

# Human Factors for Rail Traffic Management

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## SUMMARY

Rail traffic management (TM) is representative of an emerging class of technologies that provide supervisory control and decision support in collaborative contexts. This paper presents observation and interview analysis to outline the critical dimensions of TM from a human factors perspective in order to inform the case for further investments in TM development and deployment and to support strategic infrastructure capacity benefits (Soone, 2024).

## KEYWORDS

Railway; Automation; Coordination; Traffic Management

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## Context, aims and objectives

Traffic management (TM) is a key enabling technology for reliable railway operations that enables the planning, and re-planning, of the train service. Through simulation, TM can predict train movements and performance (highlighting where specific conflicts may be present in the plan) and calculate key performance indicators (KPIs) to assess ongoing punctuality. TM also harnesses different representations—particularly the train graph and platform docker—to visualise the train service and act as a point of input for end users. As such, TM offers additional ways of representing the state of the railway to help improve shared understanding and to facilitate performance-led decision making. There has been, however, limited systematic analysis of current deployments of TM in Great Britain and few assessments of TM from a human factors (HF) or user-centred design (UCD) perspective. An HF analysis of TM would provide an evidence base to specify TM human-machine interface (HMI) and operational process design, facilitate the development of deployment and training guidance, and help to specify future human-automation integration and functional design. Furthermore, TM is of wider interest as it is typical of an emerging class of cyber-physical systems that combine supervisory automation, data synthesis, and predictive simulation to drive control in cooperative settings (Woods & Branlat, 2010).

This paper presents an in-service HF analysis of TM – the objectives of the work were:

Objective 1: Describe current patterns of TM use.

Objective 2: Review theoretical frameworks for human-automation interaction.

Objective 3: Synthesise the baseline and framework analyses (Objectives 1 and 2) to derive a structured description of human-automation configuration and interactions with TM.

Objective 4: Identify short-, medium-, and long-term recommendations.

## Method and results

The work commenced with document review and site visits to railway control locations that use TM. This familiarisation informed interviews with 20 subject matter experts (with a mixture of operational, managerial, and strategic backgrounds) from Network Rail, train operating companies (TOCs), and the TM supply chain. Interviews were subject to a qualitative thematic analysis,

resulting in 652 non-unique instances of codes that could be grouped under five themes: user, team, organisational, TM function and business (design/procurement/deployment) processes.

- *User* – importance of HMI design and specific HMI feedback; workload and effort as both an enabler and barrier to TM adoption; the changing nature of operational decisions with TM.
- *Team* – the role of a clear operations model; TM at the centre of coordination; team workload both as an enabler and barrier.
- *Organisational* – the role of organisational goals; expectations around operating strategy; regional interoperability; greater integration with timetable planning functions.
- *TM function* – variable definitions of TM; the importance of diverse and high-quality data feeds, relevance and value of current TM functions; priorities for future TM functions.
- *Business (design/procurement/deployment) processes* – the importance of a clear definition of TM; training design; design and procurement strategies; TM within wider software development strategies and architectures; deployment strategies and their impact on user acceptance.

### Implications

In terms of Objective 1, TM has multiple *aspects* (a novel HMI; decision support; a new way of thinking about performance; ways of working and concept of operations) requiring multiple HF approaches to fully interpret, and guide, the design and use of TM (e.g. HMI design, training design, communication and coordination principles). There are also different *perspectives* of what TM is across two dimensions – process change and technical change. Definitions and expectations of TM must be agreed and made explicit across different levels of relevant organisations to have an orchestrated approach that supports a common, interoperable view of TM use. A range of HMI factors were identified, including different reasons why (and when) to use the platform docker in preference to the train graph, with the familiarity of the platform docker, and its utility as a place for user input, significantly shaping perceptions. One of the most valuable aspects of TM is its ability to reduce workload. However, what is implied by ‘workload’, and therefore the benefit of TM, is different for different roles – whether it reduces keystrokes, number of tasks, communications, or cognitive complexity. Certainly, TM should not increase workload; this would be perceived as critical barrier to adoption. The study delivered a first taxonomy of how workload links to TM.

An important outcome was the criticality of the ‘TM function’ and ‘business process’ themes for HF and acceptance. For example, local context informs not only technical localisation, but also a number of socio-technical factors that influence the usefulness of TM, such as local prior experiences of technical change. TM is new class of application from a software, hardware, and architectural standpoint, as it is often web-based. While the use of cloud technologies opens up new opportunities for HMI flexibility, it is potentially quite different from a traditional rail systems engineering standpoint. Therefore, the HMI design needs to harness these new ways of working with technology suppliers. TM also demands new HF considerations for controller and TOC roles, in addition to the signaller role.

With regard to Objectives 2 and 3, the importance of the collaborative aspect of TM, and many of the challenges of successful use (identified in Objective 1), defied easy categorisation within existing human-automation theories. The analysis identified a human-automation model for TM, assigning different functions of the train control/regulation process to a cognitive model based on the information processing stages of ‘identify-interpret-decide and –act’ (Parasuraman et al, 2000). Crucially, for TM, each of these cognitive stages is often a collaborative activity across multiple roles, rather than just a relationship between an individual user and TM. This model helps to clarify the share of cognition attributed to TM across roles and therefore the change in working that arises through TM. In turn, the model identifies where future TM deployments can add the most value to

the service control process, and the future value of using approaches such as EAST (Salmon et al, 2022).

Objective 4 established short-, medium- and long-term recommendations for future work. The suggested short- and medium-term points of action include corralling existing HMI feedback and knowledge into a single resource, reviewing training to include more “why TM?” content, delivering refresher training, and benchmarking usability and function use for existing TM implementations. Looking to the long-term, HF activities to maximise the acceptance and benefits of TM, such as a new TM workload toolset, HF principles for controller and TOC roles, and improved prediction algorithms (Pascariu et al, 2025) to deliver measurable improvements to passenger experience, have been recommended.

## References

- Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans*, 30(3), 286-297.
- Pascariu, B., Flensburg, J. V., Pellegrini, P., & Azevedo, C. M. L. (2025). Formulation and solution framework for real-time railway traffic management with demand prediction. *IET Intelligent Transport Systems*, 19(1)
- Salmon, P. M., Stanton, N. A., Walker, G. H., Hulme, A., Goode, N., Thompson, J., & Read, G. J. (2022). The Event Analysis of Systemic Teamwork (EAST). In *Handbook of Systems Thinking Methods* (pp. 129-156). CRC Press.
- Soone, J. (2024). Improving use of rail infrastructure capacity (PE 754.599). European Parliamentary Research Service. Retrieved from <https://www.europarl.europa.eu/thinktank>
- Woods, D. D., & Branlat, M. (2010). Hollnagel’s test: being ‘in control’ of highly interdependent multi-layered networked systems. *Cognition, Technology & Work*, 12(2), 95-101.