HIGHWAYS AGENCY

Highways Consultancy Group - Highways Research Group

Best Practice Human Factors Guidance for Control Room/HMI Design

Contract Reference:	2/1308
Task Reference:	166(1308)MOTT
Project Sponsor:	Stuart White
Date:	November 2010

Executive Summary

Control room, plant and equipment design can have a huge impact on human performance. Designing tasks, equipment and work stations to suit the user can reduce human error, accidents and ill-health. Failure to observe human factors principles can have serious consequences for individuals and for the whole organisation. Effective consideration of human factors will make work safer, healthier and more productive.

The fundamental and consistent philosophy of human factors is to ensure that the human element, or user, is of principle concern within the design process. This approach promotes the inclusion of user (and operator) needs, capabilities, limitations and goals into the design process.

This document contains guidance to summarise the best practice human factors approach to system/product design and development, within the general project lifecycle, in order to provide support to Highways Agency in creating more cost effective and usable designs. This guidance should prove useful to both Highways Agency project sponsors/managers and human factors specialists involved in Highways Agency system/product design and development projects.

This document also contains a simple flowchart and checklist to allow the reader to determine whether the guidance is relevant to their project, and if so, which parts of the guidance should be focused on.

The guidance presented in this document provides some simple steps that you can include within the project plan and supports the reader in this through raising a number of questions for consideration. The guidance can be read as a whole, or the reader can focus on the sections of particular relevance to their situation.

A number of case studies and tips have been presented within this document. These have been collected during the course of this work and are used to provide examples and context for the best practice/methods that are described.

List of Contents

List of Tables

List of Figures

Section 1 - Introduction

1.1 Human Factors

Any system that has a human interface will have human factors (or ergonomics) issues associated with it. Both these terms are used to describe the environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work.

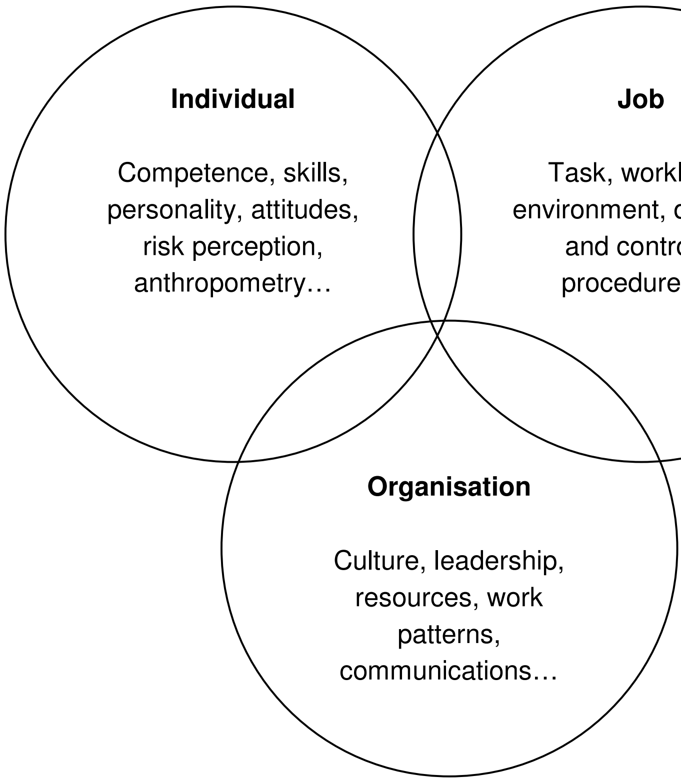


Figure 1 Definition of Human Factors (after HSE, 2005).

Human factors is also a process: human factors assessments look at the whole life cycle of an organisation, system or product, from design through to normal operation, maintenance, fault diagnosis and recovery, as well as emergency scenarios. A human factors assessment can result in recommendations for change that have the potential to reduce human error.

CASE STUDY: A report by the European Agency for Air Traffic Control (EuroControl) studied accidents across aviation and nuclear industries and concluded that 50% of all accidents have a root cause in design (e.g. some aspect of the design of equipment, system or process). It was established that central design problems leading to accidents are caused by:
- designers' misconceptions about the operators, operators' intentions and the operating environment
- operators' misconceptions about the design, its rationale and boundaries of safe operation

Source: Roelen et al 2004.

Human factors problems contribute to system inefficiency or failure and there are many real life examples where this has happened. Most people can think of examples from everyday life where things are difficult to use through poor design. There are also high profile cases where human factors issues contributed directly to a serious accident.

CASE STUDY: "The average user interface has ~40 flaws. Correcting the easiest 20 of these yields an average improvement in usability of 50%. However, if when usability (human factors) is factored in from the beginning of the interface design, efficiency improvements of over 700% can be achieved."
Source: Landauer 1995.

The design of control rooms, plant and equipment can have a huge impact on human performance. Designing tasks, equipment and work stations to suit the user can reduce human error, accidents and ill-health. Failure to observe human factors principles can have serious consequences for individuals and for the whole organisation. Effective use of human factors will make work safer, healthier and more productive.

CASE STUDY: A 1:10:100 rule of thumb has been established through case studies in the domain of usability for interface design. Therefore, if it costs £1 to fix an HMI usability issue during design, it will cost £10 to fix once the system is developed and £100 once it is operational.
Source: Pressman 1992.

1.2 Benefits of Human Factors

The application and integration of human factors into a project is client focused and can add value and reduce cost through the following benefits:

Benefit 1 - Reduction in major costs

EXAMPLES:
☑ Redesign costs are reduced due to a more effective design and development process
☑ Incident and accident rates, and associated sickness absence and compensation costs, are reduced due to better system/product design and a reduction in the potential for user error
☑ Human factors enables an improvement in user productivity and efficiency due to enhanced product/system usability (see Benefit 2)
☑ Improvements in job satisfaction and physical and mental well-being, as a result

Benefit 2 - A safer and more usable product/system design

EXAMPLES:
☑ Human factors considers the user which is particularly important as products and systems are becoming more complex due to increases in the use of technology
☑ Human factors results in well designed, easy to use products and systems
☑ Environmental conditions are designed to support successful operations
☑ Workplace hazards are minimised

Benefit 3 - Exploitation of established theories and methods that complement existing good project management approaches

EXAMPLES:
☑ Human factors ensures that tasks are within the physical and cognitive capabilities of operators and maintainers
☑ Human factors creates a systematic training and competency assurance process
☑ Human factors creates information systems that ensure that communications are understood

1.3 Purpose of this document

The purpose of this guidance document is to summarise the best practice human factors approach to system/product design and development, within the general project lifecycle, in order to provide support to the Highways Agency in creating more cost effective and usable designs. The emphasis of this document is specifically on Highways Agency control room design and development. However, it should be noted that the underlying principles can be applied to the general design and development context of any product or system.

This guidance should prove useful to both Highways Agency project sponsors/managers and human factors specialists involved in Highways Agency system/product design and development projects:

- This guidance should provide **Highways Agency project sponsors/managers** with a good introduction to the human factors considerations of a design and development project and allow for the planning of such a project:
    - At the very least, it should result in the Highways Agency project sponsor/manager having a questioning attitude about the human factors on the project, and in the process, creating a better designed system/product and a more cost effective design process
    - If, upon reviewing the questions in Section 2, the project sponsor/manager decides to engage a human factors specialist on the project, then this guidance can be used by the project sponsor/manager as a checklist to ensure that the required human factors activities are undertaken by the specialist and as a communication tool between the project sponsor/manager and the human factors specialist in demonstrating Highways Agency requirements for human factors input
- This guidance should prove to be a valuable reference to **human factors specialists** also, as it can be used as a communication tool between the project sponsor/manager and the human factors specialist in demonstrating Highways Agency requirements for human factors input

This guidance gives examples of the techniques and tools used to address human factors issues. It should be noted that, depending on the level of competence and experience of the reader, many of these techniques may require the skills of a human factors specialist to be carried out correctly. The procedures in this document are also highly abbreviated and will only serve as an introduction to that technique. The reader can find references at the end of each section if they require further information. In addition, Appendix A summarises the best practice design and development processes, including the general human factors approach to system design and the approach specific to the design of control centres and control centre HMI.

1.4 Using this document

This document is structured in the following way:

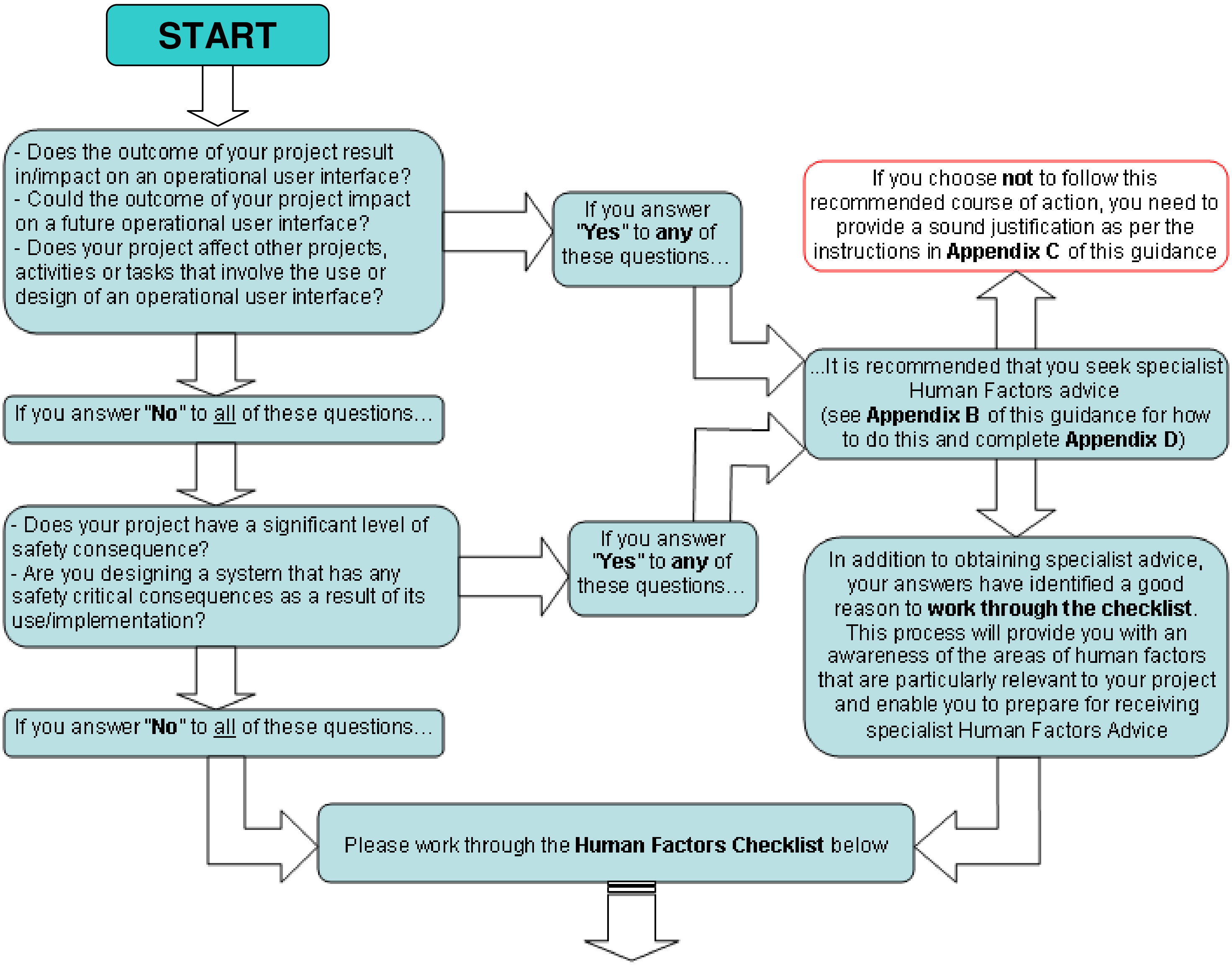
Section 2 Provides a checklist to establish whether the guidance in this document is relevant to the project

Section 3 Describes the essential steps that need to be followed to apply human factors to your design and development process

A number of case studies and tips have been presented within the document. These have been collected during the course of this work and are used to provide examples and context for the best practice/methods that are described.

Section 2 - Is This Guidance Relevant To Your Project?

The flowchart below will help you to decide if the guidance in this document is relevant to your design and development project and whether you may benefit from specialist human factors advice. Consider the project that you are involved with and the outcome (e.g. design) that you are aiming to achieve:



NB. This checklist will take you approx **5 minutes to complete** and its application could help you save costs on the project via a more efficient design process and through the creation of an enhanced end product.

HUMAN FACTORS CHECKLIST: Have you considered these issues?

- **If you are at the very start of a project**, it is appreciated that there may be a number of questions where your answer is 'unknown'; however, you are invited to review the relevant sections of the guidance as prompted and revisit this checklist (and the associated guidance) at each stage boundary/gateway on your project, to ensure that human factors are being managed and included in your project as it develops
- **If your project is well underway**, e.g. you are at the detailed design stage or even more advanced, it is not too late to apply this checklist and review the relevant guidance to improve the human factors in your design

NB: The purpose of the questions presented in this checklist is to highlight the type of human factors issues you should be considering on your project and the questions are in no way exhaustive. Each design issue should be discussed with respect to the uniqueness of the task/project in order that suitable trade offs and compromises can be made.

- **Key question summary: Can this person …. With this training … Do these tasks … To these standards … Under these conditions?**

TIP: Definitions

User = a person who will be interacting with the product/equipment that you are designing, e.g. an operator in an RCC using an interface.
Task = operational task conducted in RCC, etc.
System = computer based system that has a user interface in the RCC

Particular responses to the different questions in the checklist will refer you to different steps in the guidance (presented in Section 3). To summarise, the guidance contains the following elements:

HIGHWAYS AGENCY

HCG Highways Consultancy Group HRG Highways Research Group

1. Review the checklist questions below with respect to your project and the product/equipment and/or operational task you are developing

2. Any question that results in a pink **box response requires the review and application of at least one Step of the guidance**

3. Refer to the guidance (Section 4). The guidance can be read as a whole, or you can focus on the **sections of relevance** as noted in this column

Topic Area and Questions	Response				Pink Box = Action: see relevant Step in Section 3…
	Yes	No	Unsure	N/A	
Staffing and Personnel Topics: Staffing levels, workload, team, organisation, job specifications, team organisation, selection, recruitment and career development, qualifications and experience required, competence requirements, physical characteristics (body size, strength, eyesight, etc).					
Will you define who your users are going to be?					1
Will the task require more than one person to complete it?					1, 2, 4
Will the task demand either a particularly high or a particularly low workload?					4
Will the users' skill sets be considered?					1, 3, 5
Could the system have a negative impact on staff job satisfaction?					5
Will the system be designed to match the mental and physical abilities of users and maintainers?					1 - 5, 7, 9
Will the project outcome result in any changes to existing operational teams?					5
Training Topics: Developing and maintaining the required knowledge, skills and abilities to operate and maintain the system, training documents and courses, training facilities, specialist training, etc.					
Will there be clear job descriptions that illustrate the tasks that will be undertaken?					5
Will users require specific training to use the product/outcome of your project?					1, 5
Will different competency levels be required?					5
Are you automating any part of the system?					4
Will there be a plan in place to effectively manage the transfer of skills?					4, 5

Topic Area and Questions	Response				Pink Box = Action: see relevant Step in Section 3…
	Yes	No	Unsure	N/A	
Task Design Topics: Organisation changes, communication, task support, working arrangement, operator tasks, automation and shifts.					
Will the impact of the new operational task be considered in relation to existing tasks and workload?					2, 3, 4
Will there be any tasks that are required to be performed in parallel?					2, 4
Will there be any time pressure put on the operators?					2, 4
Will there be any cumbersome or monotonous tasks?					2, 4
On completion, will the task require a review, e.g. by a peer, supervisor?					2, 4
Will the impact of the new operational task be considered in relation to existing tasks and workload?					2, 3, 4
Human Factors Engineering Topics: Equipment design, workstation design, workspace layout, maintenance access, human characteristics, user interface design, allocation of function.					
Will it be clearly understood how the new product/equipment that you are developing in your project will be integrated with existing systems/equipment/operational tasks?					3, 4, 7, 9
Will the maintenance requirements be defined, and will they be examined to ensure they are they feasible?					2, 5
Will the design ideas of the displays, controls, software interfaces etc. be considered at an early stage of the design process?					4, 7
Will the operating environment change as a result of the implementation of this new system/product?					7, 9
Will best practice for the layout of the operating environment be identified and considered, e.g. to manage communications, tasks, etc.?					7, 9
Will the impact of the operator's and team's situational awareness, decision making and communication be assessed?					4, 5, 7, 9
Health and Safety Hazards Topics: Short or long term hazards to health resulting from normal operation, of the system, e.g. exposure to toxic materials, electric shock, physical injury, musculoskeletal injury, working environments (e.g. climate, lighting, noise).					
Will the relevant health and safety standards be identified and considered?					1, 5
Will the range of environmental issues be considered in relation to task performance, e.g. temperature, lighting and noise levels?					5, 7, 9
Could there be risk of injury through use or maintenance of the system?					2, 5, 7, 9
Will any tasks require repetitive movements or heavy lifting?					2, 4, 7, 9
Will criteria be defined to manage the trade offs between health and performance?					4, 7, 9

Topic Area and Questions	Response				Pink Box = Action: see relevant Step in Section 3…
	Yes	No	Unsure	N/A	
System Safety Topics: How to avoid the safety risks which humans might cause by operating or maintaining the system abnormally, sources of human error, effects of misuse or abuse and decision making.					
Will you consider how the system can support operator decision making activities?					4, 7, 9
In the event of an error will the system provide clear feedback to the operator?					4 - 10
Will the operator easily be able to correct the system if any errors are made?					4 - 10
Will the operator be required to respond to system alarms?					4 - 10
Could the safety of the related operating environments (e.g. motorway) be negatively affected as a result of this project?					4
Will you think about maintenance processes for the system and how the system will be safety returned back to service?					2, 4, 5
Organisation Topics: Organisational structure, team working, leadership, job description, communication and training.					
Will the new system impact on how separate groups/teams of people interact with one another?					2, 4, 5
Will the system change be communicated to all levels of the organisation?					5, 7, 9
Will contractors be used to do any of the operational tasks?					5, 7, 9
Will changes to existing personnel plans and performance management systems be required?					5, 7, 9
Will the commissioning of your project outcome affect existing systems?					2, 4, 5

Thank you for completing the checklist.

If your response to any of the questions has resulted in the ticking of a 'pink' box, it is recommended that you now review the relevant Step(s) in Section 3: Human Factors Guidance.

Are you going to review the relevant Step(s) of the Human Factors Guidance at this time?
If **yes**, please complete the form in **Appendix F**
If **no**, please complete this form in **Appendix G**

If none of your response to any of the questions has resulted in the ticking of a 'pink' box, there is no requirement, at this stage, for you to review the Human Factors guidance. *However, if you feel it would assist your project you can review the Guidance steps in Section 3: Human Factors Guidance.*

Please complete the form in Appendix E

It is recommended that you **revisit this checklist at each project stage boundary** to reconsider the need for human factors input and complete an additional form for the project file.

Section 3 - Human Factors Guidance

The best practice guidance is presented in 11 steps. The purpose of the guidance is to summarise the best practice human factors approach to system/product design and development, within the general project lifecycle, in order to provide support to the Highways Agency in creating more cost effective and usable designs.

The guidance provides some simple steps that you can include within your project plan and supports you in this through raising a number of questions for you to consider. The guidance can be read as a whole, or you can focus on the sections of relevance.

- **If you are at the very start of a project**, it is appreciated that there may be a number of questions where your answer is 'unknown'; however, you are invited to review the relevant sections of the guidance at each stage boundary/gateway on your project to ensure that human factors are being managed and included in your project as it develops
- **If your project is well underway**, e.g. you are at the detailed design stage or even more advanced, it is not too late to apply this guidance to improve the human factors in your design

Disclaimers:

- It is assumed that members of your project design team have some knowledge or understanding of ergonomics/ human factors
- The guidance presented is high level and therefore significant human factors issues should be discussed with the wider project teams
- There is no single way to tackle human factors issues; it always depends on the task and its context, therefore this guidance should be used with caution

Each step within the guidance is presented in terms of what, why and how it can be undertaken and the output that results from following the approach. Further sources of information are also provided.

Step 1 - Clarify goals and requirements

Step 1.1 - What? The purpose of this first step is to clarify operational goals, relevant requirements and constraints associated with the design of control centre(s) and operational system interfaces. The purpose and role of the control centre (e.g. descriptions and functions of the sub-systems, for example process units, power systems, communications systems etc.), the control room and the human machine interface (HMI) (e.g. control panel/interface purpose and functions) and their relationships with other relevant sub-systems should be identified and documented.

TIP: Experience from existing or similar control centres can make a valuable contribution to refurbishment or new projects and this experience should be given appropriate consideration at the start of project.

Step 1.2 - Why? Clarifying the goals and requirements at the earliest stage in the design and development process allows them to be used as a driver and to be constantly referred back to, to ensure the project, and ensuing design, is on track to fulfil its purpose.

CASE STUDY: Regional Information Display Demonstrator (RIDD)
(*This Highways Agency system was trialled in 2008 and remains available for use in certain areas)*
Summary Description - The RIDD is a service for RCC operators that provides speed and journey-time information across the South West and neighbouring RCC areas. The system also has the capability to display details of incidents, road works and VMS settings on a graphical display of the network. There are two ways of viewing information on the RIDD, these are, a regional view which provides an overview of journey times, and a detailed view which shows actual speeds, local events and Variable Message Sign settings. Although the system was only intended as a trial demonstrator, the system proved so useful to RCC operators that they requested that the system remain installed for continued use.
Human Factors Issues - Development of the RIDD involved input from Human Factors specialists. The initial concept considered user requirements and the process followed involved an iterative development approach which resulted in continuous design enhancements.

Step 1.3 - How? In order to fully understand and explore the purpose and the role of the control centre/HMI, the project team will need to examine a range of human factors.

The characteristics of the users, tasks/activities and the organisational and physical environment define the circumstances in which the system is (to be) used. Therefore, it is important to identify and understand the details of the circumstances so as to guide early design decisions, and to supply a basis for evaluation. Information should be gathered about the context of use of new products and systems. The context in which the system is to be used should be identified in terms of:

- The intended users
    - Knowledge, skill, experience, education, training, physical attributes, habits, preferences and capabilities (for different user groups or different roles)
- The tasks/activities the users are to perform

   - Frequency and duration of performance, implications for health and safety (use of personal protective equipment etc.) – this process should consider normal, unusual and emergency conditions/tasks
- The environment in which the users are to use the system
   - Hardware, software, materials to be used, relevant standards[1], regulatory guides, attributes of the wider technical environment, the physical environment, the ambient environment, the legislative environment, and the social and cultural environment. What feedback is available from existing similar contexts/control rooms so that you can learn from previous mistakes?

TIP: A range of stakeholders, e.g. potential/current operators, managers, maintenance teams, should be involved to ensure that as much relevant information is captured as possible.

Several techniques can be employed to elicit the requirements from stakeholders, e.g. contextual interviews, focus groups (requirements workshops), and checklists. Where necessary, a combination of these methods can be employed to establish the exact requirements of the stakeholders, so that a system that meets the user and organisational needs is produced.

The product of this activity should be a 'context of use description', a working document that contains a description of the relevant characteristics of the users, tasks and environment which identifies what aspects have an important impact on the system design. Additionally, any requirements or constraints to be taken into account in the design of control centres should be identified and documented. The description should:

- Specify the range of intended users, tasks and environments in sufficient detail to support design activity
- Be derived from suitable sources
- Be confirmed by the users or, if they are not available, by those representing their interests in the process
- Be adequately documented
- Be made available to the design team at appropriate times and in appropriate forms to support design activities

An example of attributes of a 'context of use description' is provided in Appendix H.

Operational feedback from other projects should be incorporated (Step 11 - Gather operational feedback) and any conflicting requirements (there are usually several!) should be documented, evaluated and resolved. Those issues that cannot be resolved should be placed on an Issues Log (see Appendix I for an example) and monitored to ensure that they are dealt with at a suitable point in the design lifecycle before they have chance to cause a bigger (and more expensive) problem later down the line in the design process.

[1] See Appendix J for a list of relevant human factors and ergonomics standards that might be relevant to your design.

Step 1.4 - Outputs? The outputs for this task include a common set of user and organisational requirements (context of use description) that incorporates:

- A statement of operational goals (e.g. what the system's functions should be);
- Relevant requirements and constraints;
- Conflicting requirements and solutions of compromise.

…**PLUS** - any issues/uncertainties/problems should be documented in the Issues Log.

This common set of user and organisational requirements can thereafter be used to validate that a design fulfils its needs.

Step 1.5 - Want more information? Review the following:

ISO 13407 (1999). *Human-centred design processes for interactive systems.* International Standard, International Organization for Standardization. Available at: http://www.bsigroup.com/

Context of use analysis. Available at: http://www.usabilitybok.org/methods/context-of-use-analysis

Usability context analysis: a practical guide. Available at:
http://www.usabilitynet.org/papers/UCA_V4.04.doc

Step 2 - Define operator tasks

Step 2.1 - What? Based on the findings of Step 1, a high level task analysis should be carried out and documented. This means considering what the key, high level tasks are that need to be undertaken to achieve the goals and requirements documented in Step 1.

Step 2.2 - Why? This step is conducted as a first action in understanding what key tasks are required to achieve the objectives defined in Step 1, before these tasks can be appropriately designed to be conducted as efficiently and safely as possible.

CASE STUDY: Adaptive CCTV *(being trialled across parts of the network)*
Summary Description - The Highways Agency has been trialling ACCTV to assist operators in the WMRCC to monitor a stretch of motorway. The ACCTV system is a computer algorithm that operates with the CCTV system to automatically detect incidents and abnormalities on the road. The system is capable of detecting abnormalities such as, debris, pedestrians and broken down vehicles. It is intended that the system provides an early warning notice to operators, and highlights suggested CCTV images that the system has detected an incident in.
Human Factors Issues - Operators face many screens and are expected to interact with many systems – human factors consideration should be given to the way in which alarms and early warning notices are presented to operators. There may be a reduction in vigilance amongst CCTV operators as a result of reliance on the system. The operator needs confirmation that the ACCTV is active – even when no incidents are detected – so that they are confident that the system is operational.

Step 2.3 - How? The analysis may be undertaken by several methods, e.g. functional breakdown, flow charts, simulations and operational walk-throughs (if you have this level of detail at this early stage). The scope of the analysis shall include all anticipated operational modes of the controlled system, e.g. what tasks need to occur during:

- Normal state of operation, from start up, usual operation, to shut down
- Emergency/abnormal operation
  - E.g. what happens after an emergency/abnormal operation, because such operations may impose temporary function/task allocation changes, special safety considerations, job redefinition and environmental changes?
- Maintenance (scheduled as well as unscheduled)
  - E.g. what happens when some or all of the systems' process equipment, machinery, displays and controls, utilities, etc. are unavailable due to maintenance activity?

The tasks should be documented in a simple list format, see Figure 2. Anything that is uncertain at this early stage should also be noted on the list to ensure that it is not forgotten later down the line in the design and development process.

Operator task: Responding to a call from an ERT (emergency roadside telephone)

1. Telephone rings at operator workstation
2. Operator answers call – via touch screen and headset?
3. Operator obtains details of incident – specific protocol for this needs to be defined
4. Operator logs details of incident – need to make sure software allows easy interaction
5. Operator checks location on map – define how this can be done through automation of the system
6. Operator actions the response

Figure 2 Example of a basic task list and issues to be defined.

Step 2.4 - Outputs? A list of high level tasks associated with the overall operational goals and sub-goals.

…**PLUS** - any issues/uncertainties/problems should be documented in the Issues Log.

Step 3 - Allocate tasks to the people or the technology/system

Step 3.1 - What? The high level tasks identified in Step 2 should now be allocated to people (operators) and/or machines (system/technology).

Step 3.2 - Why? This step is conducted so that a preliminary decision can be made about which tasks are going to be undertaken by people and which by the machine/system (or a combination of the two), in order to work to the strengths and characteristics of these two different system components. For example, machines are far more suitable for routine monitoring tasks and for high accuracy/repetitive tasks. However, people are much better suited to tasks that require adaptation, strategy and planning.

CASE STUDY: NASS - Network Active Traffic Management Supervisory Subsystem
(Highways Agency system in development)
Summary Description - This system aids operators to make tactical decisions for controlling the motorway. It works by collecting real time traffic flow data detected by roadside sensors, and compares it to previously modelled data of traffic patterns. The NASS analyses the comparison of the two sets of data and attempts to predict when flow breakdown, i.e. congestion is likely to occur. The system prompts an RCC operator that it senses congestion building, and offers a number of solutions to the operator to take action to alleviate the current situation. The system provides options on the best course of action for a defined traffic management tactic, based on past data.
Human Factors Issues - The system is designed to perform much of the 'donkey work' (e.g. monitoring traffic flow against modelled data), alerting the operator when decisions need to made. Therefore, the strengths of the person and the machine (system) have been taken into consideration; this design enables the operator to focus on more tactical tasks whilst the system performs the mundane, repetitive tasks.

Step 3.3 - How? Initial allocation of function between equipment and humans or a combination of these, should be carried out taking into account the respective capabilities of humans and machines for given task requirements. This initial allocation of function should then be reviewed and confirmed using detailed task analysis (see Step 4) as the design progresses. This will ensure that a systematic approach is adopted that will enable the identification of impacts of allocating a function or task to a human, machine or both and at both the single and complete system level.

TIP: It should be noted that these function allocations are subject to change as more detail is developed during the design and a greater understanding is subsequently provided about the allocated tasks.

The most suitable allocation of functions between the operator and machine should be decided after considering the requirements of the task and environment and the strengths and limitations of both the human and machine in this context. Preliminary allocation of function by designers should be based upon the relative strengths and weaknesses of human and machine including:

- Physical workload
- Strength
- Repetition and duration

- Precision and vigilance requirements
- Environmental conditions
- Commercial and any other pressures

Overall co-ordination of tasks will also be required and each operator should have clearly defined roles and responsibilities where functions are allocated to them.

Step 3.4 - Outputs? These should include:

- Sets of functions (tasks) that are anticipated to be performed by people (operators)
- Sets of functions (tasks) that are anticipated to be performed by the technology/machines, and associated requirements for error-tolerant technology/machine design
- The interactions between humans and technology/machines

…**PLUS** - any issues/uncertainties/problems should be documented in the issues log.

Step 3.5 - Want more information? Review the following:

Dearden, A., Harrison, M & Wright, P (2002). Allocation of function: scenarios, context and the economics of effort. International Journal of Human-Computer Studies,
Volume 52, Issue 2, February 2000, Pages 289-318. Available at:
http://homepages.cs.ncl.ac.uk/michael.harrison/papers/deardenhw99.pdf

Function allocation. Available at: http://www.usabilitybok.org/methods/function-allocation

Step 4 - Define the task requirements

Step 4.1 - What? A task analysis should be conducted to examine the basic elements of the tasks that have been allocated to **people** during Step 3. The task analysis can include notes on (preliminary) design/engineering solutions based on prior experience or on opportunities for innovation and invention that may be identified.

TIP: It is acknowledged that only limited information about these task elements may be available at this early stage in the design and development process. Therefore, the project team should document what they can and add to the task analysis as more information becomes available.

Step 4.2 - Why? The process will capture information relating to what people will do when carrying out their tasks/jobs to enable the project team to consider any design issues that might need rectifying at an early stage. This step is conducted to ensure, very early on in the design and development lifecycle, that the basic, early ideas about the tasks are achievable by the users and that any fundamental problems are captured so that they can be managed appropriately. The outcomes of task analysis can help to:

- Define selection criteria for operators (e.g. operator skills and abilities)
- Identify training requirements
- Develop good procedures
- Determine the best layout for equipment
- Estimate the number of staff required for a job
- Estimate workload
- Investigate human error
- Make recommendations for improvement

TIP: Applying task analysis methods can be complex. You may need some specialist help to carry out the analyses.

Step 4.3 - How? There are two widely used methods of task analysis. The section illustrates when it would be appropriate to follow these techniques by referring to a control room case study scenario:

> *SCENARIO: The project team want to design a new control room interface that enables operators to open the hard shoulder for use as a running lane. They want to know the best way of integrating this with existing systems and to find out whether the task is achievable or not with the time, personnel and resources available.*

At the concept stage (and earlier) in the project, it is likely that very little detail will be available about what the interface will look like or how the task will be undertaken, which is appropriate as the task design should be driven by the requirements and not 'set in stone'. Therefore, a hierarchical task analysis is appropriate, see Figure 3. This sets out in a clear structure, what each step of the task involves. Starting at the top, the first box specifies the overall task goal i.e. in the example provided – opening the hard shoulder. The next layer of boxes break down the goal into discrete steps, or sub-goals.

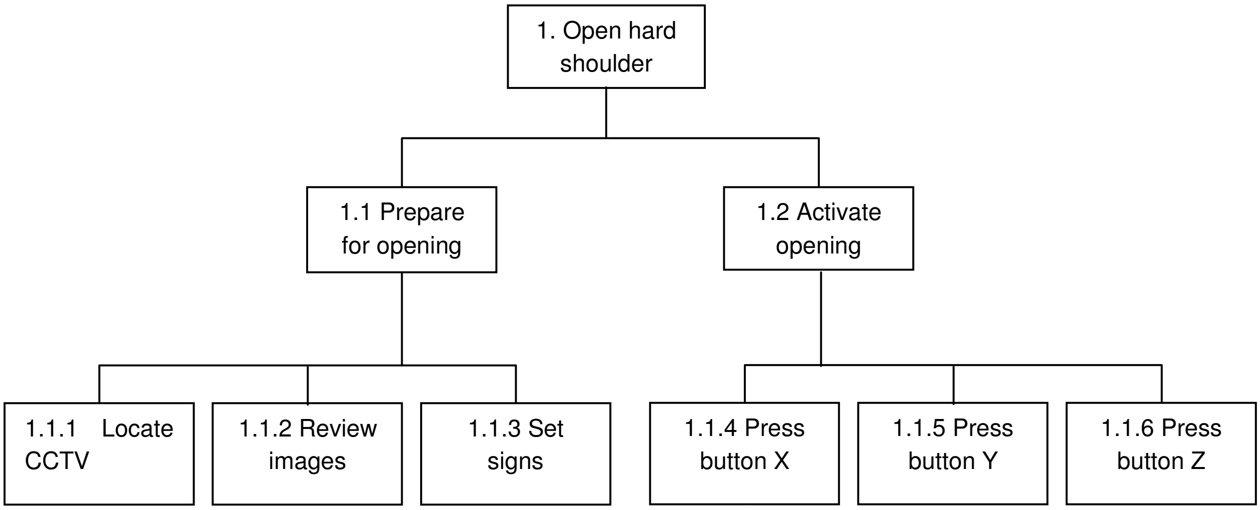


Figure 3 Example of a basic hierarchical task analysis.

In this example scenario, as it is a new concept and since this particular task has not been attempted before, there is no 'system expert' to take the team through the specific steps. However, lessons can be learnt from similar tasks and experiences. Therefore, it is appropriate for the team to discuss the proposed task with some experienced control room operators, and from this put together a basic procedure. They can then draw up a basic list of actions and 'walk through' the task.

TIP: This section provides you with an introduction to some of the basic skills needed to conduct an analysis, but you are strongly recommended to read further about the techniques you intend to use, and to attend a training course in this subject.

Breaking down task descriptions into increasing levels of detail should continue until the project team are satisfied that they understand the task completely (which may not be possible early on in the design process, more details should be added as they become available). Notes are usually added to clarify the information, for example, to indicate sequences of operation. The 'tree' format can get very wide and difficult to fit on one page. An extract from the same task analysis is shown in the alternative, 'tabular' format below, Figure 4. Note that more task details can be included in this format.

Task Step	Potential errors	Consequence of error	Task support	Recovery opportunities	Recommendations/ Solutions
1.1 Prepare for opening.					
1.1.1 Locate CCTV.	Identify the incorrect CCTV image.	Operator unable to view the appropriate hard shoulder. Operator may think hard shoulder is clear when the incorrect CCTV is being viewed.	Procedures / manuals. Training. Camera location and ID on video image	Operator realises that CCTV needs to be viewed. Operator realises that wrong CCTV image has been selected.	Ensure feedback is provided to the operator for CCTV image selection (e.g. onscreen identifiers). Ensure an additional task step is included so that the operator has to confirm the location of the CCTV image against the hard shoulder location.

Figure 4 Example of a tabular task analysis structure.

As a minimum the following should be recorded in columns in a tabular task analysis:

- Potential errors and violations
- Consequence of human failure
- Task support, e.g. interfaces & equipment; environment; procedures; training; supervision
- Recovery opportunities (if an error is made)
- Recommendations/solutions for the design

You may also want to consider the following elements of the task steps:

- Manual and cognitive activities
- Task frequency, duration and complexity
- Communication requirements
- Environmental conditions

When a task is time dependent, the following columns may be added to the tabular task analysis:

- Time available
- Estimated time required to successfully complete the task

Where there are potential concerns about organisational and management issues then the following should also be considered. These are likely to be considered at the task goal level rather than in relation to individual task steps, as management and organisation features tend not to vary at the sub task level, but influence the task as a whole:

- Allocation of function
- Task Characteristics (frequency, duration, repetition, physical & cognitive demand)
- Type of supervision

- Task planning and workload
- Competency assurance and training
- Safety Management Arrangements

Conducting a task analysis gives the project team invaluable insight into the proposed task. Further task analysis techniques can be applied to gather more information on aspects of a task:

- Timeline analysis - used to estimate the time taken to complete a task
- Link analysis - used to show the number of links (communications links or movements between different parts of a plant) required to achieve a task

Step 4.4 - Outputs? The output will include a flow diagram or a table (See Step 4.3 above) that presents a clear summary of peoples' task goals, the order in which they must take place, and an indication of any constraints relevant to the different sub-tasks.

…**PLUS** - any issues/uncertainties/problems should be documented in the Issues Log.

Step 4.5 - Want more information? Review the following:

Kirwan B and Ainsworth L K (Eds), 1992, 'A Guide to Task Analysis'. Taylor and Francis: London. Available at: http://www.taylorandfrancis.com/books/details/9780748400584/

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C. & Jenkins, D. P (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate: Aldershot. Available from: http://www.ashgate.com/default.aspx?page=637&calcTitle=1&title_id=8082&edition_id=9199

Hierarchical task analysis. Available at: http://www.uxmatters.com/mt/archives/2010/02/hierarchical-task-analysis.php

Task analysis. Available at: http://www.usabilitynet.org/tools/taskanalysis.htm

Contextual task analysis. Available at: http://www.usabilityfirst.com/usability-methods/contextual-task-analysis/

Step 5 - Design the job and work organisation

Step 5.1 - What? After the tasks have been examined, job design is then undertaken. This means that the tasks that have been allocated to people during Step 3 are examined alongside the user requirements (e.g. policy for work organisation) and any regulatory requirements (e.g. requirements for work organisation, i.e. hours of operation), identified during Step 1. This enables tasks to be assigned to particular roles according to the planned work organisation.

Step 5.2 - Why? In order to reduce the opportunity for error and retain a motivated workforce, the job design process should enable the operators' physical characteristics, cognitive and analytical abilities, and the organisational context, to be considered so that the job design can be modified accordingly.

CASE STUDY: On-off button for lighting - Midnight switch-off
(in operation across parts of the Highways Agency network)
Summary Description - This is an initiative by the Highways Agency to reduce carbon emissions and light pollution by turning off selected road lighting after midnight. During times of low volume traffic, some motorways deemed to be suitable are selected to operate with illumination turned off in the early hours of the morning. The switching off of motorway lighting is carried out by timing devices at the road side, however RCC operators are provided with a push-twist type override button to enable them to turn the lights on if required. During the trial, the decision about which lights to switch off and where this would be managed from was governed by time of day and current traffic flow rates. A push-twist type switch was mounted on an operator desk in a local RCC, and used to turn off the selected lighting.
Human Factors Issues - Some human factors considerations to prevent accidental activation of the switch had been given due to the multiple actions required to depress the switch. However no feedback was provided to the operator to confirm if the action of pushing the switch had actually resulted in the intended outcome. The only way verification could be achieved was to carry out a check using the CCTV system. Applying best practice human factors principles would highlight the benefits of providing feedback to an operator.

Step 5.3 - How? The first thing to do is to prepare a preliminary work organisation structure that satisfies user and regulatory requirements. Consider:

- Team structure (number of people and skills/abilities)
- Lines of responsibility (line management)
- Workplace culture
- Union/management arrangements
- Communication requirements

After documenting a preliminary work organisation structure, conduct a job design assessment:

- Define a set of job assignment criteria; this should include criteria/job features that can be considered when assigning tasks to particular roles (people), e.g. workload, job sharing, information and data requirements, required tools/facilities/desk space etc.
- Determine jobs that are going to be carried out by each operator

The types of questions to consider whilst designing the work organisation structure and job/s include:

- What are the Highways Agency policies, and UK/EU rules, regulations and best practice that you need to abide by when designing the job roles? These should have been identified during the user requirements step (Step 1)
- What operational tasks need to be conducted by operators? These should have been identified during Step 4
    - Which tasks are related and might be appropriate to be undertaken by a particular individual?
    - Which tasks will be conducted most frequently?
    - What skills, abilities (physical and mental) and knowledge are required to do the tasks?
    - What are the requirements for training?
    - What are the requirements for operating procedures?
    - What information/task support is needed to conduct the tasks?
- What work organisational structure suits the policies/rules/regulations/best practice and the tasks?
    - What are the operators' individual needs for job satisfaction?
    - Will there be scope for personal growth/career progression?
- What are the communication requirements (e.g. between operators, control rooms and control centres)?
    - Which people need to communicate?
    - How frequently do they need to communicate?
    - What's the best method for communicating?
    - If you are introducing new communication methods/equipment…
        - …how are users going to be trained?
        - …what are the maintenance issues?

TIP: Job design is an iterative process which may require several iterations as the design develops to manage all the human and organisational issues that need considering.

5.4 - Outputs? These should include:

- The work organisation (structure and number of operators, lines of reporting)
- The jobs that are assigned to each operator
- Requirements for communications between operators, between control room and local control centres
- Requirements for operating procedures
- Requirements for training
- Requirements for information and control

Step 5.5 - Want more information? Review the following:

Parker, S.K & Wall T.D (1998). Job and Work Design: Organizing Work to Promote Well-Being and Effectiveness (Advanced Topics in Organizational Behavior). Sage Publications.

Reason, J & Hobbs, A (2003). Managing Maintenance Error: A Practical Guide. Ashgate, Aldershot. Available from:
http://www.ashgate.com/default.aspx?page=637&calctitle=1&pageSubject=451&pagecount=4&title_id=70&edition_id=160

Smart working: the impact of work organisation and job design. Available at:
http://www.cipd.co.uk/subjects/corpstrtgy/orgdevelmt/_smrtwrkgri.htm

The process & content of job & work organisation (re)design. Available at:
http://www.moderntimesworkplace.com/Work_Redesign_Guide.pdf

Step 6 - Test the early design ideas

Step 6.1 - What? Early and regular testing of the design ideas/design concepts that have been developed to date, against the goals and requirements, is key to ensuring that the user is provided with usable interfaces and a suitable working environment.

- Verification exercises should show whether something is designed to meet the requirements and answer the question – "Does it meet the original system specification?"
- Validation exercises should show whether something is effective and answer the question – "Does the system work?"

TIP: The verification and validation activities should be an integral and continuous part of the design process, done as early as possible to allow modifications to be made, and conducted prior to each project gateway.

Step 6.2 - Why? This step is conducted to ensure that the user is provided with usable interfaces and a suitable working environment and that any 'hidden' or unanticipated problems can be realised and managed at a very early stage in the design process. If conducted appropriately and at an early stage, this process can save significant time and effort (and money) over the lifetime of the project.

Step 6.3 - How? There are a number of ways of testing a design, depending on how advanced the design is (e.g. concept, detailed design), what aspects of the design you wish to evaluate or verify, how much time/money you have, and how detailed you want to be, e.g.:

- Check (verify) design features against the original design criteria to ensure compliance
- Evaluate (validate) functions and usability through the application of heuristic ("rule of thumb") evaluation
- Conduct link analysis and/or time-line analysis to evaluate:
    - Traffic patterns and communication links (i.e. for control suite design)
    - Communication and coordination tasks (i.e. for control room design)
- Conduct walk throughs of scenarios or task sequences to ensure designs are suitable for tasks
- Use basic representations of the new design and involve users to test them out, e.g.:
    - Drawings
    - Photographs
    - Mock ups
    - Virtual reality

Whatever method is chosen, a number of steps need to be followed to evaluate a design:

NB. This section focuses on the perspective of evaluating the usability of a computer interface.

TIP: The design of the HMI is probably the stage of development where human factors specialists work most closely with engineers and designers. The role of human factors in relation to HMI design is to provide information regarding the human performance implications of the various design alternatives. This involves the process of human performance testing, analysing and interpreting the human performance data, and conducting in-depth evaluations of suggested designs.

A. Determine the test statements(s)

The test statement(s) determines the focus for testing, the required participants, the test tasks and the measures that will be taken. Test statements can be informed by:

- Characteristics of the intended user group or groups;
- Usability or design goals defined as outputs of the requirements review (Step 1);
- Business or corporate objectives, e.g. product comparisons.

Usability can also be defined by three dimensions which include effectiveness (the accuracy and completeness with which users achieve specified goals as measured by the number or proportion of tasks successfully completed); efficiency (the resources expended in relation to the accuracy and completeness with which users achieve goals as measured in time, money, or effort e.g. key strokes) and satisfaction (the comfort and acceptability of use as measured by attitude scales, perception in relation to enjoyment, fun, frustration and other indicators such as health problems). Once the test statements have been defined in general terms they are redefined in ways that can be measured. The following examples are typical of measurable usability statements[2]:

Example test statements associated with user characteristics

- 80% of users with a high-school (GCSE equivalent) education, 90% of users who have completed high school (A Level equivalent) and 95% of users with a higher education degree will be able to complete task A within 'x' minutes after no more than three attempts (efficiency);
- 90% of all users will be able to complete all tasks with no more than three errors on their first attempt (effectiveness);
- 90% of all users will rate their level of frustration using the interface at less than 3 on a 5-point Likert scale (satisfaction).

Example test statements associated with design goals

- All users will be able to find Y information within 1 minute on 90% of occasions (efficiency);
- All users will be able to complete task B without training. (effectiveness);
- 90% of users indicate that they would recommend interface A as opposed to its competitor to a friend (satisfaction).

Example test statements associated with the Highways Agency's objectives

- All users will be able to complete task C without error using either product (one is more expensive than another, for example) (effectiveness).

[2] It should be noted that these statements will be relevant only when there is some aspect of the HMI that has been designed and communicated, which could be as basic as a sketch or as detailed as a prototype.

- All users will be able to complete task D at least 5 seconds faster using the new product compared to the old (efficiency).
- 70% of users indicate that they would be prepared to pay £xxxx.xx to own this software given their current salary (satisfaction).

B. Choose the task scenarios

Task scenarios are based on the purposes for which the application is to be implemented in relation to the relevant user group(s), the context of its use and with reference to design or usability goals. In addition, three criteria can be used to select test tasks: typicality or representativeness; criticality or risk; and the potentially problematic. Typical tasks are those that a majority of users will execute for the majority of their time. Critical tasks are those for which the consequence of error may be catastrophic. Potentially problematic tasks are those that may be associated with idiosyncratic interface design. For all selected tasks the 'ideal' or optimal task completion sequence should be defined in advance.

C. Select test participants

Test participants should represent the group or groups for whom the application is intended. The objective in participant selection is to reduce variation associated with user characteristics so that results can be interpreted with respect to the user interface rather than being confounded by participant differences, for example, by age, education level, computer experience. Results from the requirements stage (Step 1) can assist in defining important user groups.

D. Test context and materials

Ideally, usability testing should occur in a setting where extraneous variables associated with environmental factors can be controlled, e.g. in a laboratory. Within this environment data collection ranges on a continuum from observer-based manual data collection to data collection via highly instrumented simulators.

E. Data collation and analysis

The purpose of usability testing is:

a) To assess the usability of a product
b) To identify and classify design defects

Thus data is typically collated at two levels of analysis for each scenario or across all scenarios if they are of comparable complexity. At the first level, global indicators of usability are calculated in terms of efficiency (task time), effectiveness (errors, task completion) and satisfaction (results of post-test interviews or surveys). Where research questions specify targets, mean indicators facilitate an assessment of how 'far' the application is from its ideal usability state.

TIP: If you are engaging a supplier/contractor to build a product you may wish to consider implementing the following suggestions to ensure the supplier's design meets the project's human factors requirements:

- Ensure the supplier has an integrated project team that understands and applies human factors principles, e.g. specify human factors best practice standards that the supplier must adhere to (see Appendix J for suggestions);
- Ensure that gateway reviews/fail-gates/system readiness checks include human factors verification and validation activities;
- Consider having a human factors specialist involved on a call-off basis to check that the design is appropriate from a human factors perspective.

Step 6.4 - Outputs? Approved initial design specifications and an improved design.

Step 6.5 - Want more information? Review the following:

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C. & Jenkins, D. P (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate: Aldershot. Available from: http://www.ashgate.com/default.aspx?page=637&calcTitle=1&title_id=8082&edition_id=9199

Rating scales for usability problems. Available at: http://www.useit.com/papers/heuristic/severityrating.html

First principles of interaction design. Available at: http://www.asktog.com/basics/firstPrinciples.html

How to conduct a heuristic evaluation. Available at: http://www.useit.com/papers/heuristic/heuristic_evaluation.html

Formative evaluation. Available at: http://www.usabilitybok.org/methods/formative-evaluation

Heuristic evaluation. Available at: http://www.usabilitybok.org/methods/p275

Step 7 - Develop conceptual design

Step 7.1 - What? The purpose of this step is to develop and compare some concept design ideas, taking on board the human factors and requirements explored so far. The features of the conceptual design of a control room environment that are particularly important to consider from a human factors perspective include:

- Layout of the control room
- Individual workstation layout and dimensions
- Choice of displays and controls
- Information and data flows
- Special security and access controls
- Environmental conditions and control
- Operation and management systems
- Communications and information links

The conceptual design phase is characterised by comparative evaluation of numerous alternative design concepts potentially reaching the design requirements.

Step 7.2 - Why? The development (and evaluation) of concept designs is a key part of the design process and is essential to enable good decisions to be made about the final design specifications.

CASE STUDY: Co-operative Vehicle Highway Systems *(current research)*
Summary Description - The future of motorway driving is expected to see an increase in communication, e.g. electronically between the road and the vehicle. The Highways Agency is researching technology to enable this communication to happen. The ultimate vision is for road signs and information signs to no longer exist in a physical form, and instead be presented to the driver by means of an electronic in-vehicle device.
Human Factors Issues - Human factors play a significant role in the way in which the information is presented to the driver, e.g. text type, size, font, menu structures, quantity of information, alarm format, to reduce distraction and enhance usability. The way in which the RCC operators' tasks or interfaces may change as a result of this proposed change in technology need to be considered, e.g. the different human machine interfaces that might be used to set the message signs, the frequency of the message setting, the way in which the information is presented within the vehicle etc.

Step 7.3 - How? Design specifications should be developed by reviewing the human factors requirements and system requirements explored so far. In addition, design policy, e.g. Highways Agency device selection policy, should be considered.

Step 7.4 - Outputs? These include several design ideas that can be taken forward for evaluation and review to ensure they meet the design needs.

Step 7.5 - Want more information? Review the following:

What is design? Available at: http://www.usabilitybok.org/design/p286

Step 8 - Test the conceptual design

Step 8.1 - What? The conceptual design phase is iterative in nature, therefore several design concepts can be developed and tested against the requirements, then revised, reevaluated, etc. until one or more satisfactory concepts is achieved.

TIP: Lots of compromises will be made during the design and development process. Many aspects need to be considered in the design and each major design decision and compromise should be documented to enable verification and validation.

Step 8.2 - Why? This step is conducted to ensure the design achieves its ambitions. For further explanation, see Step 6.

Step 8.3 - How? There are a number of ways of testing a conceptual design depending on what aspects of the design you wish to evaluate or verify, please see Step 6 for details.

Common methods used to test the concept design ideas include:

- Scenario "talk-throughs"
- Scenario "walk-throughs"
- Interface simulations, for example team working, mock-ups
- Computer visualisation and animation studies
- Standards compliance audit

Step 8.4 - Outputs? Approved concept design specifications and an improved design.

Step 8.5 - Want more information? Review the following:

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C. & Jenkins, D. P (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate: Aldershot. Available from: http://www.ashgate.com/default.aspx?page=637&calcTitle=1&title_id=8082&edition_id=9199

Rating scales for usability problems. Available at:
http://www.useit.com/papers/heuristic/severityrating.html

First principles of interaction design. Available at: http://www.asktog.com/basics/firstPrinciples.html

How to conduct a heuristic evaluation. Available at:
http://www.useit.com/papers/heuristic/heuristic_evaluation.html

Formative evaluation. Available at: http://www.usabilitybok.org/methods/formative-evaluation

Heuristic evaluation. Available at:
http://www.usabilitybok.org/methods/p275

Step 9 - Develop detailed design

Step 9.1 - What? This step enables the development of detailed design specifications that are of sufficient detail to be used to plan the construction of the control centre, and initiate requests for tenders from suppliers. The features of the detailed design of a control room environment that are particularly important to consider from a human factors perspective include:

- Control suite arrangement
- Control room layout
- Workstation layout and dimensions
- Design of displays and controls
- Environmental design
- Operational and managerial requirements

NB. The focus of this part of the guidance is on the detailed design of displays and controls.

TIP: HMI is an essential element contributing to users' performance. Both standardisation and legislation play an important role in the design of HMI at national, European and at international level. However the constant proliferation of new functions and new devices may jeopardise the user performance and system safety when devices are misused intentionally or unintentionally due to their poor HMI.

Step 9.2 - Why? This step is conducted to enable detailed design specifications that are of sufficient detail to be used to plan the control centre's construction and initiate requests for tenders from suppliers.

CASE STUDY: Autonomous VMS Switching from Positional Information of Gritters
(Highways Agency proof of concept completed)
Summary Description - When gritting vehicles were deployed, RCC operators would manually set Variable Message Signs to display a warning to road users that gritting vehicles were in operation. RCC operators tended to blanket cover a large area with the warning when the gritters were operating. Due to the widespread warning, this proved to be a nuisance to drivers who observed the warning signs but saw no gritters. In addition, the drivers would lose trust in the VMS display information and begin to ignore them, the opposite of what is desired by the Highways Agency. The display of "Gritting in progress" messages has now been automated by the use of GPS units attached to each gritting vehicle. The on board GPS unit communicates with the Variable Message Signs so that the signs only display the gritting message when appropriate, i.e. the gritting vehicle is within a predetermined distance of the message sign.
Human Factors Issues - The public's opinion of the reliability of information provided by message signs will increase, therefore, it is likely that road users will modify their behaviour in accordance with the message information displayed. In addition, due to the automation of the messaging, there is no requirement for the RCC operators to spend time on the mundane task of creating "Gritting in progress" messages and subsequently monitoring gritter location and removing messages as necessary, reducing the scope for error.

Step 9.3 - How? The following aspects of the control room design need to be developed in detail, based on the information gathered during the earlier steps, plus additional human factors questions, knowledge and standards:

- **Control suite arrangements** - reconsider the system functions, operator tasks and job roles and use this information to specify the workplaces and other areas within the control suite:
  - What zones/areas are required in the control suite e.g. control rooms, equipment rooms, rest areas, training rooms, offices, maintenance areas etc.?
  - What tasks and jobs are going to be conducted in the different areas of the control suite?
    - How many people will be in each area/room?
    - How many workstations will be required?
    - Where will handovers and team briefings occur?
    - What about filing and storage facilities for frequently required documents/equipment?
    - What space allowances do you need to make for future growth/modification?
  - What interaction/communication/accessibility is required between the different areas of the control suite?
    - Consider who needs to access different areas (e.g. police, RCC staff) and what their needs might be
    - Consider location of the different areas in proximity to each other – would it be useful to co-locate areas? E.g. frequently accessed materials are stored in close proximity to their users
    - Consider how you can reduce travel distances to aid communications and efficiency within the control suite?
    - Is visual contact required between certain areas, e.g. between a control room and a training room?
  - What are the environmental requirements for the control suite?
    - Consider noise levels, lighting, temperature, hazards etc. – what are the requirements and how are these requirements going to be controlled by the design (e.g. floor surface materials used to dampen noise etc.), and by the users (e.g. blinds, accessible thermostats etc.)?
  - What are the security and safety requirements for the control suite?
    - Will special entrance doors/gates/passes be required for access to certain areas?
    - What about other stakeholder groups, e.g. visitors and maintainers – how will their visits/tasks be conducted with maximum security management but minimum disturbance to operations?

- **Control room layout** - review the user characteristics, task requirements and job design features previously considered:
  - What are the primary tasks to be conducted in the control room?
    - What equipment do these tasks require, e.g. workstations, sightlines to wall displays etc.?
    - What are the communication requirements between the different team members in the control room, e.g. how can you best facilitate interactions between operators, which team members should be seated close together?

- What are the other tasks to be conducted in the control room?
  - What equipment do these tasks require, e.g. workstations, sightlines to wall displays etc.?
  - What are the communication requirements between the different team members in the control room, e.g. how can you best facilitate interactions between operators, which team members should be seated close together?
- What are the requirements for circulation of staff within/around the control room and where are the entry and exit points - how can the design be planned to minimise distraction for the control room operators?
- What are the requirements for maintenance access within/around the control room and how can this be done in the least distracting way for the control room operators?
- What storage will be required in the control room and where should this be located?
- Think about emergency scenarios and back up plans as well as normal working arrangements, e.g. will additional equipment be required to be used in the control room?
- How much usable space is there in the control room?
  - How much space is required (ideal world)? A rule of thumb for planning floor-space allocation is to allow $9m^2$ - $15m^2$ per individual working position, although precise requirements should be based on a task analysis.
  - Ensure that any planned structural features do not interfere with the control room layout
  - Consider the requirement for any additional facilities, e.g. changing rooms and relaxation facilities

- **Workstation layout and dimensions** - reconsider the work tasks and characteristics and the equipment/technologies that are required to perform the tasks at the workstation:
  - What are the tasks to be performed at the workstation and which are to be performed most frequently?
  - What equipment technologies are required to perform the tasks? E.g. displays, input devices, communication equipment
  - What other facilities might the operator need access to, e.g. paperwork, hard copy procedures, and therefore space requirements?
  - What are the working postures of the users (e.g. standing, sitting)?
  - What is the anthropometry of the expected user population (e.g. gender, height, physical abilities, reach envelopes, etc.)? Workstation dimensions should accommodate at least 5^{th} to 95^{th} percentile of the user population
  - Design for good viewing of displays etc. first, then check for control activities.
    - Displays requiring frequent or critical monitoring should be positioned in front of the operator in the primary display zone
    - Off-workstations displays (e.g. wall mounted dynamic display screens) should be fully visible from all working positions

TIP: The physical layout of systems/equipments within the facility workspaces is an important factor in safety, operational and maintenance effectiveness. The aim of the equipment layout process is to ensure that personnel are afforded with optimised and sufficient space and appropriate positioning in working arrangements.

- **Design of displays and controls** - reconsider the individual task components, as broken down in the earlier task analysis:
    - What information is needed to be able to undertake each task step?
    - What is the best way of presenting information to the operator?
    - How should this information be organised?
    - How should the information be controlled/input?

  See Appendix K for detailed guidance on the design of displays and controls.

- **Environmental design** - reconsider the working environment of the control room and wider control suite and the tasks being conducted:
    - Temperature and humidity should be comfortable for the tasks being carried out in the area
        - Is the general room temperature and temperature in control room environments between 19° – 22 °C?
        - Is the relative humidity designed to be between 30-70%?
    - Consider ventilation requirements – do not place air conditioning vents where they will provide discomfort to operators e.g. from being in the direct air stream
    - Consider the sound levels in the environment
        - Does the design ensure that noise levels from plant, equipment, etc. are below the statutory levels of daily/weekly exposure and peak sound pressure values?
        - Are noise levels set so that they do not mask voice communication or auditory alarm signals?
        - Is task design and organisation and the environment such that operators are not regularly exposed to intermittent noise?
    - Think about lighting levels – is enough light provided to make details of any task easy to see and to ensure high levels of accuracy?
        - If use is to be made of daylight via windows, consider variations in natural light due to poor weather and if shift-work is required?
        - Are window blinds/louvers required to reduce glare?

TIP: Operators working in a control room environment with a number of illuminated controls and VDU screens may prefer to work at a lower lighting level. This will create a greater contrast between illuminated controls and their background; this will also help to reduce the effect of glare from artificial lights.

- **Operational and managerial requirements** – think about the organisation and support that is needed to be able to perform operations in the control room:
    - What are the working hours and will shift work be required? What shift patterns can be applied to optimise worker wellbeing and performance?
    - What will be the process for recruiting and selecting team members?
    - What training is required, how is training going to be delivered and when?
    - What are the maintenance requirements and how is maintenance going to be conducted efficiently without disturbing operations?

Step 9.4 - Outputs? Detailed design specification that are of sufficient detail to be used to plan the control centre's construction and initiate requests for tenders from suppliers.

Step 9.5 - Want more information? Review the following:

Principles for user centred design. Available at: http://www.usabilitybok.org/design/p287

Where should you put the "Submit" button? Gestalt laws and interface design? Available at: http://www.ixda.org/resources/michael-salamon-where-should-you-put-submit-button-gestalt-laws-and-interface-design

Step 10 - Test the detailed design

Step 10.1 - What? Prior to being used to plan the control centre's construction and initiate requests for tenders from suppliers, the detailed design(s) need to be tested against the requirements, and suitably revised, reevaluated, etc. until a satisfactory detailed design is achieved.

TIP: Test and evaluation are critical features of system design, providing a means for continual refinement during the systems development life-cycle spiral. Simply put, human factors has a key role in assessing the impact of system design features on human performance outputs. These outputs can be objective indicators related to the speed and accuracy of primary and secondary tasks and workload, and subjective outputs related to user satisfaction, acceptance and comfort. Human performance must also be considered in terms of the impact it has on overall system performance and efficiency.

Step 10.2 - Why? This step is conducted to ensure the design achieves its ambitions. For further explanation, see Step 6.

Step 10.3 - How? There are a number of ways of testing a detailed design depending on what aspects of the design you wish to evaluate or verify, please see Step 6 for details.

Common methods used to test the detailed design ideas (specifications) include:

- Scenario "talk-throughs" and "walk-throughs" to conduct task analysis
- Interface simulations, e.g. team working, mock-ups (the further advanced in the design process, the higher the level of fidelity)
- Computer visualisation and animation studies
- Standards compliance audit

When the design is at a detailed stage, human performance testing can typically involve more expensive testing methods. For example, it may be appropriate to build mock-ups and prototypes and test these with representative samples of users to gather useful data for analysis and comparison. While this type of testing is usually expensive and time-consuming, the development of rapid prototyping tools and methodologies have provided some advantage, particularly in human computer interaction. Interface design includes the design of both the physical and cognitive components of the interface. The design, positioning and specification of controls and displays are important issues in relation to the physical design of the interface. Similarly, the cognitive components including information processing aspects, including information content, layout and the modality through which information is conveyed, are important issues related to human task performance.

A primary objective in HMI development is how to design and allocate functionality in order to support the user in the best possible way with regard to the primary and secondary tasks he or she must perform.

Step 10.4 - Outputs? Approved detailed design specifications and an improved design.

Step 10.5 - Want more information? Review the following:

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C. & Jenkins, D. P (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate: Aldershot. Available from: http://www.ashgate.com/default.aspx?page=637&calcTitle=1&title_id=8082&edition_id=9199

Rapid prototyping. Available at: http://www.usabilitybok.org/methods/p312

Rating scales. Available at: http://www.usabilitybok.org/methods/rating-scales

Step 11 – Gather operational feedback

Step 11.1 - What? The purpose of this step is to conduct a post commissioning review to identify successes and shortcomings in the finished design to continue to improve the commissioned design (if possible at this stage) and in order to positively influence subsequent designs.

TIP: Collection of operational experiences from earlier projects or systems is very worthwhile at the start of your project (see Step 1).

Step 11.2 - Why? Despite following best practice and including human factors principles in the design process, there will always be something that can be improved (albeit something smaller and far less costly to fix if you have followed human factors best practice!). Therefore, it is worth identifying and documenting any further improvements that could be made to the design post implementation to ensure that these issues are managed better in future design.

Step 11.3 - How? There are a number of ways of gaining operational feedback, including the application of the methods indentified in the test and evaluation sections, please see Step 6 for details.

Common methods used for obtaining operational feedback include:

- Field observations
- Interviews with users
- Reviewing error trends/operational logs
- Questionnaires with users
- Task analysis

The lessons learnt from this feedback process should be clearly documented so that they can be applied to future projects so that the same mistakes cannot made again.

Step 11.4 - Outputs? An improved operational design (where possible to implement any further changes) and valuable lessons learnt are captured for future projects (including user interface issues, ergonomics problems).

Step 11.5 - Want more information? Review the following:

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C. & Jenkins, D. P (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate: Aldershot. Available from: http://www.ashgate.com/default.aspx?page=637&calcTitle=1&title_id=8082&edition_id=9199

Stanton, N. A., Salmon, P. M., Jenkins, D. P., Walker, G. H. (2010). Human factors in the design and evaluation of control room operations. Taylor & Francis, Boca Raton, USA. Available from: http://www.taylorandfrancis.com/books/details/9781439809914/

References

All business (2010). www.allbusiness.com/manufacturing/computer-electronic-product-manufacturing/4059182-1

Dreamliner (2010). http://www.fea.ru/pictures/boeing_787_Dreamliner_inside.jpg

HSE (2005). Inspectors Toolkit, Human Factors in the Management of Major Accident Hazards, Draft.

ISO 11064-1 (2001). *Ergonomic design of control centres – Part 1: Principles for the design of control centres.* International Standard, International Organization for Standardization.

ISO 13407 (1999). *Human-centred design processes for interactive systems.* International Standard, International Organization for Standardization.

ISO 15288 (2002). *Systems engineering - System life cycle processes.* International Standard, International Organization for Standardization.

Landauer TK (1995). Usefulness and Usability. In Landauer TK: The trouble with computers. The MIT Press, Cambridge, MA, pp 141-168.

Pressman RS (1992). Software Engineering: A Practitioner's Approach. McGraw Hill, New York.

Roelen A, Kinnersly S, Drogoul F (2004). Review of Root Causes of Accidents due to Design. Eurocontrol Experimental Centre, Project Safbuild, EEC Note No. 14/04. Available at: http://www.eurocontrol.int/eec/gallery/content/public/document/eec/report/2004/027_Root_Causes_of_Accidents_Due_to_Design.pdf

Appendix A – Best Practice Design and Development Process

A1 The human factors approach to design

There are a number of approaches to system development. Traditionally the approach has been technology centred and gives only secondary consideration to human needs. Issues pertaining please change pertaining for another word to the task or environmental factors that might affect performance are largely overlooked. Development of technological capabilities and computer automation has created the need for new approaches to system design. The systems development lifecycle should be an iterative, continuous improvement process, which includes the principles of human-centred design, illustrated in Figure 5. The systems development lifecycle fits into the wider lifecycle process, particularly the concept and development stages, but with additional further input into the earlier and subsequent stages of design and development, as documented in Table 1.

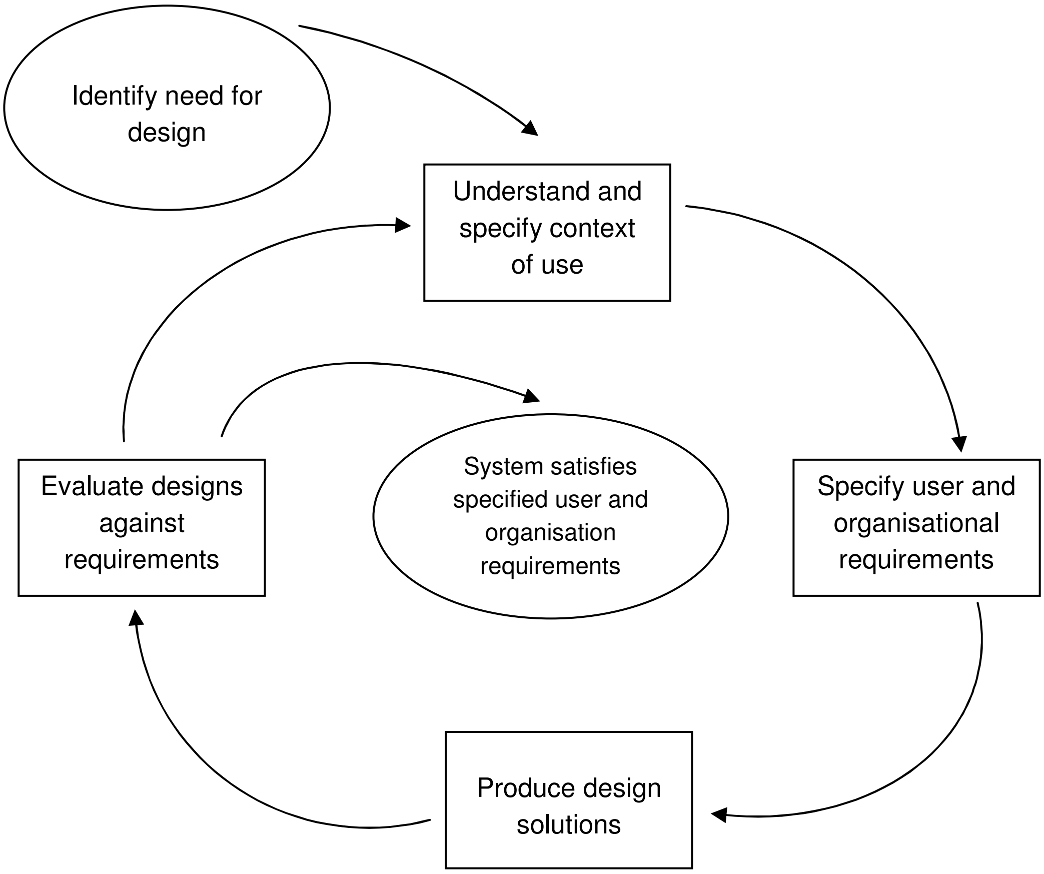


Figure 5 ISO 13407 System Lifecycle Processes (from ISO 13407 (1999)) that should be followed in design.

Table 1 The 6 stages of the general lifecycle process with human factors inputs (after ISO 15288 (2002)).

Stage	Key Purpose	Commentary on outputs related to best practice human factors
Concept	Identify stakeholders' needs Explore concepts Propose viable solutions	Stakeholder requirements capture Allocation of function Substantiation of feasibility Concepts of operation Usability specifications for HMI Outline design solutions
Development	Refine system requirements Create solution description Build system Verify and validate system	Interface specifications Operating instructions Training manuals for operators Prototype of system is built Summative and formative evaluation
Production	Produce systems Inspect and test	*Continuous evaluation to assure user requirements are attained and that operator performance is not negatively affected*
Utilisation	Operate system to satisfy users' needs	
Support	Provide sustained system capability	
Retirement	Store, archive or dispose of the system	*Continuous evaluation*, plus repeat of Concept and Development stages as required if new design/approach is required

A2 The 'rules' of human factors

The fundamental and consistent philosophy is to ensure that the human element, or user, is of principle concern within the design process. This approach promotes the inclusion of user (and operator) needs, capabilities, limitations and goals into the design process. The human factors approach is characterised by the following 'rules':

- The active involvement of users to gain a clear understanding of user and task requirements
- Appropriate allocation of function between the human and technology
- The use of an iterative design process
- The utilisation of a multi-disciplinary design team

TIP: The earlier that consideration is given to human factors and ergonomics in the design process, the better the results are likely to be. However, it's important to use human factors and ergonomics expertise appropriately by involving people with knowledge of the working processes involved and the end user. For that reason, user involvement is key to designing operable and maintainable systems.

TIP: Poor design contributes to work-related ill-health and has been found to be a root cause of accidents – well known examples include:.the Herald of Free Enterprise, Chernobyl and Ladbroke Grove disasters.

It must be emphasised that the human factors approach has many wider benefits (in addition to those documented in Section 1.2) including:

- Improved user engagement and uptake, central to project success
- Marketing and branding success
- Improved efficiency in development and implementation processes
- Reduced personnel costs (training and recruitment)

CASE STUDY: To date the launch of the 787 Dreamliner is the most successful commercial airplane launch the world has ever witnessed. This example demonstrates the application of several components of a human factors approach.

Since the launch, orders and commitments have been placed for more than 400 airplanes from five continents. Firm orders are valued at $59 billion at current price lists. The creative alliance formed by Teague and Boeing effectively demonstrates the benefits of fully collaborative, open-source design processes.

Source: Dreamliner 2010

The design team comprised designers, engineers, sales and marketing, differentiation and manufacturing representatives as well as partners and vendors. To ensure that all areas were represented in tandem, the team held meetings over a period of five years. The team was bought together to forge new ideas, to perfect existing concepts, to discuss findings and to engage in discussions. The Dreamliner was inspired by the preceding design, the Sonic Cruiser which was unveiled by Boeing in 2001.

The team were compelled to consider passengers and their needs, requirements of pilots, flight attendants, mechanics, modifications engineers, leasing companies and almost anyone who would come into regular contact with the new airplane. The researchers asked consumers to design their vision of an ideal travel experience and enumerate elements of an aircraft interior that would best allow that experience. Empirical and qualitative research performance at the Passenger Experience Research Centre (PERC) offered a scale model of the airplane's interior cabin to test and rapidly iterate new ideas with the public in regard to passenger preference for cabin width, seat arrangement and stowage, etc. The team developed concepts around individual travellers, anticipating what their needs and wants would be. For the first time ever the unarticulated needs of the flying public were embodied in the interior design.

Source: All business 2010

A3 The design of control centres

The role of the operator in a control centre can be very demanding. The consequences resulting from inappropriate operator action in control rooms, such as acts of omission, commission, timing, sequencing and so on, can be potentially disastrous.

The design of a control centre is generally complex, involving multiple clients, conflicting objectives, diversity of new technologies and possible solutions, ambitious schedules, first time applications and inexperienced personnel.

TIP: For many project teams designing control rooms, human factors have been considered only towards the end of the program, a delay that can cause problems that are not easy to resolve. Therefore, the earlier you consider human factors, the greater the cost saving.

Similarly to other aspects of control room development, human factors need to be considered systematically if unproductive work is to be avoided, and the initial approach needs to think about the general requirements followed by specific, detailed needs.

ISO 11064 (Ergonomic Design of Control Centres) was developed specifically to describe the best practice human factors process for the design of control centres and the detailed requirements associated with specific elements of a control centre (e.g. layout/dimensions of workstations, displays and controls, environmental requirements). Part 1 of ISO 11064 has been prepared to set up a generic framework for applying requirements and recommendations relating to ergonomic and human factors in designing and evaluating control centres with the view to eliminating or minimizing the potential for human errors. Part 1 of ISO 11064 lists principles for the ergonomic design of control centres, which are to be conducted across the different phases of the project lifecycle. This best practice framework for design and development is summarised in Figure 6 and is the basis for the Section 3 guidance.

In order to understand the characteristics of human performance for the purposes of interface design there are many sources of information including: handbooks, best practice manuals, standards and guidelines; and also a great many scientific theories, methods and models of human performance that can be used to predict the effects of designs in terms of human performance variables. Therefore, it is not possible to document all of these in this guidance document. However, relevant information sources have been identified and key approaches and best practice summarised.

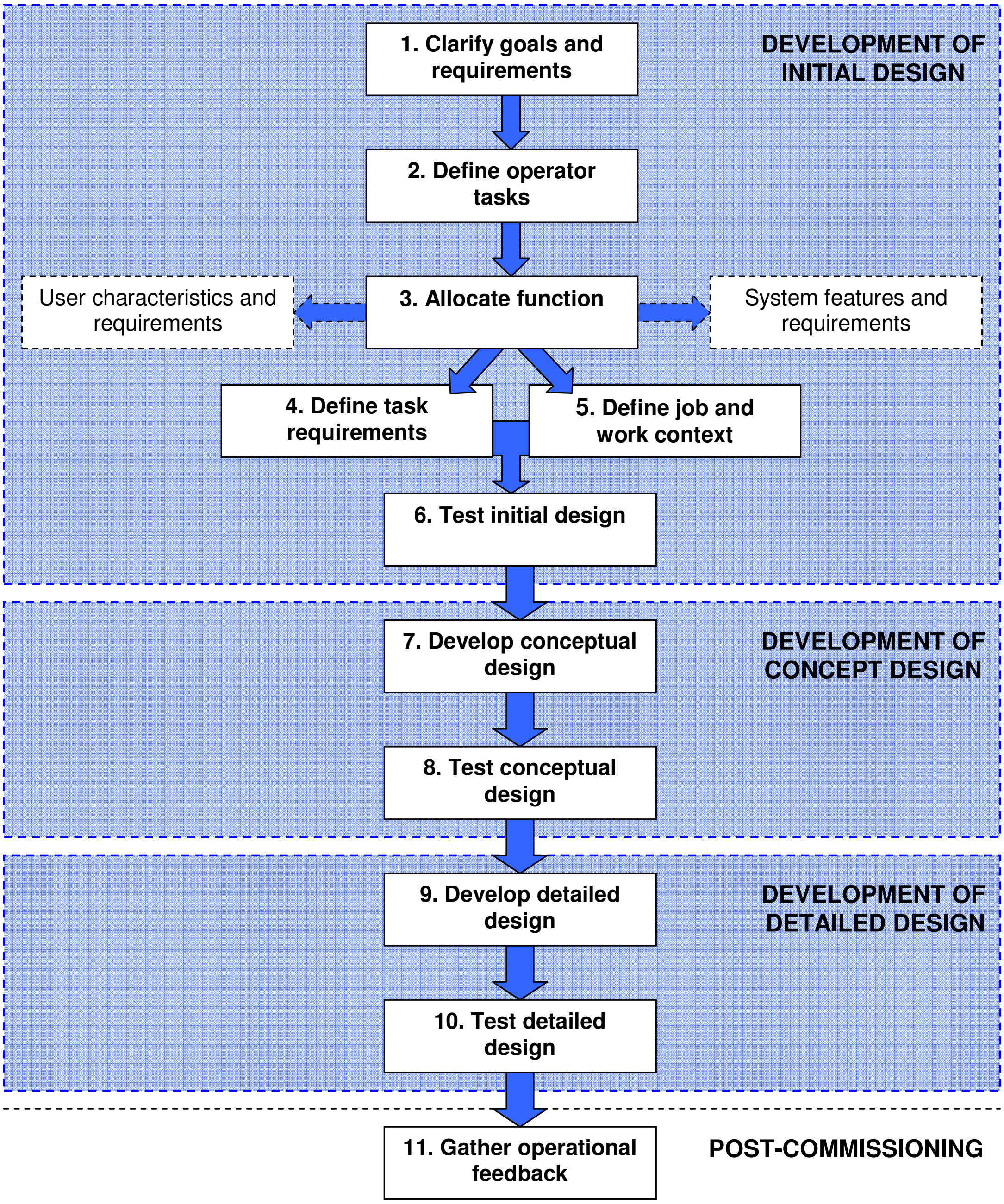


Figure 6 Ergonomic design process for control centres (after ISO 11064-1).

Appendix B – How do I seek specialist Human Factors advice?

- Contact the Highways Agency HUMAN FACTORS CHAMPIONS via email:

  human.factors@highways.gsi.gov.uk

  - Provide a summary of your project and its intended outcome
  - Provide a copy of the completed Human Factors Checklist to demonstrate the specific areas where you may require support

- The human factors champions will be able to advise you on the Human Factors Specialists that are available to support you via Highways Agency framework agreements.

Appendix C – Justification for not seeking advice from a Human Factors Specialist

If your responses to the questions in the flow chart on page 11 result in the recommendation that you should seek advice from a human factors specialist and you do not follow this recommended course of action, you need to provide a reason why and lodge this intention as per the instructions below:

- Review the checklist (on page 13-15) and review the relevant sections of the guidance as suggested in the checklist;
- Complete the form below;
- Lodge a copy of the completed form with the project ICF, for audit purposes;
- Revisit this flow chart (and associated checklist) at each project stage boundary to reconsider need for specialist human factors input and complete an additional form for the project file.

JUSTIFICATION FOR NOT SEEKING ADVICE FROM A HUMAN FACTORS SPECIALIST:

Your name	
Your role on project	
Name of project manager (if different)	
Name/ID of project	
Stage boundary/gateway	
Please justify why your project does not require expert input from a Human Factors Specialist	

Your signature: **Date:**

Appendix D – Justification for seeking advice from a Human Factors Specialist

If your responses in the flow chart on page 11 result in the recommendation that you should seek advice from a human factors specialist and you follow this recommended course of action, you need to lodge this confirmation as per the instructions below:

- Review the checklist (on page 13-15) and review the relevant sections of the guidance as suggested in the checklist;
- Complete the form below;
- Lodge a copy of the completed form with the project ICF, for audit purposes;
- Revisit this flow chart (and associated checklist) at each project stage boundary to reconsider need for specialist human factors input and complete an additional form for the project file.

JUSTIFCATION FOR SEEKING ADVICE FROM A HUMAN FACTORS SPECIALIST:

Your name	
Your role on project	
Name of project manager (if different)	
Name/ID of project	
Stage boundary/gateway	
Please comment on why/which parts of your project require expert input from a Human Factors Specialist	[insert step numbers of the guidance that were deemed to be relevant based on your responses to the checklist questions]

Your signature: **Date:**

Appendix E – No requirement to seek advice from a Human Factors Specialist/review Human Factors Guidance

If your responses to the questions in the flow chart on page 11 result in no requirement to seek advice from a human factors specialist (and you follow this course of action), please lodge this intention as per the instructions below:

- Review the checklist (on page 13-15) and review the relevant sections of the guidance as suggested in the checklist;
- Complete the form below;
- Lodge a copy of the completed form with the project ICF, for audit purposes;
- Revisit this flow chart (and associated checklist) at each project stage boundary to reconsider need for specialist human factors input and complete an additional form for the project file.

NO REQUIREMENT TO SEEK ADVICE FROM A HUMAN FACTORS SPECIALIST/REVIEW HUMAN FACTORS GUIDANCE:

Your name	
Your role on project	
Name of project manager (if different)	
Name/ID of project	
Stage boundary/gateway	
Justification	The human factors checklist was completed on [INSERT DATE] and the responses provided suggest that there is no requirement, at this stage, to review the Human Factors Guidance or to seek specialist Human Factors advice for the project.

Your signature: **Date:**

Appendix F – Justification for reviewing Human Factors Guidance

If your responses in the flow chart on page 11 result in the recommendation that you should review the Human Factors Guidance and you follow this recommended course of action, you need to lodge this confirmation as per the instructions below:

- Review the checklist (on page 13-15) and review the relevant sections of the guidance as suggested in the checklist;
- Complete the form below;
- Lodge a copy of the completed form with the project ICF, for audit purposes;
- Revisit this flow chart (and associated checklist) at each project stage boundary to reconsider need for specialist human factors input and complete an additional form for the project file.

JUSTIFCATION FOR REVIEWING THE HUMAN FACTORS GUIDANCE:

Your name	
Your role on project	
Name of project manager (if different)	
Name/ID of project	
Stage boundary/gateway	
Please comment on why/which parts of the Human Factors Guidance were relevant to your project at this stage	[insert step numbers of the guidance that were deemed to be relevant based on your responses to the checklist questions]

Your signature: **Date:**

Appendix G – Justification for not reviewing the Human Factors Guidance

If your responses in the flow chart on page 11 result in the recommendation that you should review the Human Factors Guidance and you do not follow this recommended course of action, you need to provide a reason why and lodge this intention as per the instructions below:

- Review the checklist (on page 13-15) and review the relevant sections of the guidance as suggested in the checklist;
- Complete the form below;
- Lodge a copy of the completed form with the project ICF, for audit purposes;
- Revisit this flow chart (and associated checklist) at each project stage boundary to reconsider need for specialist human factors input and complete an additional form for the project file.

JUSTIFICATION FOR NOT REVIEWING THE HUMAN FACTORS GUIDANCE:

Your name	
Your role on project	
Name of project manager (if different)	
Name/ID of project	
Stage boundary/gateway	
Please justify why you do not need to review the Human Factors Guidance for your project	

Your signature: **Date:**

Appendix H – Attributes of a 'context of use description'

A context of use description needs to contain details about the following aspects of use, when known (**NB**. This list is not exhaustive and may not be relevant to all situations):

Statement of operational goals		
Purpose/objectives of system		
Users	**Tasks**	**Equipment**
User types - *Primary* - *Secondary and indirect users* Skills and knowledge - Product skill/knowledge - System skill/knowledge - Task experience - Organisational experience - Level of training - Qualifications - Language skills Personal attributes - *Age* - *Gender* - *Physical capabilities* - *Physical limitations and disabilities* - *Intellectual abilities* - *Attitude* - *Motivation*	Task breakdown Task name Task frequency of use Task duration Frequency of events Task flexibility Physical and mental demands Task dependencies Task output Risk resulting from error Safety critical demands	Basic description - *Product identification* - *Product description* - *Main application areas* - *Major functions* Specification - *Hardware* - *Software* - *Materials* - *Services*
Environment		
Organisational environment	Technical environment	Physical environment
Structure - *Hours of work* - *Group working* - *Job function* - *Work practices* - *Assistance* - *Interruptions* - *Management structure* - *Communications structure* Attitudes and culture - *Organisational aims* - *Industrial relations* Job design - *Job flexibility* - *Performance monitoring* - *Performance feedback* - *Pacing* - *Autonomy* - *Discretion*	Configuration - *Hardware* - *Software* - *Reference materials*	Workplace conditions - *Atmospheric conditions* - *Auditory environment* - *Thermal environment* - *Visual environment* - *Environmental instability* Workplace design - *Space and furniture* - *User posture* - *Location* Workplace safety - *Health hazards* - *Protective clothing and equipment*

Appendix I – Example of an Issues Log

The human factors Issues Log should be used to track all human factors issues/actions for the project. Each of the issues identified below, and those that emerge as the design matures, should be addressed through appropriate and commensurate human factors activities and ergonomic input to the design process. Below is an example Issues Log for the design of a new control room interface that enables operators to open the hard shoulder for use as a running lane:

ID	Date / step identified	Date/ step last updated	Issue owner	Issue	Mitigation/ actions	Status of action	Date/ step for issue revisit
1	1 Jan 2010 Step 1	1 Feb 2010 Step 2	A. Person	It is currently assumed that the RCC operators will be responsible for managing all hard shoulder monitoring activities. However the number of staff required for each task has not yet been defined.	Task analysis needs to be undertaken to define the tasks and so that the roles and responsibilities for the different control room tasks need to be carefully defined, substantiated through the task analysis and user requirements and ultimately reflected in procedures and training and the plant safety management arrangements.	Ongoing issue	1 March 2010 Step 3 and 1 April 2010 Step 4
2	1 Jan 2010 Step 1	1 Jan 2010 Step 1	A. Person	There needs to be a general ergonomic consistency of all user-interface, control and display design and information presentation.	Design in accordance with best practice standards and appropriate task analysis output to ensure a consistency across all user interfaces, controls and displays is achieved throughout the control room to minimise potential for operator errors to occur.	Ongoing issue	1 April 2010 Step 4 and 1 July 2010 Step 7
3	1 Jan 2010 Step 1	1 Jan 2010 Step 1	A. Person	Displays should present cues for operator actions as readily interpretable signs and also	Design displays in accordance with best practice standards and based on task analysis output to ensure they are simple and easy to understand and	Ongoing issue	1 April 2010 Step 4

				indicate any precondition for their validity and feedback success.	diagnose.		and 1 July 2010 Step 7
4	1 Jan 2010 Step 1	1 Jan 2010 Step 1	A. Person	Design of control room workstations must ensure that operation of a control does not obscure any corresponding display and visual field of the operator over the controlled equipment and that simultaneous control activation and viewing is possible without awkward postures.	Design control stations and consoles in accordance with human factors best practice to ensure adequate viewing is provided over operations. human factors review of technical specifications to ensure adequate visual access to process.	Open issue	1 July 2010 Step 7
5	1 Jan 2010 Step 1	1 Jan 2010 Step 1	A. Person	Software displays and controls should enable operators to be able to select and maintain safety information, specific alarms and critical parameters without having to select different windows or such information being obscured/marked or 'flooded' with other information. Alarm/safety information should always be on display to ensure operator has immediate access to safety significant system information.	Human factors review of design technical specifications. Review of procedures to ensure the ability to select and maintain safety information is adequately defined and supported. Design will follow requirements of project human factors style guide and ISO standards. Task analysis to inform specific requirements and any trade offs for control room operations.	Ongoing issue	1 April 2010 Step 4 and 1 July 2010 Step 7

Appendix J – Where to find further Human Factors information: standards and associated areas of application

Reference	Year	Standard or Guidance	Workplace	Workspace	Environment	Displays	Controls	Input Devices	Communication	Alarms	HMI	Labelling	Colour	General human factors
BS EN 614 – Safety of Machinery - Ergonomic Design Principles Part 1 – Terminology and General Principles	1995	Standard		✓	✓	✓	✓			✓			✓	✓
BS EN 614 – Safety of Machinery – Ergonomic Design Principles Part 2: Interactions between the design of machinery and work tasks	2000	Standard												✓
BS EN 981 – Safety of Machinery – System of auditory and visual danger and information signals	1997	Standard				✓				✓			✓	
BS 7517 – Nuclear Power Plants – Control Rooms – Operator Controls	1995	Standard		✓	✓	✓	✓				✓	✓	✓	
EN ISO 11064 - Ergonomic design of control centres – Part 1: Principles for the design of control centres	2001	Standard												✓
EN ISO 11064 - Ergonomic design of control centres – Part 2: Principles for the arrangement of control suites	2001	Standard	✓	✓	✓				✓					✓

Reference	Year	Standard or Guidance	Workplace	Workspace	Environment	Displays	Controls	Input Devices	Communication	Alarms	HMI	Labelling	Colour	General human factors
EN ISO 11064 – Ergonomic design of control centres – Part 3: Control room layout	2000	Standard	✓	✓	✓	✓								✓
EN ISO 11064 – Ergonomic design of control centres – Part 4: Layout and dimensions of workstations	2004	Standard		✓		✓	✓							
EN ISO 11064 – Ergonomic design of control centres – Part 5: Displays and controls	2008	Standard				✓	✓							
EN ISO 11064 – Ergonomic design of control centres – Part 6: Environmental requirements for control centres	2005	Standard			✓									
EN ISO 11064 – Ergonomic design of control centres – Part 7: Principles for the evaluation of control centres	2006	Standard	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BS EN 894 – Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 1: General principles for human interactions with displays and control actuators	1997	Standard												✓

Reference	Year	Standard or Guidance	Workplace	Workspace	Environment	Displays	Controls	Input Devices	Communication	Alarms	HMI	Labelling	Colour	General human factors
BS EN 894 – Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 2: Displays	1997	Standard				✓								
BS EN 894 – Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 3: Control Actuators	2000	Standard					✓							
BS EN ISO 6385 – Ergonomic principles in the design of work systems	1991	Standard	✓	✓	✓	✓	✓							
BS 5395 Stairs, Ladders and Walkways	2000	Standard	✓	✓										
BS 4533 Luminaries - Specification for luminaries for emergency lighting	1990	Standard			✓									
BS 6003 Specification for coding of indicating devices and actuators by colours and supplementary means	1997	Standard				✓	✓					✓	✓	
BS 3693 Recommendations for the design and scales and indexes on analogue indicating instruments	1992	Standard				✓								

Reference	Year	Standard or Guidance	Workplace	Workspace	Environment	Displays	Controls	Input Devices	Communication	Alarms	HMI	Labelling	Colour	General human factors
BS 10075 Ergonomic principles related to mental workload	2000	Standard								✓				✓
BS 9921 Ergonomic assessment of speech communication	1996	Standard							✓					
BS 60447 Man-Machine Interface Actuating principles	1994	Standard					✓	✓			✓			
BS 7179 Ergonomics of design and use of visual display terminals in offices	1990	Standard				✓								
BS EN ISO 8995 Pt 1 Lighting of indoor work places	2002	Standard			✓									
BS 13407 Human-centred design processed for interactive systems	1999	Standard												✓
ISO 11428 Ergonomics Visual Danger signals	1996	Standard								✓		✓	✓	
ISO 11429 Ergonomics System of auditory and visual danger and information signals	1996	Standard							✓	✓		✓	✓	
NUREG-0700, Revision 2, - Human-System Interface Guidelines U.S. Nuclear Regulatory Commission	2002	Guidelines	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Reference	Year	Standard or Guidance	Workplace	Workspace	Environment	Displays	Controls	Input Devices	Communication	Alarms	HMI	Labelling	Colour	General human factors
Human Factors in the Design and Evaluation of Air Traffic Control Systems (Cardosi and Murphy)	1996	Guidelines	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DEF STAN 00-250 Part 0 (2008) – Human Factors Integration	2008	Guidelines												✓
DEF STAN 00-250 Part 1 (2008) – Overarching People-Related Requirements	2008	Guidelines												✓
DEF STAN 00-250 Part 2 (2008) – Particular People-Related Requirements	2008	Guidelines												✓
DEF STAN 00-250 Part 3 (2008) – Technical Guidance	2008	Guidelines	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DEF STAN 00-250 Part 4 (2008) – Human Factors Integration Methods, Tools and Techniques	2008	Guidelines	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Human Factors in Engineering and Design (Sanders and McCormick)	1992	Guidelines	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
The Ergonomics of Workspaces and Machines (Corlett and Clark)	1995	Guidelines	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Reference	Year	Standard or Guidance	Workplace	Workspace	Environment	Displays	Controls	Input Devices	Communication	Alarms	HMI	Labelling	Colour	General human factors
People in Control – Human Factors in Control Room Design (Noyes and Bransby)	2001	Guidelines								✓				✓
Bodyspace – Anthropometry, Ergonomics and the Design of Work (Pheasant)	1986	Guidelines	✓	✓		✓	✓	✓						✓
Ergonomics at Work – Human Factors in Design and Development (Oborne)	1995	Guidelines	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Human Factors in Alarm Design (Stanton)	1994	Guidelines								✓				
Human Factors in Auditory Warnings (Stanton and Edworthy)	1999	Guidelines								✓				
HS(G)48 Reducing Error and Influencing Behaviour (HSE)	1999	Guidance												✓

Appendix K – Guidance on the design of displays and controls

HMI Design Guidelines (Controls)

- The HMI should be designed to be 'error tolerant'. Single errors made by operators (e.g. operation of wrong control/push-button, the misreading of a display and subsequent action following this) should, as far as possible, not lead to a major error consequence
- Feedback should be provided when a control has been successfully actuated (audible, tactile, visual) with minimal perceivable delay unless a time delay is avoidable where intermittent feedback should be provided
- The process of designing the layout of HMI workstations and control panels should involve the definition of control actions required, information requirements, control and instrument types, and arrangements of these on the available panel surfaces, applying labels, demarcations and coding techniques to support operator task performance. This information, at least in part, is best delineated from task analysis

HMI control panel layout

Panel layout design relies heavily upon information generated from task analysis as this will affect how panels are structured in terms of display/control relationships, information presentation and feedback, grouping etc.

- The basic criteria that need to be considered when situating controls and displays are:
    - Duration
    - Importance
    - Frequency
    - Visibility and feedback
    - Clear associations between a control action and corresponding equipment and/or display response
    - Response time
- HMI/control panels should be located for easy access within the workspace. Panels should be easily accessible but of out main circulation routes to reduce the possibility of inadvertent operation of controls
- The design and position of panels should support maintenance as well as normal operation and allow sufficient space around HMI/control panels for maintenance activities

Control devices

- Task analysis should be used to inform the selection of control devices, the decision should be made balancing the following:
    - Function of control
    - Requirements of the control task – safety significant, coarse, fine control, precision required
    - Information required to guide the operator
    - Requirements imposed by the workspace
    - Consequences of error

Once this information has been obtained, the following guidelines should be applied:

Control Arrangements and Grouping

- Control devices should be designed so that they can be operated by the 5th through to 95th percentile of the target population in comfort, without requiring adoption of forced postures
- Control heights should be suitable (940mm -1500mm for general use; 940mm - 1270mm for precise/frequent use)
- There should be sufficient space in front of equipment for crouching, for any controls that are required to be located below this height
- Controls should take into account clothing limitations and operating environments
- Controls should be designed so that they do not place unacceptable demands on operators in terms of speed and accuracy of operation and forces required to operate them. They should be able to be operated with the least possible movement relative to function and operating resistance
- Most controls can be operated equally well with both hands. However, controls that demand accurate, and/or fast, operation should either be capable of being operated by either hand
- Consider the position of the operator – seated, standing; squatting needed to operate control devices, consider need for adjustability of controls. For accurate operation, prefer seated. The body movements required to operate controls (or displays) should not cause discomfort
- Foot pedals should be considered only if no other means for control is applicable
- Controls essential for system safety and critical tasks should be centrally mounted within easy reach
- Controls that attain high assessment scores for frequency, duration and importance should be centrally mounted
- Emergency stops shall be clearly visible and identifiable
- Emergency stops should be consistent in location, easily accessed/reached, and located in front of the operators' normal positions to ensure easy and non-hazardous operation
- The emergency stop function shall be available at all times
- When the emergency stop function is actuated, the system shall remain in that state until it is reset manually
- The space between controls (and displays) needs to be optimal in order to ensure efficient operation. Too much space may demand unnecessary movements, while too little space may cause accidental operation. Individual controls should be adequately separated to prevent confusion/inadvertent initiation, and be easily and accurately operated (13mm edge to edge, increased if gloves are worn). This distance may need to be increased or use other means of ensuring the correct control/pushbutton is identified before it is operated if the inadvertent operation would have a significant consequence. The operator may fail to notice the error in selecting a control, particularly if he/she is hurrying or stressed by an abnormal situation

Other means of preventing inadvertent operation are as follows:

- Control/push-button operation may be interlocked by software to disable it and thus prevent operation at the wrong time (beware implications of software reliability claims and its use in safety-related systems)

- Push-buttons can be recessed or have a covering flap (when the flap is in the open position it should interfere with other controls or displays). Ideally, the cover should return to its start position if not manually held open
- Use of another type of control may be necessary if it proves to be very important to prevent operation at the wrong time e.g. 'pull and twist' action; or the push-button/control may need to be physically locked (key-switch) or 'dead-mans handle' design

Control Devices – Direction of Movement

- How a human-machine operates and its controls should utilise the natural relationships of control movement habit patterns, which are consistent from person to person without special training
- As far as possible, the necessary action of a control should be correlated to the required final effect, according to the operating direction (movement) of a control, user expectations or to the relative location of controls
- Under stress operators can be expected to revert to population stereotypes even of they have been trained to act in a different way
- The function, movement and position of controls and display elements should correspond to what the operator expects

Control and Display Association

- Layout of HMI/control panels should support human performance to reduce confusion between different controls/displays. Devices can be grouped by importance, frequency of function, or sequence of use
- Associated sets of controls should be arranged according to their priority e.g. highest priority – top/left; lowest priority – bottom/right. The grouping principles shall be consistent across the facility and with the user's mental model of the system established by task analysis and training. The association between controls and displays is important and the general guidelines that should be followed are:
  - Locate all controls and push-buttons for easy access by operators
  - Controls that are functionally related should be grouped together unless task analysis indicates that a more task-oriented grouping would better reflect and support control usage
  - Control devices shall be logically grouped according to their operational of functional correlation, for controlling a process, machine or equipment. Grouping principles shall be consistently applied throughout the facility. The arrangement and grouping of controls should be structured to minimise the probability of incorrect actuation arising from human errors
  - Where controls are grouped, ensure good separation between individual controls/push-buttons and good labelling/coding, to prevent inadvertent operation. Functionally related controls and displays should be grouped together, with groups separated by minimum 50mm
  - Sequentially used controls/displays should be positioned in order/sequence (use the following sequence – left to right, or top to bottom (consider the nature of the use, e.g. if they are only used for maintenance, lay out appropriately for this and not normal operations). This reduces errors and increase speed of performance

- All controls having sequential relations, or associated with a particular function or operation, or which are operated together, should be grouped together along with their associated displays/indications
- If a control is adjacent to the instrument it controls or other displays, it should be located so that the operator's control hand/arm normally used for setting does not obscure the indicator or other displayed information
- Warning lights should be integral with levers, switches or other control devices by which the operator is to take action
- It should be ensured that there is clear line of sight between a control and corresponding display which is intended to provide indication of the correct control action (if actual direct visual access over the task/equipment being controlled is not possible)
- Place controls and their associated displays so that they are near each other and it is clear which relate to each other
- The operation of a control should produce a corresponding display response, which should be consistent, predictable and compatible with operator expectations and the direction of associated system responses. Ensure that the results of control actions are as the operator expects e.g. the operator would expect an alarm light to extinguish following reset operation
- Verification that an operator action has been accepted by the system should be presented to the operator without unnecessary delay. If execution is prolonged, the operator should be informed of this or preliminary feedback provided
- The feedback provides to the operator should confirm that the control action has achieved its desired system/equipment response/end state and not simply that it has been demanded

HMI Design Guidelines (Displays and Alarms)

- A display is a device that presents information to the operator. Examples of HMI displays include: indicators, enunciators, gauges, digital counters, computer monitors, video display units, CCTV, etc.
- Display devices may have single or multiple display functions. A single function device presents information in a fixed format e.g. an indicator that presents a single variable and a VDU that presents a single page containing a set of variables. A multiple-function device contains a set of display pages through which the user navigates to access desired information

Displaying HMI information

- The organisation (e.g. grouping) of displayed information is important for supporting prompt recognition and comprehension of plant status to operators. Related information may be organised by the physical arrangement of single and multiple-function display devices. For example, functionally related individual display devices may be grouped together in the same portion of a console or panel. Within a multiple-function device, the information is also organised by its placement within a display page and by the arrangement of display pages

Design to support task requirements

- Positioning of displays should consider the context of use:
    - Importance of displayed information, in terms of safety, overall objective and relative to other displays
    - The sequence in which information may be required during normal and fault/emergency conditions
    - Frequency with which information should and can be viewed
    - The information provided should be appropriate and sufficient to perform the task and make unambiguous diagnosis

Display Screen Visual Access

- The minimum viewing distance for displays should be 500mm. The maximum viewing distance should be appropriate for the size, contrast, lighting, and task precision required. Precise requirements should be obtained from task analysis
- Surfaces/screens should be free from disabling and discomfort glare or reflections that may reduce luminance contrast and interfere with the task
- Display heights should be 940mm - 1800mm for general use, 1150mm-1530mm for precise/frequent use

Display Information Presentation Requirements

- Displays are rarely used in isolation and therefore the design of appropriate layouts for groups of displays can be as important as the design of each separate display. There may be grounds for integrating more than one display or even integrating information from several displays
- Displays and information they present should be arranged so that they are easy to use in combination by grouping items:
    - Where displays (or corresponding controls) are used in a fixed sequence, they should be arranged in that sequence. This arrangement helps the operator to remember the sequence and it decreases the response time and leads to fewer errors
    - Where displays (and control) are not operated in a fixed sequence the following arrangements for grouping should be applied:
        - Displays (and controls) used for safety functions and emergencies should be designed and positioned so that they can be used quickly, easily and accurately. The safety important and frequently used items should be located/displayed in the most accessible positions
        - Items in sub-sequences are placed together
        - Functionally related items are placed in groups with visual and spatial separation from other items
        - Displays for monitoring safety parameters should continuously display this information
        - Information should be presented on a single display or display page unless this is very cluttered, (if trade off is required err towards completeness of information)
- Special consideration needs to be given to the type and amount of information presented to and processed by the operator:

  - Information should be presented so that it consistent across all interfaces and can be recognised (rather than trusting to recall)
  - Information presentation should be offered to reduce complexity
- In check reading, the accuracy of such readings may be enhanced if the pointers of the displays are arranged into a pattern so that it is easy to determine if one or several pointers deviate from the normal patterns
- Safety significant parameters that may be indicated by small changes in display status should be avoided as these place excessive vigilance requirements on operators
- Safety function displays should allow operators to comprehend a change in safety status in a matter of seconds
- The sampling rate for displayed safety functional information should be consistent with the operator's needs for performing tasks. There should be no meaningful loss of information in the presented data
- Information and data should be displayed in a consistent and concise format and this should be segregated from other information
- The display's response to fault conditions and transients should keep the operator informed of current plant status
- Where appropriate, magnitudes and trends in safety related variables should be displayed to aid diagnosis. Sufficient resolution in time and magnitude should be provided to ensure that rapidly changing variables can be observed and accurately interpreted
- Displayed information should be reliable and failure indications should be used to inform the user of the presence of failures or malfunctions
- Narrow spatial location between displays or integral displays may help parallel processing (performance of several operations simultaneously). If a system requires parallel processing, the designer should consider the use of displays made for different senses
- Displays should be placed within the operator's field of vision (ideally +/- 30 ° of horizontal line of sight)
- Important information in terms of safety and frequently consulted information should be located in the central areas most frequently scanned by the eye and presented in a clear, convenient and accessible way
- Information should be presented in the necessary form and so that it does not require further transposing, calculation or analysis

VDU/Computer Screens

- VDU displays should be designed such that they are adjustable in position, contrast, brightness, with no perceivable flicker and good colour combinations
- Flashing alerts should be synchronous and at a single rate, 2-3Hz, and reserved for important information
- The overall screen (menu) structure should be hierarchical where possible, and broad rather than deep (maximum 5 levels), with a simple means to move up, down and across
- Each display should contain complete information for an operator decision
- Each screen should have a unique and informative title to aid user navigation
- Screen formats should be consistent, with irrelevant detail avoided
- Where relevant, process overview displays should be provided to operators to avoid attentional capture and to maintain situational awareness

- Important information and alarm information should not be lost when navigating between screen levels

CCTV

- Viewers should be able to adjust the image (focus, brightness, contrast, screen position and angle) to present adequate detail for the task (the image should be stable and upright)
- Positioning of CCTVs should be examined to ensure all required information is obtainable
- An adequate view of the task should be presented
- Access for regular cleaning and maintenance is required to maintain image quality
- If simultaneous views are required, sufficient monitors or split screen viewing should be provided
- Each view should be adequately labelled or distinguished (to avoid confusion)

Status indicators/Indicator lamps

- Position valves and other equipment status indicators such that operators can see status of valve/equipment from all operating positions relevant to the task and irrespective of current lighting conditions
- Ensure stray lighting in the workplace does not make any local or control panel indicator appear illuminated when it is not. Similarly, ensure that the illuminated indicator is sufficiently bright to ensure that it is clear when on
- Use standard colours. Avoid red or yellow as these are typically 'alarm' colours. White is good as a status indicator (refer to section of Coding and Labelling)
- Ensure operators understand the meaning of status indication. If indicator lights are used to indicate that a particular control action has been carried out ensure that they positively indicate the final status of the equipment e.g. equipment end state linked to indicator not the request of demand

Alarms/Warnings

- Alarms and warnings are status indicators designed to attract attention to a condition requiring timely and urgent operator intervention. They should assist the operator in diagnosing the problem through conveyance a special message to an operator that requires some action or indicates an immediate event. Most alarms must serve two purposes:
    - To direct attention to the message that indicates a condition/fault/deviation has occurred
    - Convey the meaning of the message
- Alarms systems should be developed in accordance with a defined philosophy for prioritisation of alarms, their processing and presentation, control and management
- Consistency of alarm and interface design must be maintained throughout the plant, this includes any alarms that may exist as part of any Commercial-of-the-Shelf items, as different manufacturers tend to have their own agendas and philosophies for alarms which may be wholly inconsistent with the overall project's design conventions. This could lead to confusing signals to operators and sensory overload, increasing the likelihood of misdiagnosis and incorrect response to alarms

- The design and alarm philosophy should consider the overall demands on operators and ideally be based on task analysis

Communication Systems

- Adequate communication facilities should be provided at all major operating locations
- There should be an adequate number of communication facilities provided around the control suite, particularly for emergency response and control
- The communication systems should consider requirements for emergencies, not just normal operations
- Appropriate communication devices and requirements should be selected and used having regard to the tasks, physical and cognitive demands, prevailing hazards and environment e.g. clarity of sound/usability of headsets/radios

Software

- Software design should be appropriate for the task and enable users to complete the task efficiently without presenting unnecessary problems or obstacles
- Operators should be able to feel that they can master the system and use it effectively following appropriate training
- Dialogue between the user and software should be appropriate for the user's ability
- The software should protect users from the consequences of error, for example by providing appropriate warnings and information and by enabling 'lost' data to be recovered
- The software system should provide appropriate feedback, which may include error messages, suitable assistance to users and messages about changes in the system status, malfunctions etc.
- Speed of response to commands and instructions should be appropriate to the task and the user's abilities
- Characters, cursor movements and position changes should be shown on screen as soon as they are input
- Operators should be kept informed about the introduction, operation, functions and limitations of software/software based systems

HMI Design Guidelines (Coding and Labelling)

- Coding can help operators to identify the correct controls, displays and alarms
- Coding and labelling of control devices (and displays) increases operating reliability, reduces operating time and accelerates training and learning by improved visual and /or tactile differentiation
- All control actuators, displays and alarms should be readily identifiable
- Coding can generally take the following forms:
    - Visual/Colour
    - Labels/Text
    - Size/Shape
    - Position
    - Auditory

- The selection of the appropriate coding technique requires the designer to take into account the safety significance and demands imposed by the nature and conditions of the operator's task. For example, colour coding and label coding will not be useful if the operator must constantly maintain attention to a visual display or piece of work while selecting a control

Control device coding and labelling guidelines

As a guide, designers should consider the following factors before selecting a coding method:

- Space available for certain coding techniques (e.g. labels)
- Maintaining a balance between coding techniques and other human factors aspects. For example, the ideal coding solution may entail a series of large colour coded dials or push buttons, however, the sizes required conflict with optimum viewing angle of the operator
- Illumination of the workplace will affect the usefulness of some visual codes
- Speed and accuracy with which controls must be identified, touch is slower and usually less accurate than vision
- Number of controls to be coded; labels are infinitely variable, three or four colours only should be used throughout the facility
- Standardisation of coding of control devices, displays and alarms within the workplace is essential to ensure consistency of interface design and that operators do not confuse coding and control actions around the facility
- Colour used to associate meaning should be unambiguous, not contradictory and applied consistently across the control room interfaces and not be the sole means of coding. Generally, colour coding should be used as a 'redundant' code e.g. use stripes as well to account for colour-blindness and different lighting conditions. Shape coding is also possible e.g. rectangular vs. circular push-buttons
- Controls and push-buttons can also be coded by size
- Colour code controls/push-buttons for one function different to those associated with other functions
- Whichever coding convention is to be adopted, it must be ensured that it is consistent with user expectations and stereotypes and the meaning of coding is translated in procedures and training. If unsure of the coding to be used, suitable prototyping and trials can be performed to ensure controls are readily distinguishable under the expected conditions of use

Labelling

- All equipment, controls and displays should be clearly, legibly and consistently labelled, so that they can be viewed from the operating position
- Use negative contrast for text on labels (e.g. dark letters on light/white background)
- Characters should be upright, uppercase (unless several lines of text are used where mixed cases is more legible and recognisable); text wording, size, colour and typeface effect readability
- Physical construction of labels effects long term durability/wear. Labels should therefore be durable and permanent (adhesive labels are only acceptable for small components)
- Correct positioning of labels in relation to the control/push-button/displays/alarms will aid identification

   - Labels should be nearer to the corresponding pieces of equipment, display or control than any other
   - Labels, signs and informative text or symbols should be located on or adjacent to their associated controls and displays in such a position that they are visible when the controls are operated
- Labels should be consistently positioned
- Any nomenclature, symbols and abbreviations used in the labels should be standard, conventional and compatible across the plant (punctuation should not be included) and accurately repeated in operating procedures
- Names on equipment labels should be consistent with names used in procedures