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Integration of Human Factors in engineering design

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1 Introduction

This document provides guidance to organisations specifically on how to integrate Human Factor (HF) activities into engineering design.

The benefits of Human Factors Integration (HFI) into the engineering design process are not limited to safety. Integrating HF with the design process will assist in ensuring the asset is efficient and effective, meets its intended performance levels and is able to deliver the expected benefits to users and customers. HFI in safety risk management activities provides an important contribution to the overall safety assurance argument. HFI can also provide evidence of the implementation of controls and mitigations identified during the HF analysis.

In broad terms the aim of HFI is to ensure the human-system interactions pro-actively contribute to optimise system performance and identify and mitigate risk. This approach is in line with the principles of system engineering within which HF is a recognised discipline. It is important HFI is incorporated into the whole asset design process including feasibility, options development, conceptualising and through the entire design process.

This guide will assist organisations to satisfy requirements of the standard AS7470: Human Factors Integration in Engineering Design and will also align with HFI requirements in the Rail Safety National Law and Regulations.

1.1 Purpose

The Guide to the Integration of Human Factors in engineering design is a companion document to the standard AS 7470: 2016 Human Factors Integration in engineering design – general requirements. It is intended to provide guidance on meeting the requirements of this standard.

The objective of this document is to ensure that HF considerations form an integral and meaningful part of the specification, design, and development process, rather than being seen as an add-on, a review or as an afterthought following completion of the design and development activity.

1.2 Scope

This document provides guidance on Human Factors Integration (HFI) primarily for the following stages of the asset life cycle:

- Feasibility.
- Concept.
- Design.

It may be noted that that many of the concepts and principles described may also be applied to the following stages of the life cycle:

- Fabrication, manufacturing, and construction.
- Installation.
- Integration, test, and commissioning.
- Asset operations and maintenance.
- Decommission and disposal.

Although this document does not specifically cover these latter activities, there are benefits that an organisation working through these phases can realise by applying a HFI process to their day-to-day business.

These activities are relevant whether providing new or altered assets, including commercial off the shelf (COTS) and 'like for like' assets or products, all of which require HF consideration.

HF contributes to the assurance case of the delivered asset, including the validation and verification of HF requirements. Therefore, the following are details regarding scope:

- Within the scope of this document is provision of guidance on the use of HF principles and knowledge to ensure that the asset is selected or designed and delivered such that it can be operated and maintained safely, effectively and efficiently.
- Beyond the scope of this document is the application of HF principles and knowledge to the broader project lifecycle, or to the organisation of the day-to-day operation or maintenance of assets following its hand over to the operating and maintenance entities.

The inclusion of HF data is beyond the scope of this document.

1.3 Application

This guide is intended to be used by rail Operators and Maintainers and those undertaking work for the Australian and New Zealand rail industry. It applies to the managing of Human Factors (HF) issues that may affect asset or system performance, and therefore ultimately may influence the operations and maintenance of the delivered asset or systems.

This guide applies to managers, designers, and engineers engaged to provide new or altered assets to the Australian and New Zealand rail industry. HF consideration should also be made for like-for-like replacement projects, to avoid repeating past mistakes or reintroducing the same problems.

1.4 Terms and definitions

The following terms and definitions apply in this document: (check to standard)

Anthropometric: is a reference to the data used in anthropometry.

Anthropometry: is the science of measuring the variability of human physical characteristics. These include size, shape, weight, strength, and range of motion.

Asset: any good, product, equipment, facility or other tangible resource (excluding people) which comprises part of a rail system and which is under the control of a rail transport operator.

CAD: computer-aided design.

COTS: Commercial off the shelf.

EHFA: Early Human Factor Analysis

End user: people who will interact with, or are affected by, an asset during the operational phase. Typical end users of a transport asset include crew, control room staff, cleaners, trainers, managers, signallers, maintenance personnel, customers, and the public including pedestrians, cyclists and road users.

Ergonomics: see Human Factors.

Error resistance: ability of a system to minimise the probability of error occurring.

Error tolerant: ability of a system, through its design to minimise the potential for human error to occur, to reveal errors and/or to continue in safe operation despite erroneous inputs**.**

ETA: event tree analysis.

HAZOP: hazard and operability study.

HCI: human-computer interface.

HF: Human Factors.

HFI: Human Factors Integration.

HFIP: Human Factors Integration plan.

HFIR: Human Factor issues register

HMI: human-machine interface.

HRA: human reliability analysis.

Human-centred design: is an approach to systems design and development that aims to make interactive systems more usable by focussing on the use of the system and applying Human Factors/ergonomics and usability knowledge and techniques (ISO 9241 Ergonomics of human-system interaction part 210: Human-centred design for interactive systems)

> *Note 1: The term "human-centred design" is used rather than "user-centred design" in order to emphasize that this part of ISO 9241 also addresses impacts on a number of stakeholders, not just those typically considered as users. However, in practice, these terms are often used synonymously.*
>
> *Note 2: Systems can provide a number of benefits, including improved productivity, enhanced user well-being, avoidance of stress, increased accessibility and reduced risk of harm.*

Human Error: an action (or inaction) that may result in an unintended outcome.

Human Factors: the scientific discipline concerned with understanding the interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimise human well-being and system performance. Synonymous with ergonomics.

Human Factors Integration: the formal process to integrate Human Factors into the system-engineering life cycle. It involves applying a systematic and scientific approach to the identification, tracking, and resolution of issues related to human-system interactions. Effective HFI ensures the balanced development of both the technological and human aspects of the system and delivers the desired safety and operational capability.

HVAC: heating, ventilation, and air conditioning.

Like-for-like: a like-for-like replacement is a new item similar in form (shape, material, and so forth), fit (size and means of installation), and function (performs the same role) to the previous item.

Maintainability: characteristics of a design and installation that determines the probability that a failed or non-compliant piece of equipment, machine, or system can be restored to its normal operating state within a given timeframe using the prescribed practices and procedures. From a Human Factors perspective, this means maintenance tasks can be carried out safely, effectively and efficiently and are tolerant to human error.

Maintainer: an organisation that maintains an asset.

Maintenance personnel: Personnel who maintain an asset. For example, an equipment technician, an infrastructure worker, mechanic, locomotive maintenance technician.

Mock-up: a representation of a design solution. It can range in fidelity from a simple paper prototype of a computer interface, a rough sketch model, cardboard and paper representation of a particular aspect of a physical interface, a 3D CAD representation of a design, to a highly finished high-fidelity mock-up using some real controls and finishes to represent a full work or passenger area. A working prototype can be viewed as a mock-up, as it is a representation of the proposed design, However, typically as the mock-up fidelity increases, the opportunity to change the design reduces. The mock up process can often start with low fidelity mock-ups, and progress through to a higher fidelity mock-up as the design matures.

Negative Transfer: occurs when an end user who is familiar with a procedure or piece of equipment (learned skill) automatically transfers that skill to an alternate system or equipment when it is not appropriate. This can often result in tasks being omitted, operating the wrong controls, or operating the correct controls in the wrong direction.

New or altered systems or assets: the changes made to assets other than those due to maintenance activities, including decommissioning and removal of assets.

Operability: is the ability to keep a piece of equipment, a system, or an entire industrial installation in a safe and reliable functioning condition, according to pre-defined operational requirements.

OCD: operational concept document. A verbal and graphic statement of an organisation's assumptions or intent in regard to an operation or series of operations of a system or a related set of systems. (ANSI/AIAA G-043 Guide for the preparation of Operational Concept Documents). An element of systems engineering

> *Note: The operational concept is designed to give an overall picture of the operations using one or more specific systems, or set of related systems, in the organisation's operational environment from the users' and operators' perspective. See also concept of operations (ISO/IEC/IEEE 29148).*

Operational integration: a process or set of activities, encompassing HF, training, competence, and change management, to ensure and assure the optimum performance of the complete system.

Operational personnel: Personnel who directly operate or use an asset. For example, a train driver, train guard, controller, bus driver, driver trainer, station staff, deck hand, and ferry captain.

Operator: an organisation that operates an asset.

PPE: personal protective equipment.

Premises standards: Disability (Access to Premises-Buildings) Standards.

RAMS: reliability, availability, maintainability, and safety.

System: an asset and its context of use.

SFAIRP: so far as is reasonably practicable as defined in the RSNL s47. The ONRSR's "Meaning of duty to ensure safety so far as is reasonably practicable" guideline provides further information.

SME: subject matter expert.

SMS: safety management system.

Sociotechnical: refers to the interaction between people and technology in workplaces. The term also refers to the interaction between complex infrastructures and human behaviour.

Violations: deliberate but not necessarily reprehensible deviations from a rule or formal arrangement (such as a specified procedure).

WHS: work health and safety.

1.5 References

This guideline will assist in meeting the requirements of relevant legislation including:

- Australian legislation.
- Disability (Access to Premises-Buildings) Standards.
- Disability Discrimination Act.
- Disability Standards for Accessible Public Transport Work Health and Safety Act 2011.
- Rail Safety National Law Act 2012.
- Rail Safety National Law National Regulations 2012.
- Work Health and Safety Regulations 2011.
- Any other relevant state based or design related legislation.

Australian and International Standards as listed below are informative references.

Australian Standards *

- AS/RISSB 7470: Human Factors Integration in Engineering Design - General Requirements.

International Standards *

- ISO/TS 18152 Ergonomics of human-system interaction – Specification for the process assessment of human-system issues.
- ISO 9241-210 Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems.

*other ISO Standards or Australian Standards may be applicable.

2 Introduction to Human Factors in engineering design

Incorporating Human Factors (HF) through the asset life cycle, and particularly early in the design process, provides the most benefit. The following sections explain the concepts of HF, how it is integrated into engineering design and why organisations should include it within the asset life cycle.

2.1 The thing about humans is

Humans are flexible and adaptable, which means we can be trained and can work with poorly designed systems reasonably successfully most of the time. Experience shows, however, with poor design comes an increased risk of user error.

These errors usually occur when people are distracted, experiencing high workload, or where there are problems with the system not working as it should and the system has not been designed to adequately support user tasks, requirements or limitations.

Avoidance of errors due to poor design often require our human component to function infallibly to avoid problems and incidents, and to mitigate and recover from an escalating situation.

In the rail environment, applying fail-safe design provides a high degree of control against such system failures. However, the ability of people to recover from system failure remains an important factor, particularly in meeting operational requirements. Consideration should be given to Human Factors issues associated with operating under these degraded modes if the system is to continue to operate safely. It is important that systems are designed to be error tolerant and are not wholly reliant on perfect human performance.

2.2 What is Human Factors?

Human Factors (HF) considers the capacity and limitations of humans that should be taken into account in the design of a system, with the goal of optimising human and system performance. Legislation relating to safety and accessibility should be considered as part of the application of the HFI process.

Figure 1, shows a simple diagrammatic representation of human aspects and technical aspects overlapping in a system context. This illustrates that optimal design arises from the dual consideration of Human Factors and technical considerations.

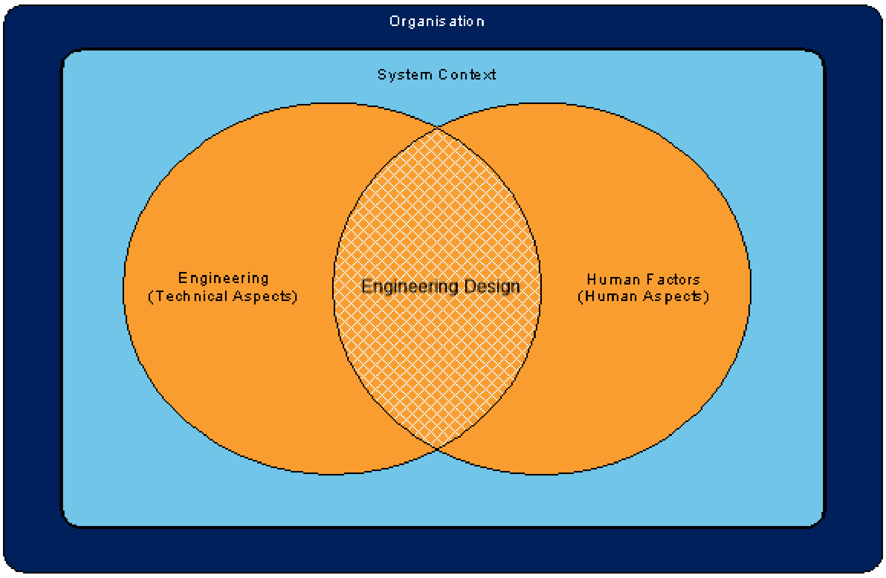


Figure 1 - A diagrammatic representation of the interplay between HF and engineering within the context of the system and organisation.

The International Ergonomics Association defines HF as follows: Ergonomics (or Human Factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and system performance.

Further, there are three commonly regarded categories of HF:

- ***Physical*** - this is concerned with human anatomical, anthropometric, physiological, and biomechanical characteristics as they relate to physical, sustained or sedentary activities.

    Example: The passenger door controls on some older trains were placed on a panel above the crew cab door. Taller guards were able to reach and operate the controls without too much discomfort. However, 25% of guards had trouble with reaching the controls. New trains have the controls positioned on the side panels at a much more convenient height for the majority of users.

- ***Cognitive*** - this is concerned with mental processes such as perception, memory, reasoning, mental workload, decision making, and so forth, as they affect interactions among humans and other elements of a system, job or specific task.

    Example: When designing a new control centre, which requires considering the workload imposed on the operational personnel under normal, degraded, and emergency scenarios. Another example is designing an alarm system, which requires providing information in a format that the operational personnel can easily understand and act upon hence reducing the probability of error response to the alarm.

- ***Organisational*** - this is concerned with the organisation and optimisation of sociotechnical systems including organisation structures, policies and processes, teamwork, and so forth.

It is important to recognise that the design or procurement of assets may have direct implications for organisational aspects.

Example: If a hand-held communication device is designed, procured or configured without adequate attention to Human Factors and is consequently limited in its application, the operator and/or maintainer may have to implement unnecessarily complex and error-prone administrative arrangements to make up for the design deficiency.

2.3 What is Human Factors Integration?

The process that considers Human Factors (HF) within an integrated approach to the engineering design and development process is Human Factors Integration (HFI). Various models of HFI exist, providing an iterative and dynamic process integral to engineering design and development.

Human Factors Integration: the formal process to integrate Human Factors into the system-engineering life cycle. It involves applying a systematic and scientific approach to the identification, tracking, and resolution of issues related to human-system interactions. Effective HFI ensures the balanced development of both the technological and human aspects of the system and delivers the desired safety and operational capability.

A number of publicly available models about how to undertake HFI exist. These range from complex, highly prescriptive processes through to more simplified generic processes. Chapter 3 gives the reader information on the characteristics of good Human Factors Integration in engineering design.

The organisation should then define a process that is commensurate with the nature of their range and scope of services to the Australian rail industry.

It is recognised that other terminology maybe used interchangeably with HFI. For example, the term Human Centred Design is often used within the software development domain.

An organisation that demonstrates it has already a human-centred design approach, throughout the design and development life cycle, may already meet the requirements within this guideline.

For organisations who refer to customer-centred design, this can also be considered a HFI process as long as this design process considers the other humans in the system who deliver the service to the customers, for example, the cleaners, maintainers, operation personnel.

In practice integrating Human Factors within the engineering design process—

- does not mean simply asking end users what they want and then giving it to them. Nor is it a licence to ignore the experience of end users simply because it does not seem to reflect the designer’s thoughts. Rather, it is a process of appropriately defining a set of end user requirements, that when incorporated into the design will enable the system performance to match its expected level. These are often captured within a user requirements specification;
- includes useability for both operational and maintenance aspects of a system.

HFI is not a simple linear process. There will be many occasions, as is the case with the development of design solutions, where initial options will need revisiting and in some cases changing. In these circumstances the HF considerations need to be re-evaluated and fed into the design development and decision-making process. Therefore, view the HFI process as being highly proactive and dynamic and as an integral part of the design and development process.

Compliance with the Disability Discrimination Act (DDA) and specifically the Disability Standards for Accessible Public Transport (DSAPT) and Disability (Access to Premises-Buildings) Standards (premises standards) legislation is generally considered to lie within the remit of HFI.

2.4 Characteristics of good Human Factors Integration in engineering design

The characteristics of good HFI process in engineering design includes the following:

- Structured, rigorous consideration of Human Factors (HF) issues and their mitigations from the beginning of the asset life cycle (feasibility) and continuing throughout the life cycle to disposal.
- Systematic and documented management of HF issues throughout the projects and the asset life cycle.
- The project has a user centred focus and uses an iterative design approach.
- The design reflects the task capabilities and requirements of all end users.
- HF principles, good practice, and appropriate techniques, tools, methods, and data are applied in a meaningful way such that they are able to actively inform design development.
- design adopts a multi-disciplinary approach.
- it contributes to the overall safety assurance argument.

When Human Factors (HF) is adequately considered within the engineering design and development process, the overall operability and maintainability of the system will deliver benefits to our customers. This may be through enabling staff to work more effectively, efficiently, and safely, or through the direct provision of a design feature to support the paying customer, or through all of these.

Specifically, ensuring that the design process accommodates human characteristics, capabilities and limitations reduces the likelihood of human errors, violations, and injury.

The application of HF during the design process can reduce redesign work, unnecessary costs and the possibility of assets failing acceptance by end users or not meeting business requirements.

For Operators and Maintainers, the application of HF to the design of assets and systems can result in performance improvements and a reduction in whole of life costs.

2.5 Relationship between Human Factors and work health and safety

Relevant transport legislation and work health and safety (WHS) legislation places requirements on designers, their contractors, and ultimately on the Operators and Maintainers of a system, to consider human related safety issues. It is appropriate for designers to address this element of compliance to WHS legislation within the Human Factors Integration (HFI) process. WHS legislation also places technical requirements on organisations to address within the design process. From a practical perspective, in the early stages of the system life cycle, all these activities aim at designing a system that is safe to operate and maintain.

During the construction, installation, testing, and commissioning phases, WHS takes on a much more significant role as workers are exposed to additional hazards related to those specific activities. Application of the relevant organisation’s safety management system (SMS) manages and controls these hazards. Many of these hazards are transient to construction activities, but some will remain through subsequent asset life cycle stages.

Management and control of the residual WHS risk during operations and maintenance lies within the responsibility of the Operators and Maintainers and are controlled through the application of their SMS.

In addition to the impact on the workforce, WHS legislation explicitly includes consideration of system safety and of the safety impact of systems on 'other persons'. Conforming to the required levels of safety needs explicit consideration of HF aspects at both a workforce and a system level in design.

> *Example: The weight of a component that needs to be manually handled into place during maintenance would be a WHS issue related to maintainability. The potential to install that component incorrectly, leading to a subsequent injury or system failure, would comprise a system safety and/or an operability issue. At the design stage, consider and address both these aspects as part of the HFI process, reducing the safety risk and system failure so far as is reasonably practicable (SFAIRP).*

3 Human Factors Integration process in engineering design

An organisation needs to manage all Human Factors (HF) relevant to their scope of work. To achieve this, organisations should have a process that identifies the need for Human Factors Integration (HFI), the HF design considerations that are required to be taken into account, and the depth or scale to which they need to be addressed. To be efficient, effective, and leverage the greatest benefit, this process should start early in the design life cycle.

The depth and scope of the HF activities required in delivering a new or altered asset, system or process depends on—

- the level of novelty or use of unique or non-standard configuration;
- the context of use;
- the number and complexity of human interfaces;
- the associated level of safety risk, and
- the exposure of personnel, customers, or the public to the change.

The nature and context of the HF activities required depends on the adopted procurement strategy. Procurement of assets can range from commercial off the shelf (COTS) through to fully tailored design. Altered assets can range from a total redesign to a simple like-for-like replacement. Integrating HF into the asset life cycle should enable an appropriate level of HF for all of these strategies, to ensure that decisions consider the whole life cycle costs.

For COTS procurement, organisations may wish to select, elaborate or enhance some of the design requirements described in this document. Where a COTS item is to be used in isolation fewer HF design requirements may be appropriate. Where a COTS item is to be used in combination with other systems many design requirements may apply. The organisation should decide which are appropriate depending on the context in which the equipment is to be used, and the complexity and risk of the overall project.

Example: An organisation may purchase a COTS product to be located within an existing operations control room. In this case many design requirements may apply in order to avoid potential difficulties in integrating the system for the operators and to allow a true understanding of the costs and benefits to be made.

By implementing relevant HF processes, organisations should be able to meet HF management requirements as identified within AS 7470Human Factors Integration in Engineering Design - General Requirements.

The following model (Figure 2) for HFI is derived from the principles of the risk management process.

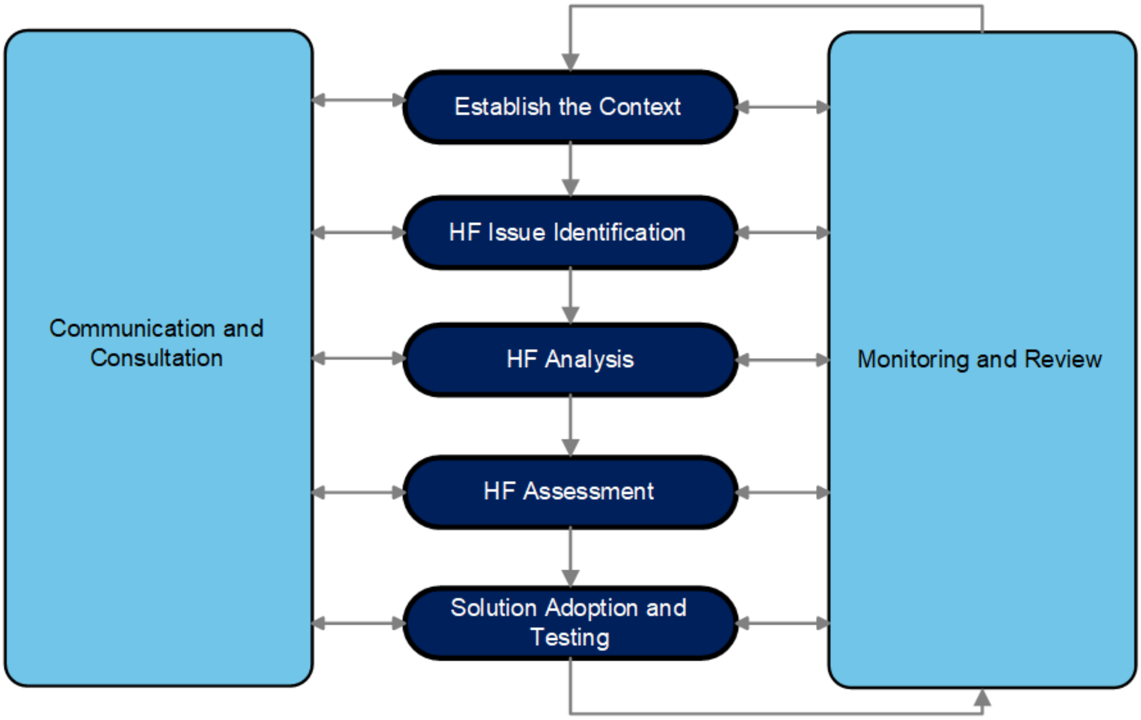


Figure 2 Diagrammatic representation of the HFI process

Applying the HFI process will likely give the following outputs:

- Operational concept, or equivalent (if not previously developed).
- HF (end user) requirements.
- HF issue log or register (HF register).
- HF integration plan (HFIP).
- HF analysis results, reports, briefing papers, and so forth.

A description of these outputs is given in appendix B

Of critical importance is timely delivery of the outputs from the HFI process, and their inclusion within the critical path analysis. Early identification of issues results in easier and more cost-effective resolution. The cost of change increases as the design progresses.

Therefore, HF activities need to be planned for and carried out early enough in the project life cycle that their outputs are able to meaningfully inform design outcomes.

As with any structured process, the HFI process needs to be auditable and traceable, including decisions taken not to provide any further action or to pursue an alternative design option. Table 1 summarises how these outputs link to elements of the process.

Table 1 - Tabular form of the HFI process indicating the result of each stage, the material required, and what may change through it.

	Process stage	Aspects	Develop	May iterate	Materials required	
Communications and consultation	**Establish context of use**	• What it is and how it's used. • Fit with existing ops. • All end users. • Human interactions.	• Operational concept. • HF requirements. • Input into system requirements. • EHFA.	• Operational concept. • User / business /system requirements.	• Operational concept.	Monitoring and review
	Identify HF issues	• Identify. • Assess? • Record. • Plan.	• EHFA. • HFIR. • HFIP.	• HF requirements.	• Operational concept. • User/Business/ System/HF requirements.	
	HF analysis	• Detailed analysis of particular issues or groups of issues.	• HF reports.	• EHFA. • HF register. • HFIP.	• Operational concept. • User/Business / System / HF requirements. • HF register. • HFIP.	
	HF assessment	• Working with other disciplines to incorporate HF analysis findings into design understanding.	• HF reports or input into other report. • HF assurance report or statement.	• HF register.	• Operational concept. • User/business/ system HF requirements. • HF register. • HFIP.	
	Solution and adoption and testing*	• Solution review. • Resolve issue and no new issues.	• HF reports on solution review. • HF assurance report or statement.	• HF register.	• Operational concept. • User/business/ system HF requirements. • HF register. • HFIP.	

* This is not the verification and validation (V & V) process but is part of the ongoing design development before the design is finalised.

The HFIR may be a standalone register / log or incorporated into the project risk / issues register / log.

The HFIP may be a standalone plan or incorporated into project / engineering plans (see section 3.2.2).

A Human Factors Integration (HFI) Prompt /Checklist that can be used throughout the project lifecycle to monitor HFI is provided in Appendix A.

3.1 Establish the context of use

The first stage of Human Factors Integration (HFI) in engineering design is to understand the context of the system.

From a Human Factors (HF) perspective, this includes describing the following:

- What the system will be used for, how it will be used and any current applicable practice.
- How the new or replacement system or subsystem fits into the existing operations.
- Who the end users of the system are, including all end user groups, not just front line operational personnel or customers.
- What the human interactions with the system are, and what tasks are required to be performed successfully for the system to meet operational and maintenance requirements.

Some of this information may already exist in other project documentation. In many organisations this may be referred to as the Operational Concept Document (OCD). This information is also critical for further developing any existing business and system level requirements into end user requirements.

Good practice in other industries is to use the OCD as one of the tools for verifying the final design. To support this, undertaking an exercise to understand ‘a day in the life' of an end user of the asset would help to test the operational concept and identify potential issues earlier than might otherwise be the case. This can be achieved by undertaking workshops and other consultation activities with end users and stakeholders, looking at how the system would be operated under different situations (e.g. normal or degraded) throughout a period of time (such as 24 hours), identifying any operational or maintenance issues, both positive and negative.

The end user, business, and system requirements form a substantive basis for the identification of the HF issues and human interactions that need addressing. In some cases, the requirement may almost directly translate into a specific HF requirement, while in other cases a number of more detailed HF requirements may need development. These are often called derived requirements. These should be added to the requirements tracking process. Some projects also develop specific user description documents. These are used to assist the development and identification of the different end users, their requirements, and the system requirements derived from these.

End users are those people who will interact with the delivered asset. They can be –

1. ***primary end users***: those people who use a given asset or system on a daily basis);

   Example: For public transport systems, primary end users could include; customers drivers and some maintenance staff.

2. ***secondary end users***: those people who interact with the asset as their primary task, but who are not primary end users;

   Example: Secondary end users for a transport vehicle could include; cleaners, trainers, and maintainers.

3. ***tertiary end users***: those who interact with the asset but more at a distance.

   Example: For a train, this would include platform staff, controllers in an operations control room, and managers who require information about asset performance.

Each of these end users will have an interest in the asset and its design, as it will have a direct effect on their work or tasks. Therefore, it is essential to identify all these end users and determine their requirements with respect to their interface with the system or asset. When designing for end users, there is also a need to address the requirements of the Disability Discrimination Act (DDA) legislation.

It can be helpful for complex projects to divide the project into parts, and identify the end users of each part and the nature of their interaction for that part. The level and nature of interaction often varies between parts. For example, in the context of a railway and buses, a driver is a primary end user for the train/tram/bus but may only be a tertiary user of a depot. At this stage, determining measures for successful performance can help. For example, this may involve stating how many people are required and target times for changing out a faulty component.

3.2 Identify Human Factors design requirements and issues

An organisation should have a process that enables it to identify the nature, scope, and scale of the Human Factors (HF) considerations, areas of focus and specific issues that it should address in order to provide a particular project or service. Many organisations refer to this activity as an Early Human Factors Analysis (EHFA).

Specifically, they should identify the potential for human error and its effect on the performance of a system as an issue that needs addressing. Traditionally, all areas of HF investigation on a project are called issues, implying both positive and negative aspects. These can include consideration of human interaction, specific design requirements etc. From this point, this document will refer to them collectively as 'issues'.

Example: For a passenger train one interaction could be how the driver will interact with an in-cab information display, a topic for investigation could be an error analysis of the boarding/alighting procedures, an area of concern could be the available width of the aisle in terms of its impact on accessibility, passenger flow rates and emergency egress.

Lessons learnt from past projects and end users of similar existing systems can be useful initial sources for identifying issues.

In those cases where the project is of a complex or novel nature, to minimise risk to the organisation, it is most likely that the identification of HF issues is best suited to a HF subject matter expert (SME).

For simple projects, using past experience through providing a HF checklist or some other form of prompt used by the project manager or by project engineers is likely to suffice.

As the project develops, and the organisation identifies the details of a design solution or alternative solutions, additional issues, including HF issues, may appear. Therefore, expect the identifying of issues to be an iterative process.

3.2.1 Record Human Factors issues

Recording is usually done through the development of a Human Factors Issues Register (HFIR). This may be a stand-alone document, or the relevant information integrated into an existing project document such as; a hazard log, risk register or issues register. If an organisation takes the latter approach, then it is advisable to identify any HF issues with a flag for easy identification and reporting. The register or log is used for recording the management of HF issues through the project to closure. Where the HFIR is standalone document, it is recommended that safety issues identified are linked to the project safety risk register.

The HFIR is a living document and should be continually updated through the design process. At the end of design, the HFIR should provide assurance of the management and resolution of HF issues.

3.2.2 Manage human factor issues

Managing HF issues begins with including Human Factors activities within the project plan, or developing a Human Factors Integration plan (HFIP). The HF activities should align with project critical paths in order to provide timely interactions with design processes.

For the HF issues identified, organisations should develop a set and scope of HF activities to demonstrate adequate consideration of HF within the design. HF activities may also be contributors to the system safety assurance plan and if so they should also be referenced from that plan.

In the case of projects that are more complex, demonstration that HF activities will be adequately considered may be in the form of a dedicated Human Factors Integration Plan (HFIP). This is one of the series of plans developed by the project and is usually referenced from the overall project plan. In these cases, the most senior project role is ultimately accountable for the implementation of the HFIP (for additional guidance of HF planning and HFIP development see Appendix B).

For simpler projects, the activities may be included within the overall project plan. In these cases, typically a project manager is accountable for the conduct of the HF activities identified, and their integration into the design process.

In either case, it is important to identify critical paths and interactions between HF activities and design processes so that HF input can be gathered and used in a timely manner within the engineering decision making process.

> *Example: It is common practice in rolling stock projects to include a mock up process as part of the design development process, and as a way of gaining end user feedback on the emerging design. If a mock-up is to be a useful design review tool, it is essential that information gathered during mock-up review can be used to influence the design; otherwise, the mock-up can become simply a representation of the production design when there remains little opportunity for change.*

3.2.3 Scaling Human Factors

The level of Human Factors (HF) activities required throughout the lifecycle is dependent on a number of factors. These include –

- the level of human interaction;
- the novelty of the system;
- the level of risk;
- the potential interaction with other systems;
- the complexity of the Human Factors;
- lessons learnt from similar past projects/events.

The more complex any of these factors are, the greater the level of HF involvement required. For projects with simple HF requirements, it may be sufficient to adopt an enhanced safety in design process. See section 3.8.3 for further details.

3.3 Analyse Human Factors

Analysis of Human Factors (HF) should be appropriate to the stage of the project life cycle, using relevant sources of data, and established tools and techniques. (See Appendix D for examples of HF methods and tools).

The organisation should conduct HF analyses on those issues and the human interactions identified, and to the level of detail that is appropriate according to the: nature, complexity and risk of the design change and its reliance on human performance.

In the early stages of the life cycle, information regarding the proposed design will be limited and high-level, and the HF analyses need to reflect this, focussing on key decisions and issues. At this early stage, HF analyses may be the consideration of different options to identify what positive and negative HF issues each option may present. This can then lead to the development of HF requirements for the selected option. As the design progresses and more detailed information becomes available, the organisation can carry out more detailed analyses.

> *Example: Human-system interactions are important in the layout of a crew cab. Therefore, it should be highly influenced by HF design principles. In the early stages, focus may be on the primary controls, displays, and interactions. But as the design develops, the understanding of the more detailed interaction requirements is revealed. HF analyses should support the cab design process at each stage. To obtain the maximum benefit HF analysis should commence during development of the preliminary concept.*

In conducting HF analyses, an organisation should do the following:

- Identify the relevant sources of HF data (human reliability data, population stereotypes, anthropometric data, perceptual limitations, and so forth) that are applicable to the specific issue being addressed.
- Use established HF tools and techniques where available.

Within engineering and safety analyses, there should be a HF component. An HF subject matter expert (SME) could attend workshops, meetings, design reviews etc. Alternately as a minimum a set of HF guidewords should be applied within the process.

> *Example: Human reliability analysis is an essential element of an overall HF approach but can be time consuming and costly. It is important therefore to be able to scale the effort accordingly. The following provides some guidance on the level of HF reliability analysis that may be required.*

An understanding of how human interactions with a system can fail is critical to producing a design that is error resistant or tolerant, and that can be safely and efficiently operated and maintained. The level of analysis required will be appropriate to the complexity, risk, reliance on human performance, and scale of the project. A good indicator of the level of effort required is to review the system safety assurance plan for the project. Each of the major activities within this plan (for example: risk assessment, reliability, availability, maintainability and safety [RAMS] analysis; failure mode and effect analysis [FMEA]; fault tree analysis [FTA]; and so forth) should include an HF component. For smaller and less complex projects, a well conducted hazard and operability study (HAZOP) will probably be sufficient.

In cases of complex projects, the output of the HAZOP may lead to the requirement to conduct a more detailed analysis to provide a full understanding on the scale and nature of the issue, and to identify suitable control measures.

In these more complex cases, it is likely that a HF subject matter expert (SME) will be required to conduct the analysis.

In a small number of cases, it may be necessary to perform a quantitative human reliability analysis (HRA). As the result of a quantitative HRA can have significant impacts on the calculated availability or reliability of a system, it is likely that a HF SME will be required to conduct this type of analysis.

In conjunction with the guidance above, organisations may wish to use the Australian standard AS IEC 62508 Guidance on human aspects of dependability to determine the specific activities required at the various stages of the project life cycle.

A description of commonly used HF analysis terms to provide prompts for further research is provided at Appendix C and a list of HF tools and methods at Appendix D.

3.4 Assess Human Factors

Human Factors (HF) assessment interprets the results of the HF analyses in terms of the potential effect on system performance. Organisations should consider the level of this effect holistically within the design process, and a decision made as to whether solutions or controls to any issues need incorporating within the design. Typically, this decision-making process best occurs during multi-disciplinary design reviews, considering all relevant aspects of the design.

Where changes are required or treatments identified, organisations should, if possible, identify and assess all feasible options. Where safety changes are required a SFAIRP demonstration, including consideration of the hierarchy of controls, cost-benefit analysis or other analyses that incorporates consideration of Human Factors should be provided. Where efficiency and effectiveness changes are suggested to improve performance, a similar assessment process can be undertaken, looking at potential costs and benefits. From an operational perspective the project may need to conduct testing, such as the use of a simple mock up, to determine the suitability of the design with regards to Human Factors. Often it is more difficult to quantify the effect from an HF perspective than for other disciplines. However, it is usually possible for the organisation to provide some level of analysis to aid the decision-making process perhaps utilising existing qualitative risk assessment criteria.

3.5 Adopt and test solutions

A solution to a Human Factors (HF) issue needs to follow the same process for adoption and testing as any other identified risk control. After identifying a prospective design solution, it is valuable to test it to ensure the following:

- The proposed solution actually addresses/solves the issue.
- Any new issues introduced by the proposed solution are identified and assessed.

As the design process is iterative, the adoption and testing of HF controls and solutions need to be iterative too. This is separate to the verification and validation process that occurs after the design is built.

An organisation may achieve early testing of proposed design solutions in a number of ways. In its least costly form, an organisation can test through scenario-based discussions with end user groups using the proposed design information. For example, it is now common practice to use 3D computer-aided design (CAD) models as part of this process.

However, depending on the complexity of the project and even with the use of 3D CAD modelling, it can be difficult for end users to understand the design concepts, and in these cases the use of mock-ups can provide significant benefit. Mock-ups are beneficial in allowing designers and end users to discuss together how the work could be performed which can sometimes differ from the original design intent.

The term mock-up relates to all forms of mock-up, and is not limited to the high cost high fidelity mock-ups commonly specified as a project deliverable within rolling stock procurement or upgrades.

Organisations need to conduct final testing of HF requirements to provide evidence for the validation and verification process. Specific HF tests should be part of the overall testing and commissioning activities conducted by the project.

3.6 Communicate and consult

Throughout the Human Factors Integration (HFI) process, communication and consultation is critical to the success of the project. An organisation should identify mechanisms for all forms of communication, including the internal communications within the design team, stakeholders, and end users.

The organisation's design process should already have internal communication mechanisms, including design review meetings, quality reviews, risk assessment activities, and so forth. All of these should consider HF requirements. In the majority of cases, the HF subject matter expert (or other person responsible) should be involved in these processes and output from HF activities should form input into these activities.

An organisation should also identify the means to conduct communications with the end users. In particular, access to operational and maintenance personnel and management staff needs planning so that the Operators and Maintainers are able to make the necessary arrangements for release of personnel for workshops, review, testing, and so forth.

The description of communication and consultation arrangements may form part of the Human Factors Integration plan (HFIP).

Apart from specific communications, many projects have found it beneficial to increase the awareness of Human Factors, its goals and benefits generally across the project, and to communicate the HF principles, HFI process and plan.

3.7 Monitor and review

In line with good practice and depending on the complexity and scope of the project, an organisation should include a number of mechanisms for the review of the effectiveness of the applied HFI process, and the results of Human Factors (HF) activities within the early stages of a project. This is particularly useful for projects that involve a high degree of novelty, complexity, or reliance on human performance.

Monitoring and review should form a part of any iterative design and development process, and in this context, an organisation should incorporate Human Factors Integration (HFI) monitoring and review into its existing engineering design process. This activity should occur prior to the formal project testing and commissioning process.

Organisations should record lessons learnt from the actual operations and maintenance of the design to allow the lessons to feed into other projects.

3.8 Special considerations

Some engineering design projects require special considerations because the scope of HFI and the degree of HF scaling required may not be immediately obvious.

Consider the following issues:

- Like-for-like' replacement.
- Commercial off the shelf (COTS) procurement.
- Safe design in new and altered structures.
- Transition of systems and equipment from old to new.

3.8.1 'Like-for-like' replacement

In the case of like-for-like replacements, detailed Human Factors (HF) analysis often is less important, particularly for smaller and less complex changes. However, do not dismiss the need for HF to be analysed, as even in these projects there may be lessons learned from the operational or maintenance context that could further improve performance. Additionally, replacing single elements on a like-for-like basis may still introduce changes at a system level. Therefore, as a minimum, organisations are encouraged to seek some end user input in such projects.

3.8.2 Commercial off the shelf (COTS) procurement

Procuring commercial off the shelf (COTS) equipment can have a number of commercial benefits throughout the life cycle of an asset or system. However, these systems may require changes in training, and operational and maintenance procedures and practices. There may also be specific conditions of use to be considered for the intended application, including any that might introduce constraints. Additionally, implementing such systems may lead to negative transfer of behaviours from the old to the new system or vice versa. In many cases, transfer of behaviours from new to old systems may be more of a concern, as older systems often do not have the same level of engineered safety functions as new ones. Therefore, the application of Human Factors Integration (HFI) within this process is essential to informing decisions based on the following:

- The true-life cycle cost of the equipment.
- An understanding of the potential Human Factors (HF) risks and identification of proposed controls, particularly during extended periods of implementation where both old and new systems are operational at the same time (see Transition of systems and equipment from old to new).
- The changes that may be required to the operating and maintenance regimes to use the equipment as designed and procured.

3.8.3 Safe design in new and altered structures

New or altered structures need to comply with legislation and standards regarding operations and maintenance. The Human Factors Integration (HFI) process can help with this.

Organisations that design structures currently need to incorporate a safe design or safety in design procedure within their overall approach to engineering design and management. For projects with simple HF requirements, such as in the design and delivery of static infrastructure e.g. buildings, track, signal infrastructure, overhead infrastructure, bridges, and so forth, it is likely that the application of an enhanced safe design process will be sufficient to meet the requirements of AS/RISSB 7470:2016 Human Factors Integration in Engineering Design - General Requirements, as long as there is sufficient focus on effective and efficient operations and maintenance tasks as well as safety. It is possible that non-HF specialists may be able to competently carry out the required HF considerations for projects with simple HF requirements. Key elements to providing evidence that there is a sufficient focus on operations and maintenance is –

- user (client) involvement in the design review process from an early stage;
- the tasks that the customers, public and operational and maintenance personnel need or want to carry out are identified.

Example: An organisation may be providing an asset that includes a number of plant rooms. The preliminary design approach for lighting of these rooms may be to provide the minimum level of lighting required at a fixed ceiling pattern around the room. Evidence of the appropriate consideration of Human Factors (HF) in this case requires that the organisation has assured itself that this approach is appropriate through understanding the nature of the equipment to be installed, and that the required operational and maintenance tasks can be carried out within the lighting provision made in the design.

Where organisations are involved in the delivery of more dynamic systems such as passenger rolling stock, track vehicles, railway control and communications systems, and so forth, they are more likely to need to incorporate a specific HFI process within their engineering design and management system to address properly the HF requirements of the projects that they deliver. These projects, with more complex HF requirements, are likely to require skilled HF specialists.

The information in Appendix F highlights some important questions and considerations that will assist in enhancing the safe design process to better integrate Human Factors. It does not contain all elements that may need to be considered through the design process for a specific project in relation to Human Factors, but helps to provide prompts for questions to ask in order to design a system that is effective, efficient and safe for users, including operational and maintenance personnel.

3.8.4 Transition of systems and equipment from old to new or modified

Negative transfer, part of the Human Factors (HF) domain, increases risk when changing from old systems and equipment to new or modified systems and equipment.

Given the scale and scope of the transport industry, the transition to new or modified systems or equipment is often conducted over a prolonged period of time, when it is necessary for simultaneous operation of old and new equipment to occur. For the Operator, this period can represent a period of heightened risk, and one source of this risk lies within the HF domain.

Negative transfer occurs when an end user who is familiar with a procedure or piece of equipment automatically transfers that behaviour to an alternate system or equipment when it is not appropriate. In the early stages of implementation, this is likely to occur from old to new but in latter stages with experience of the new system and less exposure to the old system, it can occur from new to old. This can often result in tasks being omitted, operating the wrong controls, and operating the correct controls in the wrong direction.

Example: A common example is driving an unfamiliar car that has the turn indicators on the opposite side to what the driver is used to.

Example: In rail, a similar example is applying the brake by moving the brake handle forward on some fleet types and backward on others

As a general principal, good design avoids the potential for negative transfer. However, this is not always practical because of the changing environment in which the industry operates.

It is essential to identify the potential for negative transfer and its associated risks. In those cases where errors could be significant, it may be appropriate to change the design, or alternatively put additional controls in place until full implementation of the new system.

To identify the potential for negative transfer it is of course necessary to understand the current system in terms of how it operates, who the current end users are, their experiences and current practices. This must be then compared and contrasted against the new system in order to identify areas or features where negative transfer is likely to occur.

4 Common Human Factors design considerations

Certain topics are common in Human Factors (HF) across many projects, and should be the starting point when assessing the HF aspects to be considered when evaluating the impact of an engineering design change.

An organisation or practitioner is encouraged to seek guidance of a more detailed nature on these topics as applicable to the nature and complexity of the project.

The list of topics below is not comprehensive and the order of presentation is not indicative of their importance or relevance to any specific situation. Common HF topics include the following:

- Error and violation.
- Level of automation.
- Design requirements.
- Using anthropometric data.
- Alarms and alerts.
- Human-computer Interface (HCI) and Human–machine interface (HMI).
- Workspace and task design.
- Operating and maintenance manuals.
- Training.
- Customers and the Public.

These topics are discussed in more detail in the following section.

4.1 Error and violation

Human Factors (HF) considers error because it acknowledges that humans make errors, and at times those errors can lead to consequences that may compromise safety or performance. Any system design should consider and account for the potential for error. Systems should be designed to do the following:

- Take human capabilities and limitations into account so the systems are error resistant.

  Example: A system should not require people to make distinctions in the colour of a display to identify changes in state of the system – Users may be colour blind.

- Prevent predictable small errors from having catastrophic consequences, or at least allow people to easily detect the error and correct it.

  Example: When a user requests a file to be deleted, software typically asks whether they really want to delete the file, and even after the user agrees to the deletion the software stores the deleted file for a period so that the file can be retrieved if the user later realises they have made an error.

- Encourage people not to take short cuts in procedures (these are called violations), especially short cuts that could be unsafe. Humans tend to take short cuts to reduce the perceived effort they need to expend or if they perceive there is a low risk of a negative consequence. Therefore, to discourage violations, designs should make the easy way to do something the correct way to do it.

Example: A pedestrian crossing is only provided at the opposite end of the platform to where the car park is located

- consider methods for users to receive feedback when an action has been undertaken (such as a sound occurring when a key is pressed) to maintain awareness, reducing the likelihood of errors.

Therefore, review designs to consider how people could make errors and whether the design will encourage them to violate procedures.

4.2 Level of automation

Design of automated systems benefits from considering Human Factors (HF).

Decisions around which functions to automate and which require human intervention should be made at the early stage, and should be reflected in the operational concept and end user requirements documentation. This is often referred to as the process of function allocation.

As systems become more automated, there may be a tendency to dismiss the importance of HF. This approach has been shown to be inconsistent with the goal of optimising system performance in other industries, such as aviation.

Even in highly automated systems, human interactions are still critical in degraded, emergency, and recovery situations.

Example: Automatic Train Operations (ATO) rolling stock typically requires a person to recover an unresponsive train or for movements around the depot.

HF Assessments need to be undertaken for these conditions to provide assurance that the system (including the operators) will be able to deal with these scenarios. Policies and Procedures requiring ongoing maintenance of training and competency will be particularly important for such highly automated systems.

4.3 Design requirements

System design includes the design of plant and equipment deployed within a system. Design systems such that –

- account is taken of the end users limitations, capabilities, and physical characteristics;
- all safety hazards affecting the end user that cannot be eliminated are demonstrated to be minimised so far as is reasonably practicable (SFAIRP);
- in operation it complies with work, health, and safety (WHS) legislation under normal, degraded, and emergency scenarios;
- the demand on and requirements of end users during normal, degraded, maintenance, cleaning and emergency situations is considered during the design process;
- it is impossible to fit equipment or component parts incorrectly during maintenance;
- it is easy to recognise the status of the system and difficult to leave a system unintentionally 'off-line' after maintenance;

- if a component of a system must be configured for a specific application, the configuration status is easily determined.

4.4 Using anthropometric data

Humans are variable, and anthropometry is the science of measuring the variability of physical human characteristics. Apart from size, other physical characteristics include shape, weight, strength, mobility, flexibility, joint range of motion and working capacity. It is important that design considers the characteristics of the end user population and the range of users that are likely to interface with the system or asset; anthropometry provides the data sets that can help inform design with this in mind.

All engineering design projects should involve determining the appropriate anthropometric range to use for their designated end users. There could be different ranges for different groups; for example, operational and maintenance personnel, customers, and the public. Some additional considerations include the appropriate percentiles and age ranges; for example, including children or not.

By using anthropometric data, designers are able to design systems that cater for the physical variability of humans. For example, by knowing the smallest reach, a designer can ensure all those in the designated anthropometric range can reach a particular control. Another example is that by using the weakest twist strength all those within the defined range can use a handle.

The use of anthropometric data should consider the context of the task. Examples include the following:

- The frequency of use and duration of the task may influence the acceptability of a design solution.

    Example: Fixed seating is universally acceptable for passenger areas whereas adjustable seating is provided for crew

- Anthropometric data typically refers to static postures, i.e. if a person does not move. However, there are times where it is appropriate to consider how a person would move when applying the data.

    Example: For an infrequent reach to a control it may be reasonable for a person to bend to extend their reach.

When applying anthropometric data, consider the applicability of the data to the end user, clothing, shoes, personal protective equipment it (PPE) and movement, and other corrections. For example, clearance heights in a depot may need to consider the height of tall males wearing work boots and a safety helmet. Also note that female dimensions may be larger than males in some cases.

Example: Female hip breadth should be used as an upper value when considering the width of a seat pan.

4.5 Alarms and alerts

Design of alarms and alerts needs consideration of criticality, levels of alarms/alerts, interaction with other alarms/alerts and role of the end user.

Alarms and alerts can be delivered via a computer(s), speakers or from a number of differently located sources. Regardless of delivery method, all the alarms and alerts should be considered as part of an alarm and alert system. When linked with a computer system, alarms and alerts can be considered a specific subset of the human-computer interface (HCI), which warrant special attention. A generally accepted concept is that an alarm is a condition that requires the person to act, whereas an alert can be provided to draw attention to the presentation of information such as a degradation of performance that may affect how the task is performed. These decisions are often reflected in an alarm design strategy.

Design the system for the following considerations:

- Critical alarms should be clearly distinguishable by the end user and should generally be notified in both audible and visual form. Critical alarms should generally only represent a small proportion of the total number of alarms otherwise there is a risk they will lose their significance.
- Alarms should be classified according to their importance and it is common practice to use no more than three levels of alarms.
- Where a series of alarms related to the same event is triggered on more than one system, the user should be able to acknowledge all the alarms from one place.
- In those projects where there is likely to be a high reliance on alarms from a single or multiple system it is often useful to develop an alarm strategy document in order to enable a consistent approach for the overall system.

In computer systems that are used by a number of different roles and allow for separate role sign in, the alarms and alerts should be designed to be only delivered to the relevant role and in a form most appropriate for that role.

Example: For a train operating system that allows drivers, guards, and maintainers to sign in as different roles, the alarms and alerts required for drivers are likely to be different to those for guards and maintainers.

4.6 Human-computer interface and human-machine interface

Design the Human Computer Interface (HCI) such that information presented to the end user is relevant to the role or tasks that they carry out. In line with increased levels of sophistication and technology, there is a tendency to present more and more information to the user. This is not always of benefit, adding additional costs to the overall life cycle and reducing the efficiency of the system. This section is specifically applicable to the design of railway control systems, control rooms, passenger information systems, management and layout of CCTV control rooms etc.

Specifically, the HCI should do the following:

- Present information that is timely, relevant and appropriate to the user and the tasks that they are conducting.
- Provide information in a format that is readily assimilated by the user and in terms they understand and enables error detection and recovery.
- Present information in such a way that it supports the task requirements without the need for the user to convert it to another format.

- Comply with population stereotype in terms of structures of displays and menu hierarchies, and where possible consistent with existing systems.
- Make appropriate use of colour and font as a distinguishing feature of critical information.

For software systems development and assessing the presentation of system information, it is a relatively simple task to provide 'screen' demonstration of how a system will look to test the interface. Use these demonstrations early, iteratively and with end users and other stakeholders.

In many situations, the human interface is not via a computer screen (or not only via a computer screen) but directly with the machine, human machine interface (HMI). Apply the general principles above appropriately to these situations.

> *Example: Dials should be able to be seen and read from the location being viewed (placement, letter size, colour usage); the strength to operate controls should take into account human capacities, and so forth.*

4.7 Workspace and workstation design

The design of workspaces and workstations benefit from considering Human Factors (HF) principles.

Workstations should be designed taking account of the following principles:

- Important and frequently used controls are within easy reach from the normal operating positions. Given the complexity of modern systems, some compromises may be required and, where this is the case, these should be justified.
- Critical displays and information are to be clearly visible from the normal operating position or positions.
- Grouping of equipment and displays according to their function.
- Existing stereotypes should be maintained with respect to existing control operations and population stereotypes where possible.
- Where people are expected to reach controls (whether used frequently or not), there should be a safe method provided to access and use them.

  > *Example: Heating, ventilation, and air conditioning (HVAC) vents are often placed in the ceiling and are not within reach of most people, yet most are intended to be adjusted easily.*

- Potential for negative transfer from existing equipment to new and vice versa as transitional arrangements progress should be assessed and, if required, transitional controls be put in place.
- Potential for negative transfer where a new system is going to be used alongside an existing system should be assessed and avoided where possible. For example, train crew using several fleets within a shift.

More generally, the design and layout of workspaces should take into account the different tasks being performed and the roles and objectives of the users within the space, along with the potential interactions between them.

Factors to consider include –

- necessity for proximity (or conversely, clearance) between users;
- nature of the tasks performed within the space (e.g., whether hazardous or safety-critical);
- any needs for communication (including the type of communication used); and
- environmental conditions required within the space to enable safe and effective achievement of users' objectives (e.g., requirements for appropriate acoustics, illumination, thermal conditions, etc.).

The design of both workspaces and workstations should aim to eliminate or minimise the potential for constrained work positions to be adopted.

Where feasible, designs and layouts should aim to allow users to maintain comfortable working positions, substantially vary their postures and positions and, where relevant, enable alternation between sitting and standing.

Any seating incorporated in workspaces or workstations should be appropriate for the specified range of users and for the nature of the tasks to be conducted.

4.7.1 Workload and job design

The overall job design for a role lies within the remit of the Operator, but the organisation will often be altering or replacing equipment that may affect part of an existing role, or delivering equipment that may affect the whole role (e.g. crew cab, a signalling control centre).

In either case, the organisation should ensure that an appropriate consideration of workload, both physical and mental, is made to ensure that the user can safely, efficiently and effectively operate the resultant design.

Excessive physical or mental workload can result in impaired performance of any primary or safety critical tasks. In addition, when mental workload is too low, this has the potential to also impair performance, particularly in tasks that require vigilance (i.e., sustained attention).

Any identified changes in the tasks associated with a role should be addressed by considering whether design changes are appropriate and/or by providing additional training or resources as may be indicated in the assessment.

> *Example: It could be the case that the introduction of a small number of additional tasks associated with a new piece of fitted equipment takes the overall workload to an undesirable level. There is also the risk of unanticipated additional mental workload due to the introduction of new or modified tasks.*

The overall design of tasks and jobs should also necessarily include the above-mentioned considerations related to workspaces and workstations.

4.7.2 Operating and maintenance manuals

Starting work on manuals early, making them task-orientated, and in a suitable format, gives benefits to the Operator and Maintainer.

Manuals are part of the documentation suite delivered with a project. As is the case with most documentation, this element tends to be left until late in the process. In some ways, this is understandable in terms of the cost-effectiveness gained from working from a finalised design. However, this approach often leads to difficulties in training and preparation for operational readiness. A further benefit of starting manuals early is the identification of hidden operational and maintenance difficulties before they have an impact on project delivery.

Manuals often reflect the technical capabilities of the system and describe the system features and how to use them. However, they are often not organised around tasks, requiring the user to flick back and forth between different sections to get the information they require. Manuals may need to be supplemented with procedures to address this issue.

Manuals should be designed with the following considerations:

- The intended purpose and use of the manual is clear. Training manual, reference on shelf, used while carrying out the task, in office, in the field, and so forth.
- The content should be developed with reference to the outputs of any HF analysis.
- The information reflects the needs of the user and is presented in a consistent format.
- Where possible, it provides information in a sequence that enables tasks to be easily carried out, and avoids the necessity for constant references between different sections.
- Developed to a standard format and subject to document control processes.

Manuals are often supplemented with the use of: of aide-memoires, diagrams, apps, web-based instructions, and so forth.

Depending on the specification of the contract, the Operator or Maintainer may need to adjust their operating procedures or processes in line with the new equipment or system. This requires early consultation with these organisations to ensure that they are able to fulfil their consultation requirements and demonstrate their operational readiness to use the system.

4.8 Training

Most organisations would automatically recognise training as a requirement accompanying the provision of new or altered systems or assets. In many cases, however, the implication of design decisions on training is not considered within the design process.

The design of the equipment has a fundamental effect on the level of training required, and in order for the overall system to achieve its goals, it is essential that there is clear understanding of the consequences of design decisions on the level of training required to use a system, including the associated time and money costs.

Situations that typically require additional training include the following:

- Providing a ‘different' layout or arrangements other than the existing one.
- Providing new equipment, functionality, or both to the users.
- Enhancing or altering the use of technology.
- Introducing new tasks or practices.
- Having potential for negative transfer between systems.

4.9 Customers and the public

4.9.1 Users with disabilities

Integrating accessibility considerations into the HFI process can benefit the design process and final design by ensuring the final arrangement reflects the needs of a broader user population. In many cases, design for the less able actually makes the design perform better for others as well.

The Disability Discrimination Act (DDA) legislation requires considering people with disabilities and provision of equality in design. For customers using public transport there is a requirement to meet Disability Standards for Accessible Public Transport (DSAPT).

4.9.2 Passenger flows and wayfinding

To ensure customers experience a seamless transition when navigating between different transport modes platforms, or entering and exiting or navigating within rail facilities it is essential that signage across the transport network is clear and consistent, easy to read, easy to understand and to follow.

HF considerations include –-

- considering end to end passenger journey;
- placement of signage (height, frequency of signage, orientation, positioning at key journey decision points, environmental considerations affecting visibility etc.);
- provision of auditory, visual and tactile information;
- lighting levels;
- topography – stairs, surface conditions, walkways, escalators, travelators;
- viewing distances/sightlines;
- appropriate use of language and icons to enable easy comprehension and facilitate decision making.

Appendix A Human Factors Integration prompt / checklist

This Human Factors (HF) checklist is a guide only that can be used throughout the project lifecycle. HF activities must be scaled according to project needs (considering issues such as novelty, complexity of human interactions and risk) to ensure the design and development of an effective and efficient system that is safe to operate and maintain, while delivering the required system performance.

No.	Activity	Yes	No	N/A
1	Has a plan for HFI been developed?			
2	Has HF been integrated into systems engineering/design/safety in design activities, including in project timelines?			
3	Have HF responsibilities been allocated?			
4	Has the context of use of the system been determined?			
5	Have all primary, secondary, tertiary end users been identified and consulted? (e.g. operations personnel/maintenance personnel, customers etc.)			
6	Have end user tasks and requirements been identified and considered?			
7	Has Human Factors and the end users been considered in the development of system requirements?			
8	Have the end users and HF issues associated with the system been considered in design processes?			
9	Has HF been included within multi-disciplinary design meetings/reviews/signs offs?			
10	Has HF been involved/considered in technical meetings, reviews, document sign offs?			
11	Have HF issues been identified, documented and managed?			
12	Has HF been considered in safety assurance and other project areas?			
13	Have HF activities been determined throughout the project lifecycle?			
14	Have HF schedule/reporting requirements been determined?			
15	Have mock-ups been used?			
16	Have HF data collection/monitoring/review/testing activities been identified?			
17	Have appropriate Australian and international standards been used?			
18	Has the need for HF specialist support been considered?			

Appendix B Glossary of common Human Factors documents

Document	Description
Early Human Factors Analysis (EHFA) report	The technique that is applied during the concept and scoping stages to identify and prioritise the Human Factors activities for a project or change event, such as an engineering design. The analysis will typically include consideration of the following: • The scope, complexity and scale of the proposed design change • The users impacted by the change, and the likely scale of that impact on user tasks, roles, knowledge or behaviours (both during transition and at design completion) • Any systems or design elements that are likely to have a significant user interface or safety risk • Any new or novel elements of the design, whether with respect to the design itself or to the context in which it will be implemented • Any interfacing systems or processes that might be impacted by or have implications for the design change • Any relevant HF standards, good practice or lessons learned that will be applicable to informing the design development process The output of the EHFA is then used to inform the scale of HF analysis required for a project by identifying the key HF areas of focus, the potential HF issues and risks that will need to be addressed through the design and the HF analysis activities to be undertaken. The EHFA outputs form the basis of the HF Issues Register (HFIR). The EHFA is an input to the development of the HF Integration Plan (HFIP).
Human Factors Integration Plan (HFIP)	The HFIP sets out the HF program of works that will support a design change or project, describing how HF activities will be integrated into the design development and systems assurances processes. A HFIP will typically set out the following: • The roles, accountabilities, competencies and resourcing arrangements in place for managing HFI • The process for identifying and managing HF requirements • The process for identification, capture and management of HF issues and risks within the HF Issues Register (HFIR) • The HF analysis activities to be undertaken to inform the design, including the methods and tools to be applied and any intended outputs • The intended arrangements for integration of HF analysis findings to the design development and review process • The proposed mechanism for end user engagement, including target users, methods and timing within the design development and review process • The method identified for testing and verifying identified HF controls and mitigations • The intended HF deliverables. Depending on the scale of the required HFI program of works, a HFIP may be a standalone document or it may be integrated into a broader design or system safety management plan.
Human Factors Issues Register (HFIR)	The HFIR acts as a log to track the HF issues identified over the course of a design lifecycle. HF issues will typically be identified during the EHFA stage, as an output of HF analysis activities, during

Document	Description
	risk or safety in design workshops, or during end user testing and evaluation activities. HF issues will not always be safety-related – they can also reflect issues associated with usability, maintainability, functional design and user experience. The HFIR will typically include the following information: • a unique issue ID to support issue traceability • identification of the impacted design areas and users • the HF issue identified • the anticipated HF impact of that issue • suggested controls to address the issue • issue status (e.g. Open, Closed, Transferred) • evidence to support the declared status (e.g. drawing/report reference, meeting minutes, test plan, a cross-reference to another register/issue ID following an issue transfer). The process for managing HF issues, including how issues will be captured, closed or transferred, is documented in the HFIP. For larger scale designs, the HFIR might also interface with safety or engineering change registers.
Human Factors Assurance Report	A HF Assurance Report will typically summarise the HF input to a particular design, or aspect of the design. It details the approach and methodology used and the analysis outputs, which might include a set of additional derived requirements or HF controls and risk mitigations. The report describes how those requirements or proposed controls were addressed during design development. The report forms part of the HF assurance case, detailing how HF was integrated into the design process.

B.1 Example Human Factors Integration plan contents

This section illustrates an example of the type of content that could be included in a HFIP. For some projects less will be required and for others specific elements may need to be added.

HFI aims to –

- optimise human/ system interaction and performance to ensure efficiency and effectiveness, while mitigating risk.
- ensure all users of the system are identified early and that their requirements are considered (e.g. operating personnel, customers etc.).
- incorporate HF throughout the asset life cycle of the project (planning, early design through testing and operational integration).
- Integrate HF into overall project, ensuring relevant HF activities are timed according to project phases and schedule.

Purpose of a HFIP:

- To systematically plan and document Human Factors activities, establishing a structured process and approach to managing HFI.
- Ensure HF is scaled according to the novelty, risk and complexity of human interaction, not necessarily the project size.

Elements that should be considered when developing an HFIP:

- Background of project.
- Context – where and how system is to be used/implemented.
- Scope of HF within this project (will assist with budgeting for HF work) – determined by the EHFA.
- Any constraints.
- Any dependencies.
- Relationship between HF and other disciplines, such as safety assurance, engineering (including systems engineering).
- Identification of end users, their tasks, their attributes and requirements, etc.
- Activities to be undertaken through the project lifecycle – requirement specification input, design input, *HF analysis, workshops, **consultation, Human Factors Issues Register (HFIR)/issues management, trial/testing/assessing of outcomes, etc.
- Identify any critical HF issues and process for managing them.
- Project milestone/reporting requirements: Human Factors Assurance Statement/Register (HFAS/R) at relevant gates** etc.
- Management of HF issues: HF issues register/hazard log incorporation?
- Evaluate/monitor/review processes.
- Capturing lessons learnt.

Note: A HFIP should be considered a live document and should be reviewed at each stage of the project and updated accordingly.

**HF analysis can include activities such as design review, task analysis, error analysis, workload analysis, refer to Appendix D for further guidance.*

*** Refer to Appendix E for further guidance.*

Appendix C Common Human Factors analysis terms

To carry out Human Factors (HF) work, there are a large number of possible analysis methods, tools and techniques. The most appropriate analyses to use for a specific project or change context to answer a particular question will depend on many factors, such as whether the project is for a new or altered asset, the context, time and resourcing available, the required level of depth, and the phase of the project. A HF analysis may involve the use of one or more different tools to understand a particular issue. Below is a list of terms commonly used to describe different HF analyses performed to support engineering design:

- requirements analysis.
- review of existing system and lessons learnt.
- task analysis.
- allocation of function.
- workload (physical and cognitive or mental) assessment.
- human error identification.
- human error quantification.
- cognitive workload or performance assessment.
- team design and performance analysis.
- layout, workspace, and workstation assessment.
- job and task design analysis.
- training needs analysis.
- user interface (human-computer interface (HCI) and human-machine interface (HMI)) analysis.
- human reliability analysis (HRA).
- commercial off the shelf (COTS) solution analysis.
- situational awareness analysis.
- scenario, mock-up, and prototype analysis.
- safe design or safety in design (including operability and maintainability) analysis.
- engineering analyses (human-related components).

For almost all HF work there is a need to collect data. Data can be collected in a number of ways via:

- workshops (for example, brainstorming, risk, lessons learnt, scenarios, walk-through, design review with users or stakeholder)
- qualitative observations.
- quantitative data collection (e.g., direct measurement).
- Checklists.
- Questionnaires.
- User working groups.

- Focus groups.
- Interviews.
- Literature.

Many references, such as books and academic articles, are available that provide assistance in:

- choosing appropriate techniques, tools and methods;
- comparing their relative strengths and weakness;
- obtaining specific details on how to carry out specific techniques, tools, and methods.

The table in Appendix D provides a summary of many of the HF methods and associated tools available.

Appendix D Examples of Human Factors methods and tools

*A specialist is a HF specialist and non-specialist is a person with appropriate experience or understanding of the application of the technique.

Methods	Summary	Examples of tools	Uses
Anthropometry	Measurements of the body	Various anthropometric databases	To aid design by ensuring design accounts for limitations of user population.
Cognitive Task Analysis	To describe the mental processes used when undertaking a task	Cognitive mapping	Creating a visual diagram showing how participants perceive an issue.
		Applied cognitive task analysis (ACTA)	By interview, to better understand the mental requirements of a design/task on the end user.
		Cognitive Work Analysis (CWA)	Understanding cognitive demands in the overall task and context
		Critical Decision Method (CDM)	Using set interview questions to understand demands and decisions made by expert end users in past situations.
		Cognitive Walkthrough	Evaluation of the user interface design.
Consultation		Workshops	Problem solving, issue investigation et
		Brainstorming (creative thinking)	Generate ideas to solve issues
		Mock ups	Evaluate proposed design
Data Collection	For the collection of specific data	Observational Analysis	Obtaining behavioural information
		Questionnaires	Gain information on tasks/usability etc.
		Interviews	One-on-one - qualitative or quantitative
		Workshops	With multiple users/stakeholders
		Direct measurement	Physical constraints, task performance
Design	Provide structure to the design process	Design Scenario Analysis	Workshop to evaluate new designs
		Interface Survey	Identify issues with design of systems/human-machine interfaces

Methods	Summary	Examples of tools	Uses
		Layout analysis	Analysing users mental model of how tasks are done
		Usability scales	There are many options e.g., SUS, SUMI, etc
		Use of tools and checklists/ HF design prompts	
Evaluation of interface design	Heuristic Evaluation	Nielson's 10 Heuristics	To gather feedback on interface design
		Link analysis	To identify links between components in a system
Human Error Identification & Human Reliability Analysis	Predict/analyse potential errors/human performance	HEART (human error assessment & reduction technique)	Identifies error and probability of occurrence
		Fault Tree Analysis	To understand/analyse root causes (also used for *HRA)
		SHERPA (systematic human error reduction & prediction approach)	Predicting, analysing and reducing human error
		Cognitive Reliability Analysis Method (CREAM)	Predict & analyse human error (also used for *HRA)
		TRACEr	Classifying human errors and causes (also used for *HRA)
		Human Error HAZOP (hazard and operability)	Nature & likelihood of error (also used for *HRA)
		Technique for human Error Assessment (THEA)	Identify potential interaction errors
Task Analysis	Breaking tasks/scenarios down into steps to analyse task demands and performance requirements	HTA (hierarchical task analysis)	To understand the elements required to successfully complete a task
		Murphy diagrams	To analyse human error - past errors or predictive
Situational Awareness	To analyse operator's levels of awareness	SAGAT (situation awareness global awareness assessment technique	Using simulator to determine situational awareness at random points during tasks
		Situational Awareness for SHAPE	Two techniques to ascertain awareness during and after a task

Methods	Summary	Examples of tools	Uses
		SART (situational awareness rating technique)	Determines the level of situational awareness within teams
Simulation	Simulation of the operational environment	Part or whole task simulators. Can range from low fidelity to high fidelity	Analyse human interaction
Workload Assessment	Evaluating operator workload	NASA TLX	Assessment of mental workload - multidimensional
		ISA (instantaneous self-assessment)	Estimating operator workload
		SWAT (subjective workload assessment technique)	Assessing workload
		Physiological measures	Methods for inferring workload from physiological measures (e.g., heart or respiration rate, skin conduction, EEG, eye movements, etc.)
		Mental Workload Index	Measuring primary task

Appendix E Example of how HF may input to engineering design lifecycle

The Figure below provides an example of how HF activities map onto the different phases of a typical design lifecycle. Analysis activities are typically carried out early on in the design phase so that the outputs can be used to inform design. The latter design phases will usually involve testing with end users and the verification of identified HF controls and mitigations. An effective HF program will integrate HF from concept stage all the way through to transition into service.

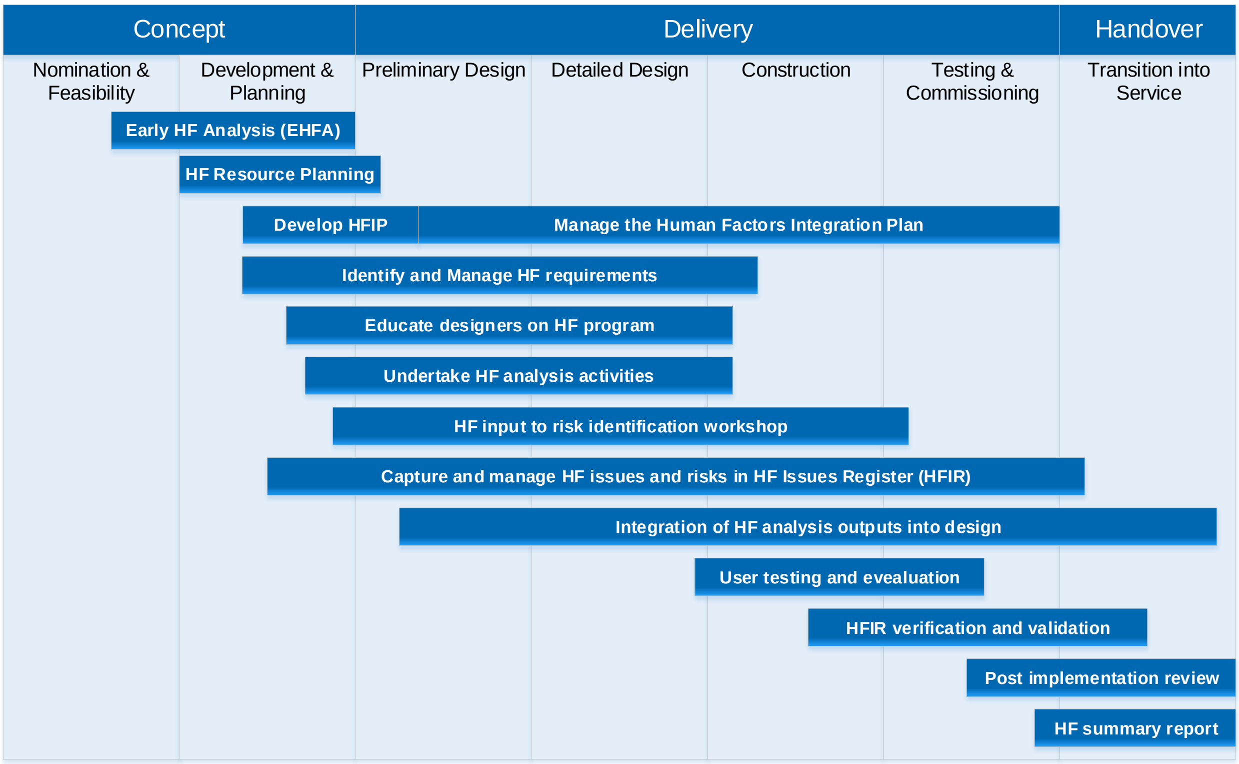


Table B.2:1 1 Example how HF may input to engineering design lifecycle

Appendix F Enhancing the safe design process

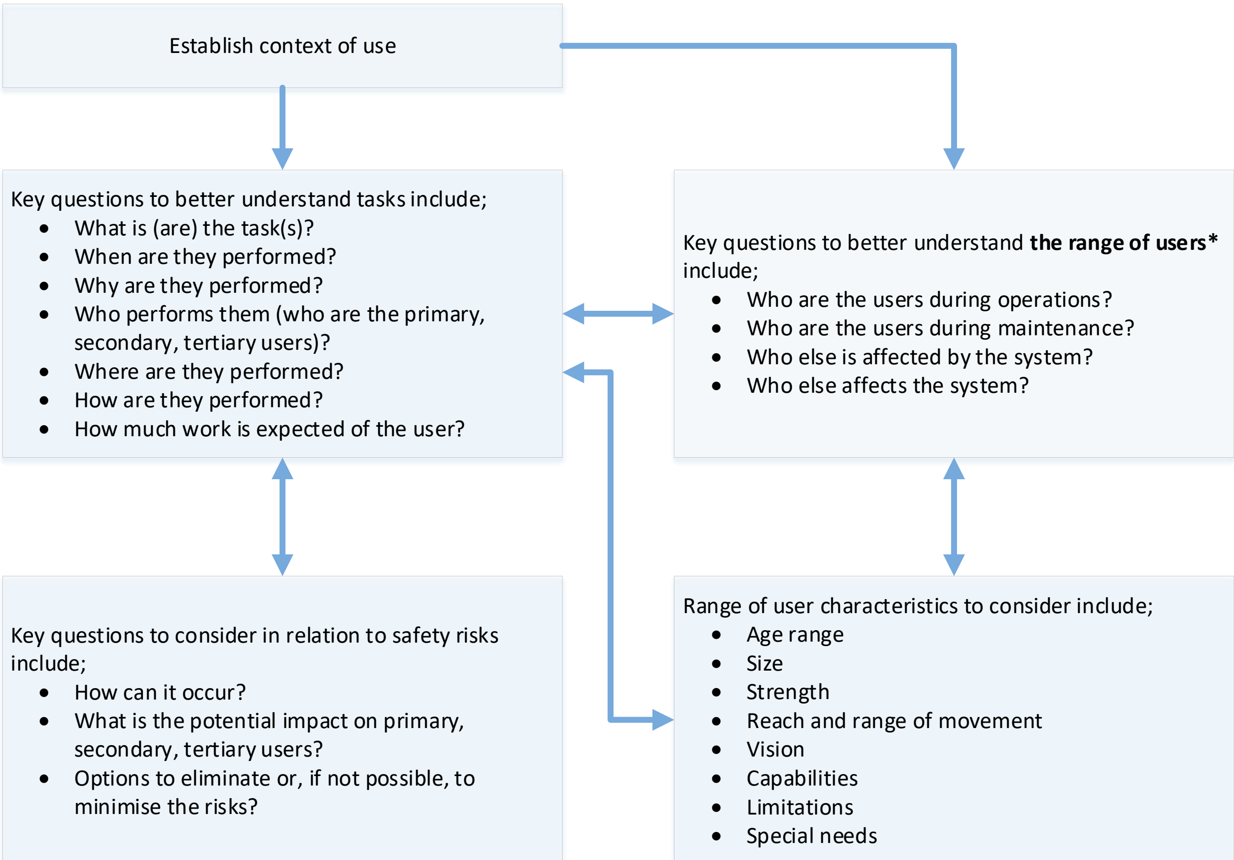
As described in this guide, Human Factors Integration is focused on human-system interactions to ensure that designs achieve their required performance in a safe, effective and efficient manner. Key steps outlined earlier in the document include –

- identification of all users, including operations and maintenance;
- identification of the tasks users may want to or need to perform; and
- undertaking an iterative process to ensure that the design allows the users to perform their tasks safely, efficiently and effectively, delivering the required system performance.

The WHS legislation requires that designers undertake a safe design approach when designing plant to ensure that it is SFAIRP without risk to health and safety. This safe design process is also known as safety in design (SiD). Safe design is a systematic process that involves consultation with key stakeholders, including users, identifying and where possible eliminating, or at a minimum reducing, identified health and safety risks. This process should be considered as an iterative one that evolves throughout the lifecycle of the project.

For projects with simpler HF requirements, HFI can be achieved by enhancing the safe design process to include efficiency and effectiveness of use alongside health and safety, considering tasks from an operational and maintenance perspective. Projects with more complex human-system interactions will require a more involved Human Factors Integration process.

Below are questions and considerations that can assist in enhancing the safe design process to better incorporate HFI.



*Range of users can include, but is not limited to, customers, operating personnel, managers, maintenance personnel, cleaners, contractors and members of the public.

Key questions to better understand specifics of task design include –

- can we make the tasks easier to perform (without inducing errors or short cuts);
- can users inadvertently make errors;
- can errors be easily identified and easily recovered from?

Key items to consider for efficient and effective operations and maintenance, include emergency and degraded –

- access/egress (users and equipment);
- forces required (sudden/high/sustained/weigh etc.);
- postures adopted/supported (awkward/sustained etc.);
- duration and frequency of activity (repetition/sustained etc.);
- location of items (too high/too low/too far/visibility etc.);
- equipment required (PPE/mechanical aids etc.);
- environment (lighting/glare/temperature/noise/sufficient space to undertake tasks and store items etc.);
- layout/location of items to support ease of use and error-free operations (frequency of use, importance, sequence of use and groupings);
- training needs;
- presentation of information for visibility (colour/font etc.) audibility and ease of comprehension;
- potential errors and ease of detection and recovery;
- cultural norms (attitudes and behaviours that are considered 'normal' for the general population or the specific group using the system);
- affordance (the perceived use or purpose of an item that determines how people will interact with the item).

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