 2022, the Rail Human and Organisational Factors (HOF) digital platform was launched by the International Union of Railways (UIC) as part of a collaborative project with the European Union Agency for Railways (ERA). "The aim of this digital online platform is to build and spread knowledge, research and information and exchange operational practices and experiences on HOF in the railway domain." (Rail HOF, n.d).

Rail HOF is positioned to be "the new place for the European and international railway community to share, discuss, and advise on HOF knowledge, with the aim of helping every organisation to increase safety and performance, through applying HOF good & best practices, including the "driving change" and "learning" methods." (Rail HOF, n.d). It is imperative that HF practitioners working on ETCS deployment projects in the UK have presence and active participation within the Rail HOF space to maximise visibility and awareness of opportunities to learn from others in this area.

Conclusion

'Leading Health and Safety on Britain's Railway' (LHSBR, 2024) is the rail industry's health and safety strategy, and "Improving our Capability" is one of twelve key risk areas identified (Improving our Capability, 2022). A Human Factors Strategy (Human Factors Strategy, 2021) has been prepared by the HF Strategy Group (HFSG) which is focused on Capability Improvement. The strategy notes that "There is a lot of communication of HF activity in the industry. But more could be done to coordinate this, and the HFSG has a key role to play."

The findings identified through the literature review and the recommendations outlined in this paper support this statement. In summary, HF practitioners working across the rail industry can assist the HFSG in this aim, specifically improving capability for HFI within digital railway projects, by:

1. Re-establishing the CIEHF Rail Sector Group and/or Special Interest Group.
2. Exploring opportunities to create an incubator or working group to form ideas and share work in progress.

3. Connecting with and participating in the European and International community through Rail HOF, to identify lessons learnt and best practice for other deployments.

There is a need and desire to improve HF capability within the UK rail industry, specifically for the success of ETCS deployment projects. It is clear that in order to bridge gaps in knowledge to inform and enable best practices for HFI in this area, we most foster collaboration within our discipline and engage with new avenues for sharing insights beyond traditional channels.

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