

Integration of Human and Organisational Factors in Railway Systems Lifecycle Processes

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SUMMARY

Integration of human factors in railway change management and systems engineering is an increasingly important topic, not least because of emerging regulatory requirements in the area. This paper will describe one model developed collaboratively in the International Union of Railways (UIC) Human and Organisational Factors Working Group (HOFWG) which maps 12 human and organisational factors steps to the 12 steps in the V-cycle model described in the railway Reliability, Availability, Maintainability and Safety (RAMS) standard (EN50126). The aim is to provide a framework, aligned with existing engineering approaches, to communicate how human and organisational factors can be integrated into a railway change project.

KEYWORDS

Human factors integration, rail human factors, V-cycle

Introduction

Consideration of human and organisational factors (HOF)¹ during design and development of new railway systems is essential for ensuring the safe and efficient operation of the system. Generally speaking, HOF are not yet sufficiently addressed and are often applied implicitly, sometimes insufficiently considered and can be limited to physical ergonomics. However, taking HOF into account offers advantages in terms of both performance and safety. MANPRINT is the original model for human factors integration (HFI) but it doesn't fit well with modern railway projects (Balfe, 2023), and so does not support understanding of the human factors inputs, approaches and outputs among key stakeholder groups. For example, some elements such as 'Personnel' are usually handled by human resources departments while the core area of Human Factors Engineering (HFE) is underdefined. More recently, the European Union Agency for Rail (ERA) has published guidance on integrating HOF in change management (ERA, 2023). This guidance draws from the 'Human Factors Case' methodology used by Eurocontrol (2011) and the human-centred design process described in ISO9241-210 (2019). The work described in this paper is complementary to the ERA guidance, and intended to describe the same type of approach, but in the context of the widely used railway system V-cycle model as described in EN50126-1 (2017).

The work was undertaken by the UIC HOFWG in conjunction with the Performance, reliability, availability, maintainability and safety (PRAMS) HOF subgroup of Europe's Rail Joint Undertaking (ERJU) and resulted in the production of a document titled 'Integration of Human and Organisational Factors (HOF) in railway system design. In many European countries, there are regulatory requirements that mandate the application of EN 50126 in the development of railway applications. The norm underlines that the inclusion of human factors in the phases of the

¹ Note that the term 'human and organisational factors' is increasingly used in European railways where it is defined in the same way as 'human factors'. The terms are used synonymously in this paper.

development process is essential. However, it does not describe how human factors integration can occur in the individual RAMS phases and what human factors activities might be associated with it. This leads to HOF being insufficiently considered or only coming into play in the later stages of projects, when adjustments are hardly feasible and costly. With the approach and model we have developed, we therefore offer concrete assistance for the systematic and verifiable inclusion of human factors throughout the system lifecycle.

The goal is to support the understanding of how to integrate human and organisational factors into railway system design from the perspectives of different stakeholders.

Method

The EN50126-1 V-cycle model was chosen as the basis for describing the steps involved in integrating human and organisational factors. This model describes 12 steps in the generic RAMS process from concept through to decommissioning. The first step was to define 12 human and organisational factors steps that aligned with the model, to describe the main human factors integration goals at each step of the RAMS process. These human and organisational factors steps were reviewed and refined with the UIC HOFWG in order to validate them. A further review and validation was then conducted by the ERJU PRAMS working group.

The 'classic' representation of the V-cycle as described in EN50126-1 is composed of 12 phases that can be divided into three major blocks (see Figure 1):

- Risk assessment and requirement development (i.e., '*Tender*' block, marked in red in Figure 1), incorporating phases 1 to 5.
- Implementation and demonstration of compliance with RAMS requirements (i.e. '*Design and Commissioning*' block, marked in orange in Figure 1), incorporating phases 5 to 10. Phases 8, 9 and 10 can be seen as an integration subphase.
- Operation, maintenance and decommissioning (i.e. '*Operation*' block, marked in blue in Figure 1), incorporating phases 11 and 12.

For all 12 steps of the V-cycle, HOF plays an important role in achieving the desired safety and performance and human factors specialists would expect to contribute at each stage. However, the HOF contribution is not explicit in the model and therefore may not be appreciated by system engineers, resulting in gaps in the application of HOF. Genuinely considering Human and Organisational Factors (HOF) from start to finish means applying a structured and practical approach to the integration of HOF. The solution we propose is an enrichment of the V-cycle model with HOF sub-steps and outputs at each stage.

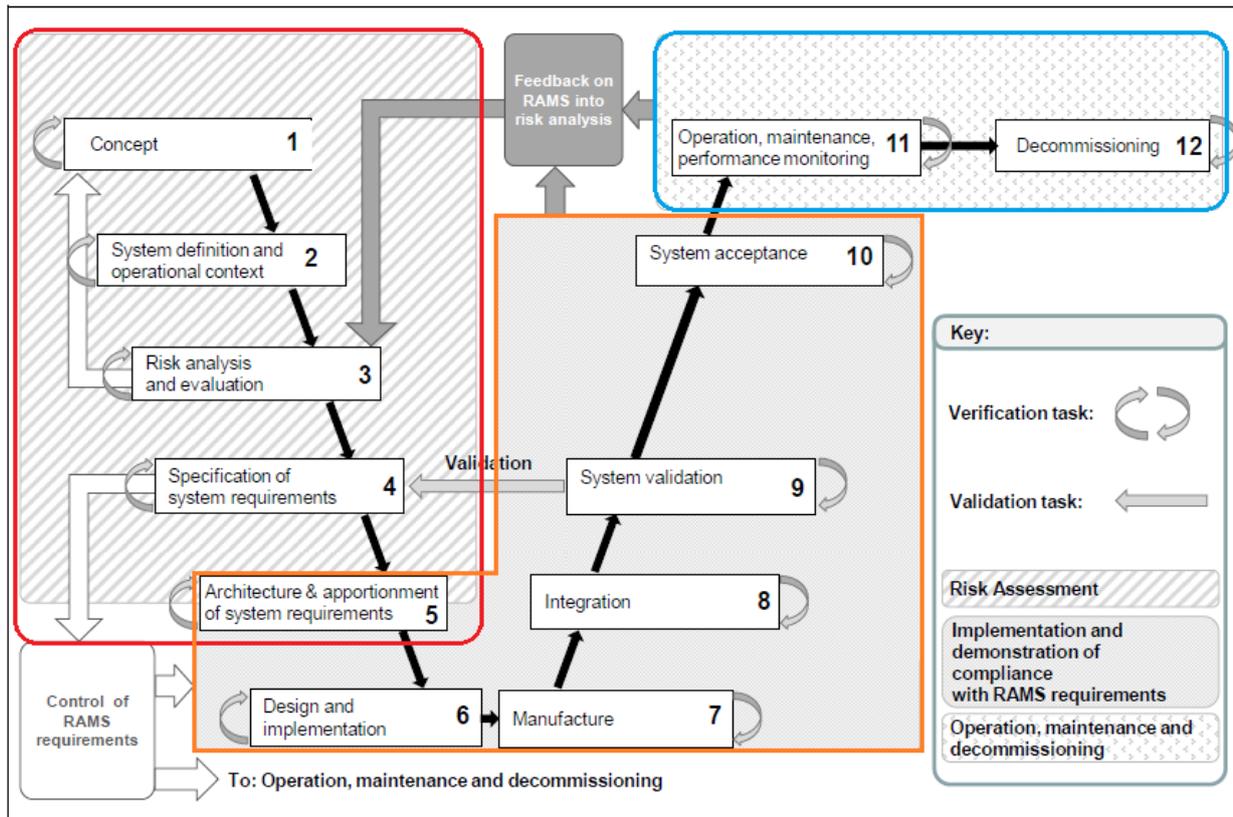


Figure 1: V-cycle model (Figure 7 from EN50126-1)

Solution

Railway organisations must have a standard process for implementing new systems, new trains, new safety equipment or major modifications (i.e., a change management process). This process is already supported from a systems engineering perspective by the EN50126-1 standard which lays out a generic process for the management of reliability and safety through system lifecycle design. Human factors is already addressed in a specific section of the standard which states that analysis of human factor is inherent within the systems approach taken by the standard. A non-exhaustive checklist of human influencing factors is included in the standard which include for example: human competence, the working environment, culture, human/machine communication, and interface design. However, the standard does not currently give any specific guidance in terms of *how* human factors can be integrated in the system lifecycle design, or even how these influencing factors can be applied in practice. This is in contrast to the integration of safety in the traditional RAM process, which was fully integrated in the EN50126 model in 2017 alongside the publication of EN50126-2 which provides guidance and methods on how to follow the Safety Management Process described in Part 1 of the same standard.

We propose that human and organisational factors can be integrated in the change management process by following the steps mapped to the EN50126-1 V-cycle model shown in Figure 1 below. This new solution proposes to use the stages that logically follow each other during the V-cycle (EN 50126), which is traditionally used as a reference to develop a new system whether they are safety equipment, new trains or any new system to set up within the company. HOF should be integrated throughout the V-cycle, i.e. in all the three phases. This is why we are suggesting a new approach to “implementing any new system within the organisation”, with HOF being considered at the same level as the technical elements. This structure is used to describe the actions to be taken at each stage of the cycle to ensure that HOF is considered at the right time. The advantage of integrating HOF

within the V-model is that HOF is systematically and verifiably incorporated, allowing the final system to be targeted at end user needs from the beginning and providing evidence to the regulator that HOF have been taken into account during the whole development process. The original 12 RAMS steps are shown in black, while the aligned HOF steps are shown in white.

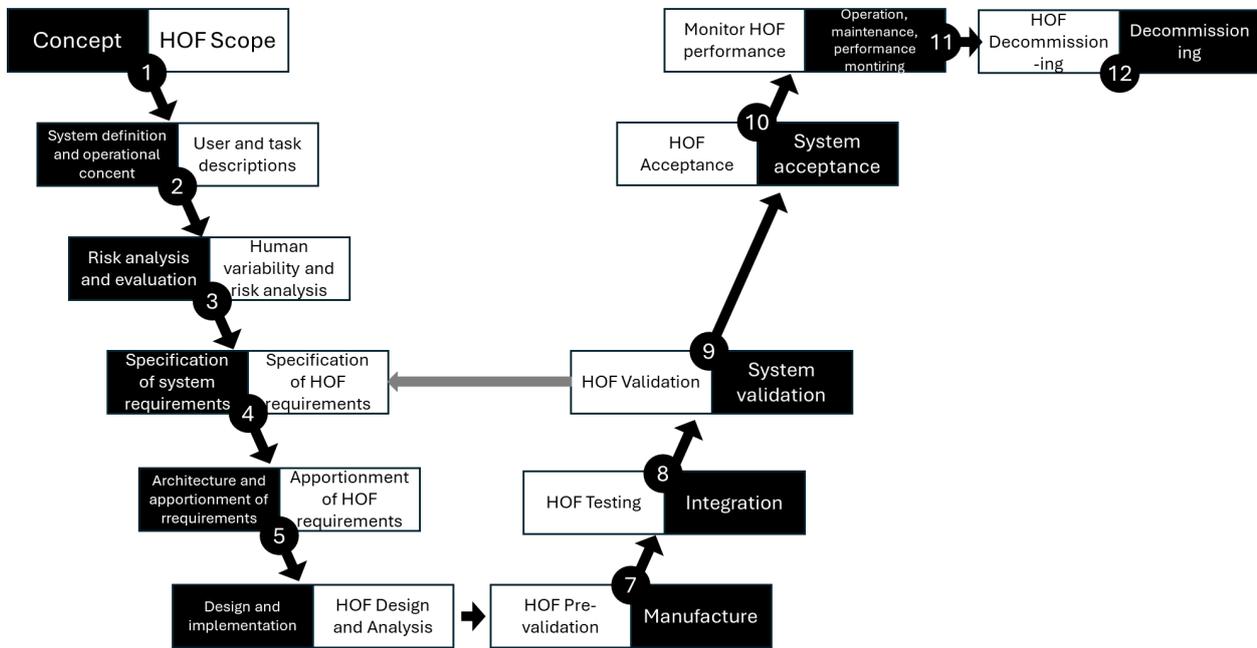


Figure 2: EN50126-1:2017 V-cycle model with additional human factors steps

The HOF steps are:

1. HOF Scope (Concept) – at this stage, the HOF Scope for the project should be set, considering the possible impact of the change on the end users and identifying high level areas of focus for the HOF work.
2. User and task descriptions (System definition and operational context) – at this stage, all end users of the system should be described in detail and a high-level description of their main goals and tasks provided. The major interfaces between the end users and technical system elements should be identified. The principal HOF goals should be defined to ensure that the users can perform their future roles effectively, drawing on the scope already defined. The HOF Assurance Plan should be produced at this stage.
3. Human performance analysis (Risk analysis and evaluation) – at this stage, HOF should be integrated with the overall risk assessment process to represent HOF hazards. Specific HOF risk assessments may be carried out into potential human performance risks. The HOF Issues Log (HOFIL) should be started at or before this stage.
4. Specification of HOF requirements (Specification of system requirements) – at this stage, HOF requirements on the end system should be developed and documented, including criteria for acceptance and means of compliance.
5. Apportionment of HOF requirements (Architecture and apportionment of system requirements) – at this stage, the HOF requirements should be apportioned to the relevant sub-systems. The HOF Assurance Plan should be updated.
6. HOF Design Analysis (Design and implementation) – at this stage, specific HOF assessments may be conducted to support the design process and provide evidence for closure of HOF issues. Human centred design is best suited to an iterative design process

where evolving designs can be tested with end users at different stages of design maturity and feedback used to improve the design. Wherever possible, this should be facilitated. HOF assessments should be conducted during the design process by the mean of simulation to determine the extent to which HOF goals are achieved and risks are mitigated. In certain cases, from an HOF perspective, application conditions may need to precisely state in which working conditions the system can operate safely.

7. HOF Pre-validation (Manufacture) – at this stage, the HOF focus is on preparing for validation of the final product. There may also be some HOF issues to be addressed relating to preparing for operations and maintenance.
8. HOF testing (Integration) – at this stage, the integration of the human component (end users) should be tested with the technical components they are required to interact with.
9. HOF Validation (System validation) – at this stage, the HOF requirements are validated against the final product and the HOF Assurance Report is produced documenting the HOF activities undertaken throughout the project, and their results. The acceptability of the design is finalised against the HOF requirements and with end users, and issues on the HOFIL should be closed out.
10. HOF acceptance (System acceptance) – at this stage, the HOF Assurance Report is reviewed and accepted by a reviewer with suitable HOF expertise.
11. Post-commissioning and in-service reviews (Operation, maintenance and performance monitoring) – post-commissioning reviews are performed with end users to close out any outstanding issues on the HOFIL and to identify any additional issues that may need to be resolved. In-service reviews may be carried out through the lifetime of the system to identify and resolve any operational or maintenance HOF issues that emerge over time.
12. Decommissioning – the HOF impact of planned decommissioning activities is assessed and a HOF plan put in place to manage any expected issues.

Table 1 below describes the HOF tasks for each of the 12 phases, aligned with the General Tasks from Table 1 of EN50126-1.

Table 1: HOF tasks for lifecycle phases 1-12

#	RAMS Phase	HOF Phase	General tasks	HOF Tasks
1	Concept	HOF Scope	Investigate scope, context, and purpose of system. Investigate the environment of the system.	Investigate the HOF impact of the system. Investigate HOF issues on similar systems. Identify relevant HOF standards. Define the HOF scope for the project.
2	System definition and operational context	User and task descriptions	Define the system and its mission profile. Define the system boundary. Define the scope of operational requirements. Establish the organisation.	Define the end users. Define high-level tasks of end users and their future roles. Identify end user interfaces with technical components/sub-systems. Define HOF goals. Establish the HOF Assurance Plan.
3	Risk analysis and evaluation	Human performance analysis	Identification and classification of hazards associated with the system.	Identify HOF risks and integrate them into the risk analysis.

				Conduct any necessary human performance analyses. Establish HOF Issues Log (HOFIL).
4	Specification of system requirements	Specification of HOF requirements	Specify system requirements.	Establish HOF requirements specification. Update HOFIL. Update HF Assurance Plan. Establish HOF requirements validation plan.
5	Architecture and apportionment of system requirements	Apportionment of HOF requirements	Define the system architecture. Identify the requirements for integration of pre-existing subsystems/components. Define acceptance criteria and processes for subsystems/components.	Allocate HOF requirements to sub-systems. Update HOFIL. Update HF Assurance Plan.
6	Design and implementation	HOF design analysis	Design subsystems/ components. Prepare operation and maintenance procedures. Define training measures for operation and maintenance. Define and establish manufacturing process for producing subsystems and components. Define and establish system integration process. Prepare installation and commissioning procedures.	Conduct iterative HOF assessments on the emerging design. Conduct user testing where possible. Provide feedback and recommendations on design improvements. Conduct HOF assessments on operation and maintenance procedures. Analyse if application conditions should be defined. Identify HOF training needs Update the HOFIL.
7	Manufacture	HOF pre-validation	Implement and operate manufacturing process.	Prepare HOF validation plan.. Update the HOFIL.
8	Integration	HOF testing	Integrate subsystems and components. Demonstrate system functionality. Test and analyse system. Arrange system support arrangements.	Conduct end user testing on the final product Update the HOFIL. Collect evidence that HOF requirements have been met.
9	System Validation	HOF validation	Establish validation report. Establish process for the acquisition and evaluation of operational and maintenance data.	Collect evidence that HOF requirements have been met. Collect evidence that HOF issues have been closed. Document results of all HOF activities. Produce HOF Assurance Report.

10	System acceptance	HOF Acceptance	Record an acceptance record. Verify the acceptance record.	Review of HOF validation activities and record of acceptance.
11	Operation, maintenance and performance monitoring	Post-commissioning and in-service reviews	Provide all information necessary to formulate plans/procedures for operation and maintenance. Implement operation and maintenance procedures. Record changes in the system configuration.	Conduct post-commissioning review. Conduct in-service reviews as necessary. Monitor HOF during operation and changes.
12	Decommissioning	Decommissioning	Establish decommissioning plan and related report.	Identify the HOF impact of decommissioning.

Conclusions and next steps

The model presented in Figure 1 describes a generic process for the integration of HOF in change management of railway systems, aligned with the V-cycle in EN 50126-1. It provides a closer and more systematic link between the HOF knowledge of the industry and practice in the transport sector, which is not limited to modelling and designing trains, but to all relevant system changes in the rail industry, based on the V-cycle used in system engineering. This model is the starting point for additional work to further specify the human and organisational factors steps and produce HF process requirements to support railway organisations engaging suppliers to integrate human and organisational factors during the system lifecycle. The UIC HOFWG, in collaboration with the PRAMS group, will focus next on producing guidance on the application of each step. The eventual output should be a standardised approach for integrating human and organisational factors into the railway systems lifecycle.

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