

Guidance

G217

Good practice in human factors integration

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1 Purpose

The purpose of this Guidance is to provide an understanding of how to integrate human factors into systems development. It provides practical advice for implementing the engineering standard [S1217](#), Integration of Human Factors into Systems Development.

2 Scope

This Guidance applies to all parties introducing modified or new technology systems to London Underground. This includes London Underground staff with responsibility for engineering, staff selection and training, the development of operations and maintenance rules and procedures, and supplier organisations and related staff.

3 Guidance

3.1 What is Human Factors?

- 3.1.1 Human factors (HF) is a multi-disciplinary approach to the analysis and design of 'interactive systems' characterised by the interaction between people (end-users or 'users') and technology (equipment) through a 'user interface'. HF accounts for human capabilities and limitations during the development of interactive systems. Whether existing systems are being modified or new ones engineered, the inclusion of HF into those development activities will ensure that overall system performance is safe and efficient being supported by desirable user intervention; timely, accurate, safe, efficient, and reliable.
- 3.1.2 An interactive system typically consists of several interacting components – people (end-users, or users), procedures (including corporate, and line based or local work processes) and technology (equipment) - which interact within a built environment. Each component, and the environment, can have an affect on users' performance during interaction and in turn overall system performance. HF considers the impact of system elements, on their own and in combination, on human performance and therefore their impact on overall system performance.

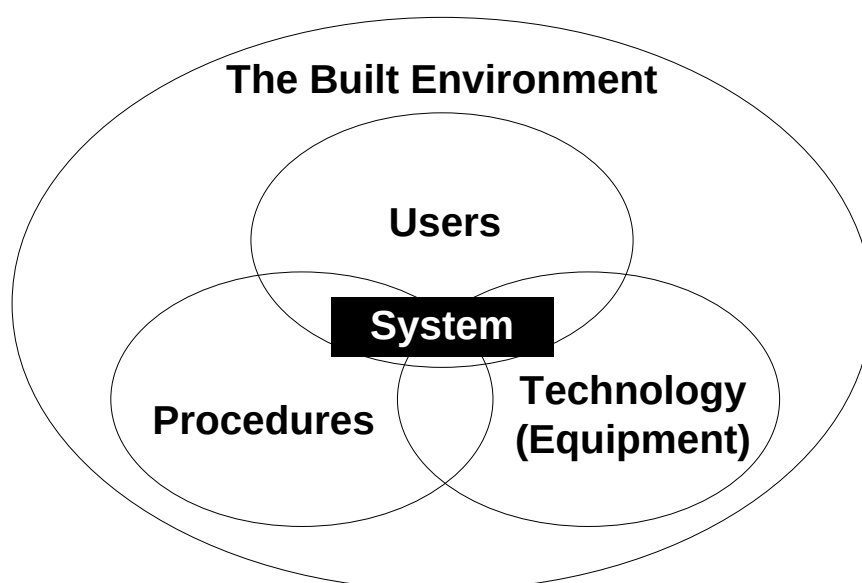


Figure 3-1: System Components and Interaction

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- 3.1.3 Technology is the traditional focus of engineering projects. If it has an interface with users, it is necessary to account for their design requirements for that interface to enable them to use it as intended. It is necessary then to account for a users capabilities and limitations (both physical and cognitive (mental) attributes), in the design of technology-user interfaces.
- 3.1.4 Procedures define the way in which users are expected to interact with technology, they describe the tasks and when they need to completed to manage a scenario.
- 3.1.5 The interaction between users, technology and procedures will typically take place in a built environment accommodating the following:
- a user workstation (or collection of workstations)
 - 'on-workstation' equipment (including control system displays and controls and communications equipment)
 - there may also be 'off-workstation' equipment elsewhere within the design space
 - ambient environment controls for lighting, temperature and humidity settings.

Because the built environment has an affect on users' performance during interaction it must be considered as an interacting component alongside all others during system development. Some built environments do not conform to the typical case and need to be given special attention because of the more pronounced effects they can have on users' performance, e.g. track maintenance, sidings and some depot environments.

- 3.1.6 Accordingly, systems' development must consider the wider built environment in which some systems will operate ('the context of use'). Shared environments in which London Underground (LU) and Network Rail (NR) each operate systems represent environmental challenges, e.g. NR and LU operators managing crowd behaviour in a co-ordinated way, customers using 'customer-facing' systems to buy tickets and navigating their way to/from platforms using NR and LU signage information. In addition, external events such as flooding and national grid power losses present themselves as wider environmental challenges that need consideration during system development.
- 3.1.7 Delivering human factors throughout system development can be challenging, and human factors integration processes need to be followed to ensure that it is achieved. Specific project management effort may be need to be applied to a number of areas. Particular importance is assigned to the following to support delivery of HF:
- a) There has to be a continuous engagement with intended users (operators, maintainers and customers) from start to finish in order to identify relevant user capabilities and limitations within proposed modified/new designs, as well as to determine the inclusion/exclusion of existing practices and procedures;

- b) Technology must be designed to account for users' capabilities and limitations by appropriate allocation of functions between technology and user. It is important that procedures are consistent with these allocations. Where possible, changes to function allocations and procedures should be available in order to easily modify system designs according to changes in business requirements for the way they operate;
- c) Procedures are likely to be changed through the introduction of new systems particularly and any changes must be evaluated as a part of system testing to ensure that changes will be acceptable;
- d) Users need to be trained prior to, and evaluated during system testing to ensure their intended contribution to overall system performance. To do this training and testing criteria need to begin their development early on and this may require access to facilities, equipment specifications, procedures and related documentation at a comparatively early point of a project.

3.1.8 Typical issues that need to be addressed during HF delivery include:

- a) The design of displays and controls so that they are compatible with the expectations and knowledge of users including the tasks they will be required to perform. Simple design conventions such as clear presentation of information and accurate labelling of indications and controls can have significant effects on the speed and accuracy of user performance;
- b) Designing the layout of facilities and workstations so that complimentary functions are within close proximity of each other thereby facilitating communications between users. At the same time this allows displays and controls to be optimally positioned. Doing this ensures that any sources of disruption associated with more random layouts are minimised;
- c) The design of displays, controls and tasks to avoid undue demands under degraded or emergency conditions. Inappropriate design may result in an excessive workload resulting in degraded performance and user stress.
- d) The configuration and presentation of notifications (alarms and alerts) via notification systems (or notification functions within systems) such that they allow users to receive timely and clear information on notifiable events in order that they can reliably plan and execute an appropriate response to them. Poorly configured and presented information leads to problems in operation, e.g. too many notifications present workload demands beyond the user's limitations and compromises their ability manage the task in hand;
- e) The modification of existing, or development of new procedures and working practices to ensure new technology is utilised in an efficient and safe manner. It is important that modifications and new developments are carefully evaluated, and the continuation of existing procedures and practices is validated;
- f) The selection of appropriate staff, staffing numbers and working patterns. New technology and procedures may significantly change job demands. If different skills or staff numbers will be required, special attention to the specification and selection of staff numbers is necessary prior to system commissioning.
- g) The development and delivery of appropriate training material covering both operation of equipment and modification of existing, and development of new procedures.

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3.2 What is Human Factors Integration?

- 3.2.1 Human factors integration is a systematic process for incorporating human factors into engineering processes. Systems that have followed a comprehensive end to end human factors integration process will benefit from first time acceptance by users on the basis that they account for their capabilities and limitations during interaction. Users will find these systems easy to use, and hard to misuse; their actions and contribution to overall system performance will be optimised, and their well-being will be maintained at all times.
- 3.2.2 Integrating human factors into systems development requires that from the earliest project stages there is management of the inherent interfaces with operations, maintenance and customer representatives, other engineering disciplines especially systems engineering, as well as project management and control functions. It may, for example, require modelling and assessment to evaluate particular mixes of people, processes and equipment at an early stage and later assessment of prototype equipment to verify expected performance.
- 3.2.3 Integrating human factors within the overall project engineering lifecycle is fundamentally about successfully 'pulling' the technical human factors analysis findings and design recommendations 'through' the development lifecycle of system engineering. Consequently, S1217 has been developed as a process standard defining development activities, rather than a design standard prescribing a specific user interface design for displays and controls etc.

3.3 Objectives of This Good Practice Manual

- 3.3.1 This manual has been developed to provide practical advice for implementing the engineering standard S1217, Integration of Human Factors into Systems Development. It will assist the reader in understanding why the clauses in S1217 have been written, and how their requirements may be delivered. It is intended to provide project managers and other stakeholders with sufficient understanding of what needs to be built into a project plan to address human factors.
- 3.3.2 The manual outlines good practice in the field of human factors which can be applied to projects carried out for and by London Underground.
- 3.3.3 The manual is not a manual of human factors methods; competent project HF engineers will determine the most suitable analysis and design methods to employ.
- 3.3.4 The manual covers the activities that need to be applied to analysing, designing and integrating technology for use by LU staff and customers. This also includes the related aspects of working environments, and procedures and staffing, except in the case of customers whose interaction within LU systems is largely determined by their user interface design.
- 3.3.5 The most immediate application of this manual will be to 'control' environments and tasks, such as signalling, service control, station control and train cabs. However, it is intended that the described principles are applied equally to maintenance and customer environments and the technology used there.

- 3.3.6 Because human factors integration requires consideration of the characteristics of system users, this manual is also relevant to those who have responsibilities for staff selection, training and the development of operations and maintenance procedures and practices, and in the case of customers those tasked with managing the 'customer experience'.
- 3.3.7 This manual's business objective is to support the application of S1217, ensuring that systems are developed which can deliver user health, safety and performance.

3.4 Structure of the Standard

- 3.4.1 S1217 has three main components:

- a) Requirements on the organisation of a project;
- b) A requirement on London Underground to define the operational, maintenance and customer concepts for the system;
- c) A requirement on HF suppliers to deliver and operate in accordance with an overarching project Human Factors Integration Plan (HFIP).

- 3.4.2 The project organisation component establishes identified roles related to human factors and the need for defined involvement of operations, maintenance and customer representative personnel.

- 3.4.3 The most substantial component of the standard relates to the HFIP. That section lists the essential inclusions of a comprehensive approach to the integration of human factors. The standard is not prescriptive about which HF processes, methods and techniques shall be used, however selecting the appropriate ones requires a human factors organisation and programme to be developed and applied.

3.5 Structure of this Manual

- 3.5.1 The remainder of this manual is in three main parts.

- 3.5.2 In the first part (Part A), a commentary is provided on each of the main technical sections of S1217. The text from each of the sections is repeated in this part of the manual to minimise the need for cross-referencing. The commentary addresses 'why' each of the specific requirements has been included within S1217 and 'how' they might be addressed. Consideration is given to the different means of addressing the requirements between small and large projects.

- 3.5.3 The specific requirements for the contents of an HFIP as outlined in S1217 are examined in detail in the second part (Part B) of this manual.

3.6 Part A – Commentary on Clauses of S1217

3.6.1 Clause 4 Responsibilities

4.1 **The Head of Human Factors Engineering** is the person within London Underground with responsibility for:

- a) the technical contents of the HF-related Standards;
- b) advising on the correct interpretation of this standard and the approval of concessions;

c) resolving any conflicting issues between standards and other related matters.

4.2 **The Surveillance Manager** shall be responsible for ensuring that a co-ordinated programme of audit and inspection is implemented to assure that compliance with this and other related standards are ensured.

4.3 **LU Human Factors Engineer** is a suitably accredited individual who is accountable for HF activities performed for a given project.

4.4 **The Human Factors Delivery Manager** is a suitably accredited individual who is responsible for all HF delivery activities performed for a given project.

4.5 **The Director of Operational Change and Upgrades** (or successor role) shall be responsible for ensuring that London Underground meets its requirements under this standard by providing the agreed level of resources, access and information necessary to support the HF process. The Director of Operational Change and Upgrades shall appoint a suitably competent individual who will perform the role of operations end-user representative for the services or works.

4.6 **The Head of Asset Performance Development** (or successor role) shall be responsible for ensuring that London Underground meets its requirements under this standard by providing the agreed level of resources, access and information necessary to support the HF process. The Head of Asset Performance Development shall appoint a suitably competent individual who will perform the role of maintenance end-user representative for the services or works.

4.7 **The Head of Customer Service Strategy** (or successor role) shall be responsible for ensuring that London Underground meets its requirements under this standard by providing the agreed level of resources, access and information necessary to support the HF process. The Head of Customer Service Strategy shall provide expertise to ensure that the requirements of an appropriate range of customer end-users for the services or works are considered.

4.8 **Operations Acceptance Manager** (formerly User Acceptance Manager) is a suitably competent individual who is accountable for the role of system design acceptance of on behalf of operations end-users.

4.9 **Maintenance Acceptance Manager** is a suitably competent individual who is accountable for the role of system design acceptance of on behalf of maintenance end-users.

4.10 **Customer Acceptance Manager** is a suitably competent individual who is accountable for the role of system design acceptance of on behalf of customer end-users.

3.6.1.1 **Why?**

3.6.1.1.1 Human factors activities arise because of the interfaces between various interested parties within a project. The development of user interfaces between users and technology are also the main point of contact between user representatives who are accountable for the acceptance of modified and new systems (the client) and engineering personnel who are responsible for producing modified and new systems (the supplier). Ensuring appropriate HF activities are planned and executed requires

a programme appropriate HF function and organisation with HF specific roles, responsibilities and accountabilities.

- 3.6.1.1.2 Similarly, a human resources function will be responsible for delivery of the operations and maintenance 'user' components of the system, who need to be trained in 'procedures' developed with operations and maintenance input, to ensure interaction with the 'technology' produced by the project. A human resources function is not applicable when the customer is being considered as the user component of the system.
- 3.6.1.1.3 For human factors issues to be managed and given suitable priority, it is essential that there are clearly understood points of accountability for human factors related issues for both the client and supplier.
- 3.6.1.1.4 The intention is to ensure that there is a focal point for human factors decisions between the parties involved within a project. This is supported by identifying operations, maintenance and customer 'Acceptance Managers' acting on behalf of London Underground (in the case of the Customer Acceptance Manager, acting on behalf of the customers too), and a 'Human Factors Delivery Manager' representing the human factors delivery organisation.
- 3.6.1.1.5 There is a single point of accountability within London Underground for the operational and maintenance support aspects of major projects, which is allocated to the Director of Operational Change and Head of Asset Performance (or their successor roles), respectively. There is a clear responsibility placed on these individuals within the standard to appoint the person who will act as the relevant 'Acceptance Manager' for a project. The Head of Customer Service Strategy is the single point of accountability within London Underground for customer support aspects of major projects, and they are responsible for appointing the person who will act as the Customer Acceptance Manager.
- 3.6.1.1.6 Acceptance managers and the Human Factors Delivery Manager have been given specific 'role titles' to ensure that these functions are clearly identified and assigned. This will also support the assurance process in providing a consistent basis for projects by which human factors will be managed.
- 3.6.1.1.7 Clause 4.1 of the standard also defines the responsibility placed upon the London Underground Head of Human Factors to audit application of S1217 (as part of advising of the correct interpretation of the standard). This is the accepted mechanism for testing compliance and ensuring continual improvement of London Underground standards.
- 3.6.1.2 **How?**
- 3.6.1.2.1 For a major project, it would be expected that particular individuals would be appointed full time to the four key roles identified; Operations, Maintenance and Customer Acceptance Managers and Human Factors Delivery Manager. These roles may have the operations, maintenance, customer, project and human factors teams reporting progress and issues to them, as appropriate.
- 3.6.1.2.2 There is no requirement for these roles to be full time, however it will be necessary as far as possible for there to be continuity of the function from project inception through to delivery.

3.6.1.2.3 'Suitable competence' is emphasised for the roles. For a large project, with significant human factors related issues, they are likely to be demanding. They would require project management skills (in terms of managing activities and personnel) and relevant technical capability.

3.6.1.2.4 For the Human Factors Delivery Manager, their technical capabilities need to include knowledge and experience in addressing human factors in projects. For Acceptance Managers, their technical capabilities need to include relevant operational, maintenance and customer behaviour and strategy experience and an appreciation of human factors principles. For Operational and Maintenance Acceptance Managers, knowledge of relevant London Underground safety and human resourcing procedures and processes is also required.

3.6.2 Clause 3.1 End User Representation

3.1.1 The roles of Operations Acceptance Manager, Maintenance Acceptance Manager and Customer Acceptance Manager shall ensure their respective end-users are represented.

a) a representative cross-section of typical end-users, some of whom may eventually form part of the delivered system, will be made available for end-user consultation;

b) An appropriate level of trade union health and safety and other stakeholder consultation shall be provided for.

Note: The Acceptance Manager roles will be executed by individuals identified by relevant business stakeholders.

3.1.2 Adequate provision shall be made for the chosen end-user representatives to support the HF process. The means by which this will be achieved will depend upon London Underground management organisations for end-user representatives, but will need to avoid remoteness from, and conflict with, the resource required for normal day to day activities.

3.6.2.1 Why

3.6.2.1.1 Appropriate involvement of end users can ensure that there is a close match between the developed system and user requirements. It can also assist with gaining buy-in and ownership. This requires users to provide input to the early stages of scoping and systems definition by commenting on current tasks and scenarios. They will also be required as the design progresses for consultation purposes and to take part in operability trials.

3.6.2.1.2 It is critical that those end users involved in informing and evaluating the design are representative of the eventual end users. The supplier organisation will use information gathered from these users to feed into the development of a design and to measure its success.

3.6.2.1.3 On matters related to the health and safety of the workforce, there is a statutory duty to consult with employees. This is provided for within London Underground through designated trade union health and safety representatives. The Acceptance Managers are responsible for ensuring that this duty has been fulfilled.

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- 3.6.2.1.4 It will be necessary to plan and organise access to end users during a project. Staffing resources in London Underground are constrained and advance notice is likely to be required to identify and obtain release for operations and maintenance staff.
- 3.6.2.1.5 The numbers, types of staff and arrangements for access will form part of the agreement between London Underground and the supplier organisation. This clause requires London Underground to arrange the necessary access and to provide staff that form a representative cross-section.
- 3.6.2.1.6 Experience has shown that end users require some management support to ensure that their concerns are properly represented within the project team and to keep their input focused and controlled. This is particularly important where comments from end users may have contractual cost implications.
- 3.6.2.2 **How**
- 3.6.2.2.1 For a large project, ideally, a representative sample of suitable end users would be chosen to constitute a user panel. The majority of these representatives would remain on shift, with day release support for attending meetings or demonstrations of equipment. This prevents them losing touch with the reality of their daily work demands and enables them to act in a communications role with their colleagues. In respect of customer end user panel members a representative cross-section of typical customers will ideally be made available for consultation via the Customer Acceptance Manager.
- 3.6.2.2.2 Some of the user panel members may be seconded to the project team. These would typically be those identified as being the more flexible and articulate thinkers. They may, for example, be staff with a strong operational and maintenance background that currently fulfil a training role. These particular individuals would assist in 'informing the design'. The remaining members of the user panel should constitute a more representative cross-sample of operational and maintenance staff, primarily involved in 'evaluating the design'. In respect of customer end user panel members the same principles should apply to inform, and evaluate, a developing design.
- 3.6.2.2.3 User trials may initially employ the user representatives, but ideally would also involve other users on a sample basis.
- 3.6.2.2.4 The management support for these teams may be best supplied by the human factors specialists. They tend to combine facilitation skills, with a willingness to understand operational, maintenance and customer issues and should have access to the wider supplier organisation where project management support resides.
- 3.6.2.2.5 For small projects, consultation and trials may be conducted in the workplace. It is still beneficial, however, to identify specific end users as designated representatives, with the role of co-ordinating with the project team and communicating with their colleagues.
- 3.6.2.2.6 The extent of consultation with the trade unions will vary according to the nature of the changes involved. For major projects, that involve significant changes, consideration should be given to including a trade union health and safety representative amongst those staff seconded to the project team. Otherwise,

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consultation may be carried out using either the established consultative framework within London Underground or as a specific activity involving the Acceptance Managers and London Underground Employee Relations managers.

3.6.3 Clause 3.2 Operational and Maintenance Concepts

3.2.1 Producing a concept of operation or maintenance for a future system is a complex process and will require the co-ordinated collaboration of appropriate technical, operational and maintenance project representatives. Preparation will be a joint effort led by a project's Systems Engineer in collaboration with the LU Human Factors Engineer, operations and maintenance representatives. The Operational and Maintenance Concepts should be produced as early as possible in order to inform the development of system requirements.

3.2.2 If HF issues can be easily resolved it may not be necessary to develop an operational or maintenance concept. A decision about the necessity for an operational or maintenance concept, or the scope of one shall be made at the planning stages during discussions between the standard owner and a project's end-user representatives and supplier.

3.2.3 An Operational or Maintenance Concept shall include, but not be limited to:

- a) The operational purpose of the system, or maintenance regime;
- b) How the system is to be operated and maintained to deliver its business purpose, including command and control philosophies, the allocation of function between equipment and end-users, and maintenance processes;
- c) Staffing concepts for the system, including intended staff grades, skills, attributes and management structures;
- d) Intended operations and maintenance strategies under normal, abnormal, degraded, and emergency operating conditions.

3.6.3.1 **Why**

3.6.3.1.1 It is essential that the design intent of the system is defined in terms of the benefits and changes that it is intended to deliver. Where overall benefits are intended to be achieved through changing or providing additional support for end user activities, this needs to be clearly communicated to both users and suppliers.

3.6.3.1.2 It is intended that the Operational and Maintenance Concepts will be a document written from an end users perspective. It should provide the Acceptance Managers with a clear description of what the system will be provided for. It should also be informative for members of the supplier organisation in explaining who is going to be using the system, for what and how.

3.6.3.1.3 A concept needs to address itself to all of the related People, Technology, and Procedure components to fully define what is expected to be delivered. Therefore, it will describe how it is expected that the provision of particular technology or technology functions will be utilised by specific personnel to perform defined tasks or to meet particular goals. Where such activities are regulated by procedures or other working rules, this needs to be defined.

- 3.6.3.1.4 A system's target end users (target user population) need to be defined in order to ensure that the system is developed with the correct end users in mind. The Operational and Maintenance Concept documents need to identify which user groups are expected to directly use particular parts of the system or who will utilise information generated by the system. For each group of users, the specific job grades or posts will be identified (e.g. station assistant, train driver, customer service manager, duty operations manager, service delivery manager, signalling systems Engineer).
- 3.6.3.1.5 Reference information should be supplied or made available regarding the specific minimum required capabilities and competencies of each of the job grades or posts concerned. This may encompass required minimum aptitude levels for a post, minimum competencies, licenses and (medical) Fitness Standards. For example, details might need to be supplied on any requirements on 'computer literacy', written communications and colour vision.
- 3.6.3.1.6 Expectations should also be stated regarding the expected level of training that each group of users will be provided with in the future and the envisaged minimum frequency at which a user will operate a particular piece of equipment or make use of a specified equipment function. This will enable the supplier to determine the level of complexity and sophistication of technology operation that the end user groups will be able to tolerate.
- 3.6.3.1.7 Effective command and control is central to railway performance under all kinds of operational conditions. Often the types of systems that are addressed by S1217 provide key support to command and control processes. Hence, it is essential that relevant command and control philosophies are defined. This might include defining the command hierarchy and the major tasks performed by Operators at each level of the hierarchy. The concept of how authority and control is to be exercised needs to be stated, including under conditions when the equipment itself is degraded (e.g. expectations on how control will be maintained over train operations if the primary control centre has to be evacuated). System reliability is determined in part by the ease with which it can be maintained or repaired. The Maintenance Concept must therefore define maintenance philosophies and associated staff hierarchy including expectations for Maintainers at each level and the procedures, practices and major tasks.
- 3.6.3.1.8 The Operational and Maintenance Concepts need to cover aspects of how it is expected that the system will support or be utilised by staff in abnormal, degraded and emergency conditions. Such information should enable the supplier organisation to appreciate the criticality of the requested system to the safety and effectiveness of particular states of railway operation. Due regard can then be directed to such scenarios to ensure that delivered technology provides adequate support to those scenarios.

3.6.3.2 **How**

- 3.6.3.2.1 The standard identifies the Acceptance Managers as being accountable for the delivery of the Operational, Maintenance and Customer Concepts. This is to ensure that there is a clear point of accountability within London Underground to provide the supplier organisation with all relevant information related to operations and