H-FIT: Assessing the human factors impact of proposed changes to the railway

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SUMMARY

This paper describes the background, development, and content of a new tool, H-FIT, to assess the likely human factors impact of proposed railway change projects. The tool provides a structured approach to identifying the scope and requirements for human factors integration at early project stages, around which the human factors activities can be specified and planned. The core of the tool is 14 design scope factors which range from planned changes to the work environment, to the introduction of new HMIs, and changes in working hours. These design scope factors are linked to physical and organisational design outcomes, such as accessibility, usability, and fatigue. Human factors goals can be set for each area of design scope against the related design outcomes.

KEYWORDS

Rail HF, Human factors integration, human performance, socio-technical system design

Introduction

Any change to railway operations can have an impact on human performance, from large changes such as the introduction of new fleet vehicles to smaller changes like the extension of a railway platform. New railway fleet vehicles, for example, should consider physical ergonomics attributes such as accessibility and comfort for staff and passengers, as well as cognitive ergonomics aspects associated with the usability of controls and displays, and organisational ergonomics aspects relating to the way information is transmitted to the vehicles for display to staff and passengers. Smaller projects may have similar considerations, but require a lower level of analysis or specific human factors expertise due to the scale and complexity of the change. A platform extension, for example, may only require a check that accessibility and information provision are unaffected for passengers, and that signal and platform-train interface visibility are unaffected for train drivers.

The inclusion of human factors (HF) in management of railway change is embedded in mandatory standards and legislation in the European rail sector, with reference to the application of human factors knowledge made in the 2016 Railway Safety Directive (EU, 2016). The EU Common Safety Method (CSM) on Safety Management Systems (SMS) is more specific and requires the integration of human factors to “address risks associated with the design and use of equipment, tasks, working conditions and organisational arrangements, taking into account human capabilities as well as limitations, and the influences on human performance” (EU, 2018, Clause 4.6.1).

Irish Rail have addressed this legislative requirement through the development of a human factors strategy, part of which is a human factors assurance (or integration) process for all proposed changes to plant, equipment, infrastructure or operations (PEIO). This sits within the wider PEIO change management and safety assurance framework under the Irish Rail SMS. When a change is proposed, the potential human factors impact is assessed, and the scope of human factors assurance activities is defined. However, it can be difficult to identify the specific human factors inputs and level of effort needed for a project at an early stage. Yet this is when the requirements are being developed for suppliers to tender against and it is necessary to provide a scope of the required HF work. This paper describes a tool, the Human-Factors Impact assessment Tool (H-FIT) developed to support the early identification of the scope of HF issues generated by the individual project. This helps to specify the correct level of human factors input in the project tender documentation.

H-FIT Development

The overall human factors assurance process at Irish Rail broadly follows the human centred design process (ISO 9241-210, 2010), but the H-FIT tool specifically focuses on the aspect of understanding and specifying the context of use and specifying high level user requirements. Existing Human Factors Integration (HFI) tools in the literature are typically based around the US Army's MANPRINT model (Houghton et al., 2015) which sets out seven domains of HFI: Staffing, Personnel, Training, Human Factors Engineering (HFE), Health Hazards, and System Safety (Widdowson & Carr, 2002). Early human factors assessments may be carried out against these domains, particularly in the defence industries (e.g., Lilliane & Jacques, 2009). However, this model is not always directly applicable to other industries. For example, in rail, the human factors discipline has relatively little input to the staff aptitudes and experience under the 'Personnel' domain since occupational psychologists have a mandate in this area. It does not therefore need to be specified under the human factors requirements for a particular project. Similarly, system safety is managed by an appointed Safety Assurance Manager as part of a mandatory safety assurance process, and while it is important that HF feed in to their analysis, that work is not specified, developed, or led by human factors. The HFE element of MANPRINT is unique to the human factors discipline, but is it still a very broad topic and it can be difficult to identify the specific and unique HF activities needed to support a particular project at early project stages. The H-FIT tool has been developed to be more specific to the HF inputs on railway change projects.

H-FIT was developed through a review of human factors taxonomies, both retrospective (supporting accident and incident investigation) and prospective (supporting human reliability analysis), including HFACS (Shappell & Wiegmann, 2000), MEDA (Rankin et al., 2000), and THERP (Swain, 1964), but particularly the 5x5 model developed by staff at the European Union Agency for Rail (ERA; Accou & Carpinelli, 2022). It was also influenced by industrial tools which the author has had the privilege to work with, but which have not been published externally. The aim of the review was to identify factors for inclusion in the H-FIT tool. The 5x5 model was a particular focus because this taxonomy is already embedded as a mandatory taxonomy in draft EU rail legislation on rail accident and incident data analysis (EU, 2020) and is proposed by ERA to be used as a non-mandatory taxonomy in the identification of human factors goals for change management, as part of forthcoming guidance which the author has contributed to.

The 5x5 model was developed by Accou & Carpinelli (2022) to provide a structured taxonomy to support the SAfety FRactal ANalysis (SAFRAN) post-incident investigation method. The aim of the SAFRAN method is to guide investigators in understanding how the composition of the safety management system may have influenced the operational decisions and actions involved in an incident or accident. The 5x5 taxonomy was initially based on a set of performance influencing factors identified in a comprehensive review of worldwide railway investigations by Kyriakidis et al., (2015). It is composed of five groups: dynamic staff, dynamic situational, static staff, static situational, and socio-interactional. The distinction between staff and situational refers to factors relating to the individual versus factors relating to the task, environment, or situation, while the static/dynamic distinction refers to the variability of the factors over time. The socio-interactional group covers teamwork and communication. Each group is composed of five factors (hence 5x5), giving 25 factors in all. The full set of 25 factors in the 5x5 tool is shown in Figure 1.

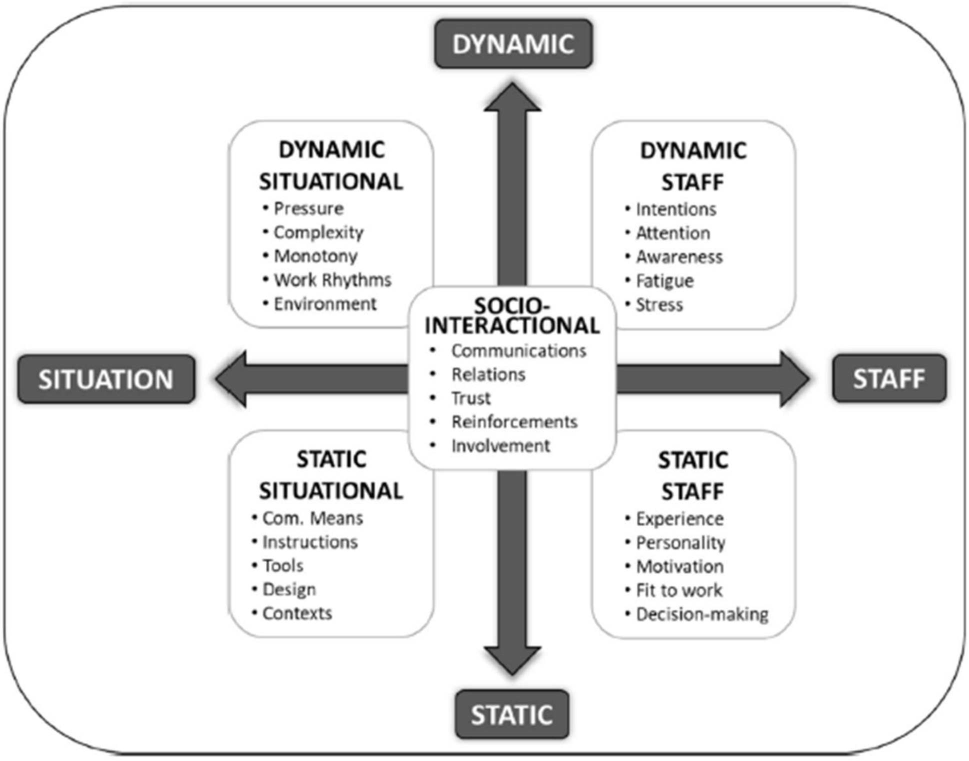

Figure 1: The 5x5 model (Accou & Carpinelli, 2022)

Within Irish Rail, the 5x5 model is not currently proposed to support human factors integration for several reasons; first, although simpler than many other human factors taxonomies, some of the factors within the model are not readily understood and some appear to overlap. For example, monotony and work rhythms have a potential overlap, as do reinforcements and motivation. Second, due to its origins as a retrospectively applied taxonomy, some of the factors are difficult to specify at early design stage. For example, the 'intentions' factor refers to the motivations for staff actions in an incident and does not apply directly at design stage. Similarly, fit to work refers to the state of a specific staff member during an incident and is not especially relevant to design. The third reason why H-FIT includes a new framework relates to the distinction between tangible, planned changes (referred to as design scope in H-FIT) and the effects of those changes on the people working in the redesigned system (referred to as design outcomes in H-FIT). In common with other human factors taxonomies, 5x5 mixes these two categories, for example communication means, instructions and tools are all tangible elements *of* the design while pressure, fatigue and stress are affected *by* the design. A clear distinction is drawn between these two elements in H-FIT with the design scope setting the required level of human factors input, and the design outcomes driving the human factors goals and activities.

Design Scope Factors

14 design factors were identified for inclusion in H-FIT (see Table 1). These are drawn from the four interaction areas within the SHELL model of human factors (Hawkins & Orlady, 1993) of Liveware-Software (L-S), Liveware-Hardware (L-H), Liveware-Environment (L-E), and Liveware-Liveware (L-L). Factor 1 in H-Fit is the environment (L-E), while factors 2-6 relate to technical changes to the system involved physical equipment, graphical user interfaces, new observable tasks, or the introduction of automation (L-H). Factors 7 and 8 relate to procedural changes (L-S), and factors 9-14 relate to more organisational factors, covered to some extent by L-L in the SHELL model, but encompassing more than just interactions with colleagues. The strong inclusion of organisational factors within H-FIT is driven by the increasing focus of European human factors on

the organisational elements, highlighted by the adoption of the term HOF, or Human and Organisational Factors, in the European legislation.

Table 1: 14 design factors

Factor	**Type**	**Description**
Factor 1	Environment	Any change to the environment where the task (including customer tasks) takes place. This may involve a change of location of the task, or changes within the location.
Factor 2	Tasks	Any change to the way safety-critical or safety-related tasks are performed, or the introduction of new safety-critical or safety-related tasks
Factor 3	Tools/equipment	Any change to existing equipment or tools used for safety critical or safety related tasks, or the introduction of new such tools or equipment
Factor 4	HMIs	Any change to existing HMIs used by safety critical staff in the course of their duties, or the introduction of a new HMI
Factor 5	Alarms	Any change to the number, format, or presentation of alarms to any role
Factor 6	Automation	Any change in the level of automation used by any role
Factor 7	Procedures	Any change to safety critical or safety related procedures, including the development and implementation of new procedures
Factor 8	Communication protocols	Any change to the communication protocols used to support safety critical communications
Factor 9	Staffing levels	Any change to the expected number of staff allocated or available to complete tasks
Factor 10	Resource availability	Any change to the availability of tools and equipment or other necessary resources
Factor 11	Roles and responsibilities	Any change to the roles and responsibilities of safety critical or safety related staff
Factor 12	Information provision	Any change to the way in which safety critical or safety related information is provided to any of the affected users
Factor 13	Leadership and supervision	Any change to the level or quality of supervision available to safety critical staff
Factor 14	Working time	Any change to the rostering of safety critical staff

There is some overlap between the factors in H-FIT, for example if Factor 2 (Tasks) is affected, it is likely that Factor 7 (Procedures) may also be affected. However, this is not necessarily the case and this means that two factors cannot be combined. For example, the format or structure of procedures may be amended without any change to the task itself. Factor 5 (Alarms) could also be regarded as a specific case of Factor 4 (HMIs), but given the critical importance of alarms and the specific requirements relating to their use, it was deemed important to have a separate category. Similarly, Factor 8 (Communications protocols) could be regarded as a sub-set of Factor 7 (Procedures), but safety critical communications are another critical topic which deserves its own category.

Design Outcomes

The design outcomes relate to the effect the design may have on human performance. In contrast to the design scope, which sets a prescriptive set of 14 factors for consideration, the listed design outcomes are intended as a set of prompts which may be supplemented from the analyst's experience. Table 2 shows the design outcomes currently included in H-FIT, mapped to the most applicable design scope factors. An argument could be made that almost all design scope factors can be related to the design outcomes; for example, a noisy environment may increase fatigue or low staffing levels could impact on the quality of teamwork. However, in practice there are some design scope factors with an obvious, direct influence on certain design outcomes. The mapping in Table 2 attempts to highlight these direct influences, and is therefore just a guide to help focus attention on the most likely areas of impact. Individual projects may have obvious direct links which do not appear in this table, and these should still be identified when analysing relevant design outcomes for the project.

Table 2: Mapping of design scope factors to design outcomes

	Design Outcomes															
	Visibility	Audibility	Thermal Comfort	Accessibility	Physical workload and stress	Mental workload and stress	Situation awareness	Usability	Human reliability and error	Fatigue	Quality of communications	Teamwork	Training needs	Motivation/job satisfaction	Risk awareness	Culture
F1: Environment	•	•	•	•	•		•		•					•	•	•
F2: Tasks					•	•			•	•			•	•		•
F3: Tools/equipment		•		•	•				•				•			
F4: HMIs	•			•		•	•	•	•				•			
F5: Alarms	•	•				•	•	•	•				•		•	
F6: Automation					•	•	•	•	•				•	•		
F7: Procedures						•	•	•	•		•	•	•		•	•
F8: Comms protocols							•		•		•	•	•			
F9: Staffing levels					•	•			•	•				•		
F10: Resources					•	•			•					•		•
F11: Roles									•		•	•		•	•	•
F12: Info provision							•		•					•		
F13: Supervision									•			•		•	•	•
F14: Working time									•	•				•		

H-FIT Structure

The overall structure of H-FIT is shown in Figure 2. The tool is held in an excel workbook which guides the user through each step. The content of the four steps, which are aligned to the ISO-9241-210 (ISO, 2010) process, are outlined below.

Figure 2: Steps in the Human Factors Impact Assessment tool for Railway Change Management

Step 1: Outline change and identify users

The first step is to briefly describe the proposed project scope and to identify the end users who may notice a change, for example, railway passengers, train drivers, signallers, etc. The purpose of this step is to capture a qualitative description of the project and to start to identify potentially affected end users. It may not be possible to provide a detailed description, but high-level information should be available from existing project documentation or discussion with the project manager. As the roles within the railway are well known and understood, a detailed target audience description is not necessary within this step.

Step 2: Identify scope of design changes

The second step is to identify the scale of the proposed change against the 14 design scope factors (see Table 1). As they are all intended to be tangible changes, they could be identified by the project manager, although in practice the table may be completed by a HF Specialist in consultation with the project manager.

Each of these 14 factors can be scored from 0 (no change) to 3 (high change). This allocation determines the level of human factors input required for a particular project. Projects with no HF impact do not require any further input; the level of effort is tailored for low-high impact projects with low impacts only needing a review of the risk assessment or a short consultation with staff for example, while high impact projects require a structured human factors integration process to plan and document the human factors activities undertaken. Some examples of the different levels for three of the factors from Table 1 are shown in Table 3. These examples are provided within the tool to provide guidance in the appropriate level to allocate for each project. The overall project is rated no, low, medium, or high human factors impact based on the highest scoring element across the 14 factors.

Table 3: Example of levels of change for three H-FIT factors

	Factor 1: Environment	Factor 6: Communication protocols	Factor 12: Working time
High (3)	A new control room or drivers cab	Introduction of new suite of forms supporting safety critical communications	Move from day to night working
Medium (2)	Installation of new lighting system within a maintenance depot	Change to a single safety critical instruction	Change from 8 to 12 hour shift pattern
Low (1)	Changed layout of a customer car park	Minor change to an existing form used to support safety critical communications	Change in time available for handovers

Step 3: Identify potential effects of design changes

The third step identifies the possible effects of a change for each affected user type against each of the factors scored above zero on step 2. The aim of this step is to start to identify the required human factors activities within the scope of the project. This step requires a much higher degree of human factors expertise, as judgements are made on the expected effect of the design scope on human performance.

For example, a new fleet of trains would represent a new working environment (amongst other factors) for train drivers (amongst other affected users) and design outcomes should be considered relating to the lighting levels within the train cab, visibility within and from the cab, noise and temperature levels within the cab, accessibility into the cab, and accessibility of the provided driver seat and console. From the passenger perspective, a new information system may be provided on-board and the visibility and usability of the information presented on that system should be considered.

Step 4: Set human factors goals

The final step is to set a human performance goal for the identified effects. Currently these are broad statements such as 'The desk shall accommodate a user from 5PF to 95PM' or 'Glare shall be minimised'. Each project is then responsible for identifying the relevant standards and HF activities to achieve these goals as part of the human factors integration process.

Conclusions

The H-FIT tool presented in this paper has been developed from existing human factors taxonomies and methods to address the specific needs of Irish Rail in meeting the legislative requirements on change management, and providing sufficient information at an early project stage to support tender documentation. The tool provides a structured approach to assessing the degree of human factors impact of a proposed change, and to tailoring the planned human factors activities depending on project complexity. The objective is to set high level human factors goals or requirements before the development of a detailed human factors assurance or integration plan.

The tool has been iteratively adjusted during application against projects at Irish Rail, with changes made to the structure and guidance, and it will likely continue to evolve. A planned development is to provide more guidance on relevant standards for each design scope factor and design outcome and to identify relevant assessment methodologies.

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