LRSSB - LRG - 29.0

LIGHT RAIL
Safety and Standards Board

# *Guidance for Human Factors in Operations Control Centres*

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**DESCRIPTION:**

THIS DOCUMENT PROVIDES GUIDANCE ON HUMAN FACTORS IN OPERATIONAL CONTROL CENTRES

**EXPLANATORY NOTE:**

LRSSB is not a regulatory body and compliance with this guidance document is not mandatory. This document reflects good practice and is advisory only. Users are recommended to evaluate this guidance against their own arrangements in a structured and systematic way, noting that parts of this guidance may not be appropriate to their operations. It is recommended that this process of evaluation and any subsequent decision to adopt (or not adopt) elements of this guidance should be documented. Compliance with any or all of the contents herein, is entirely at an organisation's own discretion.

**SOURCE / RELATED DOCUMENTS:**

LRG 1.0 Tramway Principles and Guidance (TPG) (LRSSB)
LRG 6.0 Fatigue Management Guidance (LRSSB)
LRG 11.0 Medical Fitness Guidance (LRSSB)
See also Appendix B

| **RELATED TRAINING COURSES:** | **RELATED LEGISLATION:** |
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| N/A | Health and Safety at Work Act etc. 1974<br>Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) |

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# LRSSB

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## GUIDANCE ON HUMAN FACTORS IN OPERATIONS CONTROL CENTRES

## CONTENTS

## TERMS AND ABBREVIATIONS

### Table A – Terms

| Term | Definition |
|---|---|
| **Control Room** | The room / area where specific management of the operation of the tram (Light Rail) service is performed. |
| **Degraded Operating Conditions / Control Centre** | Where the tramway is not working to its normal operating conditions. |
| **Operations Control Centres** | The building where tramway operations are managed. |
| **Project** | The scheme to build a new OCC or make amendments or alterations to an existing OCC. |

### Table B – Abbreviations

| Abbreviation | Definition |
|---|---|
| **3D** | Three Dimensional |
| **CCTV** | Closed Circuit Television |
| **HCI** | Human Computer Interface |
| **HF** | Human Factors |
| **HFI** | Human Factors Integration |
| **HFIP** | Human Factors Integration Plan |
| **HMI** | Human-machine Interface |
| **ISO** | International Standards Organisation |
| **IT** | Information Technology |
| **LRSSB** | Light Rail Safety and Standards Board |
| **OCC** | Operations Control Centre |
| **ORR** | Office of Road and Rail |
| **RAIB** | Rail Accident Investigation Branch |
| **ROGS** | Railways and Other Guided Systems 2006 |
| **TPG** | Tramway Principles and Guidance |
| **VOC** | Volatile Organic Compounds |

# 1. Introduction

1.1. This guidance supports the high level principles set out in LRG 1.0 Tramway Principles and Guidance (TPG) published by the Light Rail Safety and Standards Board (LRSSB).

1.2. This document provides guidance on human factors in Operations Control Centres (OCCs) for those delegated this responsibility in relation to UK Light Rail systems / tramways based on 'line-of-sight' operations only. As with all guidance, this document is not prescriptive and is intended to give advice not to set a mandatory industry standard, and it is based upon goal setting principles as best practice.

1.3. Much of this guidance is based on the experience gained from existing UK tramways and from published documents. It does not prescribe particular arrangements adopted by any existing UK tramway and is intended to give guidance and advice to those involved in the management of human factors in OCCs.

1.4. This guidance is not intended to be applied retrospectively to existing tramways. However, owners and operators should consider and assess any implementation of this guidance and / or any subsequent revision, to ensure continual improvement in reducing risks related to human factors in OCCs.

## 2. Scope

2.1. The Operations Control Centre (OCC) is at the heart of tram operations. Its design should adequately support staff whose role it is to help provide safe, effective and efficient tram services. This guidance document sets out how a human factors (HF) approach can help optimise the design and therefore operations for new OCC as well as when amending existing facilities.

2.2. Central to this is the concept of human factors integration (HFI) as a way to address HF topics either as part of a wider project that is delivering an OCC, or for an OCC project. This is described further in Section 3 and includes the following:

- HF activities should inform (and be informed by) engineering practice and project management processes early and then throughout the project;
- Getting feedback from end-users through use of structured approaches; and
- Having HF competence represented as part of a multi-disciplinary team approach to design to assist overcoming design challenges and to create an optimal design.

2.3. LRG 1.0 Tramway Principles and Guidance (TPG) document states the importance of human factors in relation to an OCC:

*"A human factors study should be carried out at the design stage or when there is a significant change to the Control Centre or systems".*

2.4. This guidance document sets out the various ways the project to build a new OCC or make alterations to an existing OCC can be delivered and covers the following:

- Approaches for new and existing OCC projects;
- HF competence and multidisciplinary teams;
- The specific HF activities and studies that may be required;
- Applicable HF standards; and
- How HF work feeds into the wider project.

2.5. The following are not considered within this guidance:

- Fatigue management (for further guidance refer to LRG 6.0 Fatigue Management Guidance and LRG 11.0 Medical Fitness Guidance);
- Operational procedures (for example, for shift handover); or
- Coordinating engineering works.

2.6. This guidance is relevant to those involved with the following:

- OCC concept design including early scheme development, appraisal, and selection;
- Project management responsibilities for the OCC element and wider programme management accountabilities;
- Companies that will, or do, operate the OCC;
- Functional and technical specification development that impacts on the OCC;
- OCC design;
- Procurement and contracts approval responsibilities;
- OCC operations representatives; and

- Suppliers of equipment and software for use in the OCC.

## 3. Process for Managing Human Factors in OCC Design Projects

3.1. A Human Factors Integration Plan (HFIP) is a structured way for HF issues, opportunities and risks to be identified and managed as part of engineering projects. The HFIP should set out:

- What HF work is required;
- Why the HF work needs to be performed;
- How the HF work will be managed;
- Who will be undertaking the HF work, including key roles and responsibilities; and
- When the HF work needs to be undertaken in the project lifecycle.

3.2. Ownership of the HFIP is important to define at the outset and depends on the wider project structure. A new OCC facility might mean the plan sits with the client, whereas smaller projects may have the HFIP sit with the operator.

3.3. The following steps should form part of the HFIP:

- Step 1 – HF screening of the OCC project;
- Step 2 – Defining HF analyses and HF support activities;
- Step 3 – Planning HF work;
- Step 4 – Delivering HF work; and
- Step 5 – HF approvals and assurance.

3.4. The material presented below follows this structure and as such, aims to help both produce the HFIP and then to execute the activities within it.

**Step 1 – HF Screening of an OCC Project**

3.5. The purpose of screening is to identify the HF topics, risks and issues that need to be controlled and optimised as part of the project. Many high-hazard companies have developed bespoke screening tools for this purpose. These tools look at a range of parameters such as the following:

- Has the proposed technology been proven in other settings, including consideration of application differences and novel combinations of technology;
- Does the application of existing standards adequately address human factors issues, including human error;
- What human factors issues affect the safety, operational performance and maintainability goals of the system; and
- Does the wider project team understand and / or can fulfil regulatory expectations around HFs.

3.6. A screening workshop should be used to review the project for HF issues. This should be facilitated by a technically competent HF specialist and attended by project members involved in developing the project.

3.7. Screening can be undertaken at a project, equipment and task level:

- Project level screening tends to lead to a holistic approach to human factors integration and is suited for larger projects;
- Equipment-based screening identifies hardware items that require targeted HF input as this is more suited to a smaller project such as new display screens; and
- Task screening looks at the critical tasks performed in the control room and the key decisions that need to be taken around allocation of function, i.e. whether to automate (and how) or whether tasks should be performed manually.

3.8. Central to the workshop will be identifying HF topics that need further HF analysis. Rating HF topics in terms of possible consequences for operations, and their likelihood can help determine where to prioritise effort. However, this does not mean lower scoring items do not need to undergo a HF analysis.

3.9. The output from the workshop exercise can feed into a prioritisation table as illustrated in the example in Table 3.1 below. It is important to note that such ratings help prioritise HF effort on the project and also, to note that the outputs are topic assessments, not risk assessments. Additional columns can be added to give overall ratings, owners, dependencies etc.

Table 3.1: Example HF Topic Prioritisation Table

| Topic | Consequence on operational phase of control room | Likelihood of impact on operational phase of control room |
|---|---|---|
| Errors in route setting as the proposed design relies on manual route setting. | High | Medium |
| Operators will have to select which tram to call based on a shortened version of the full tram identifier; there is a risk of communicating with the wrong driver. | High | Medium |
| The proposed workstations have attracted criticism from operators at other locations as they have to lean forward regularly to reach controls. | Medium | Medium |
| The existing control centre floorspace is limited and the proposed additional workstations may lead to a loss of circulation space and / or supervisory desk space. | High | High |
| One proposed option from the supplier is to use headsets; controllers do not like wearing headsets for long periods. | Medium | Low |

3.10. The output from the screening activity will be a set of HF topics, risks and issues that need to be within the HFIP and then managed and optimised.

**Step 2 – Defining HF Analyses and HF Support Activities**

3.11. Step 2 is about looking at the list of HF topics, risks and issues identified in Step 1, and defining what HF analyses and activities are required to develop the HFIP. The following subsections set out the types of analyses that might be performed as part of the HF study. The content aims to help those building or commissioning a programme of HF work by describing how the analyses support the design of the control room.

3.12. In the development of the HFIP, it is important to consider the following principles:

- HF work should have an established link to risks that are managed through the control room;
- HF analyses should identify and demonstrate suitable risk controls, based on a hierarchy of risk controls approach (for example, using engineering solutions to remove or mitigate risk is preferred to a procedural measure);
- HF analyses should, wherever possible, be based on scenarios that have been designed to test the limits of the system, including covering emergency situations, equipment failures and operational problems etc.;
- For safety critical systems it is necessary to provide independent assessment of the human factors aspects; and
- The standards that are going to be applied to the project (refer to Appendix B).

<u>Overview of HF Analyses</u>

*Task Analysis*

3.13. Task analysis is about understanding what tasks need to be performed in the OCC and how staff perform these in order to achieve their goals. Task analysis is also a core part of many other HF analyses. There are many resources available about how to conduct task analysis as set out in Appendix A Section **Error! Reference source not found.**.

3.14. The process typically starts with establishing goals for the system such as 'safely control tram operations for area A'. In support of each goal will be a set of high-level supporting tasks which themselves are then broken down further into sub-tasks and so on, with increasing levels of detail provided as appropriate.

3.15. The aim is to provide a complete picture of what tasks need to be executed, and how they are performed. It is good practice to record how the task is undertaken in reality (reflecting how the majority of operators undertake the role), rather than how it is imagined that the role might be done; this underlines the need to have experienced operators feed into the process. Clearly this is much easier to do for existing control rooms, than for new OCCs.

3.16. Early task analysis is especially useful as this is done *before* key design decisions have been taken, even if there are limited details available. As such, early task analysis can:

- Highlight parts of the design where there is uncertainty about how tasks will be done, especially for emergency situations;
- Be used to test assumptions about how the control room will operate;
- Help define staffing levels;
- Provide the foundation for other HF analyses such as workload assessment, layout analyses, HMI (human-machine interface) design etc.; and

- Help define the HF work that needs to be performed by the different suppliers.

3.17. It is important to prioritise task analysis effort on topics where safety risks and operational considerations need to be managed. Further information on resources for prioritisation of task analysis effort are contained in Section **Error! Reference source not found.** of Appendix A.

3.18. Often early task analyses need to be updated as the design evolves. Inputs to task analysis may include the following:

- Functional and technical specifications for the project;
- Observations at other similar control rooms;
- Interviews with staff experienced with tram operations;
- Equipment lists at other similar control rooms;
- Existing task analysis, especially when creating the high-level structure; and
- Control room procedures, rules and instructions.

3.19. Task analysis of control room activities should cover the operational associated with tram movements that are coordinated through the OCC. Task analysis should also consider the upkeep and maintenance tasks that the control room itself requires, and how these are performed (for example, equipment cleaning, renewal, IT support desk space etc.).

3.20. For operational tasks, the following top-level tasks provide a good top-level starting point:

- Enable the safe timetabled movement of trams under normal conditions;
- Enable safe movement of trams under abnormal conditions (tram system is working, but external events pose a challenge, such as part of a route being blocked by crowds from an event (concert, sport etc.));
- Enable safe movement of trams under degraded conditions;
- Respond to emergency conditions;
- Enable tram vehicle maintenance to be completed; and
- Enable infrastructure maintenance activities to be completed.

3.21. Task analysis should be accompanied with a description (sometimes referred to as 'task rules') that explain the conditions that apply to the task. Tasks should also be presented in the order that they are completed.

*Human Error Analysis*

3.22. Task analysis describes how the role is undertaken. Therefore, human error analysis looks at these tasks to consider the following:

- Understand how they can go wrong (human failure);
- Determine what the consequences of errors and violations might be; and
- Identify and appraise suitable risk controls.

3.23. Human error analysis helps to demonstrate that risk controls have reduced the risk to as low as reasonably practicable. There are numerous approaches for conducting human error analysis. Most take data from the following sources:

- Key word analysis: prompts used to identify human failures for each task, such as (too little, too much, wrong object, too early, too late, check omitted etc.);
- Incident investigations that identify immediate and underlying causes;
- Incident data that looks at trends in immediate and underlying causes; and
- Feedback from users through workshops and interviews etc.

*Workload Assessment*

3.24. Failure to properly factor in controller workload in a timely manner can be expensive to remedy, or result in operational restrictions for the life of the tramway. High workload situations also increase the risk of controller error and so any workload issues should be highlighted early.

3.25. Control room operations are often characterised by long periods of low workload and short periods where there is an exceptional demand. Both high and low workload present different challenges.

3.26. Workload assessment helps to demonstrate that controllers can adequately undertake the volume of tasks allocated to them and can help define an overall operating strategy for the tramway. It can also help define staffing levels, number of workstations needed, layout etc., all of which have a significant bearing on control room design and operation.

3.27. Elements of workload include the following:

- Time pressure, such as signalling trams in and out of a depot;
- Cognitive, such as overcoming a radio system failure;
- Conflict workload, when tasks are performed in parallel; and
- Physical movement and physiological effort required to perform tasks.

3.28. Workload assessment can be a complex activity and there are many models that have been developed in rail and other transport sectors (refer to Appendix A for further information**Error! Reference source not found.**).

3.29. To determine minimum staffing levels, it can help to focus on emergency response scenarios as these often stretch workload levels to the maximum, and are unplanned.

*Human-machine Interface (HMI) Analysis*

3.30. Controllers will be presented with information on a variety of displays, and will interact with systems in various ways. Although equipment will have been designed in accordance with standards governing HMI design, this does not mean that the systems provide coherently for the controller.

3.31. Often suppliers will use standards to define colour schemes, legibility, contrast levels etc and therefore will conclude that they have considered HF. However, sometimes critical design decisions are taken without consideration of how the controller will use the system. To address this, the following is important:

- The task analysis informs the HMI design; and
- HMI requirements are correctly defined and embedded in tender specification.

3.32. Where HMI requirements can be determined early, these should be included in the tender specification. Sometimes generic off-the-shelf requirements can be included, such as:

- Provide feedback to the user:
  - Physical buttons shall provide discernible tactile feedback at the moment of operation;
  - Controllers should be able to locate all trams on their area of control without providing a control input;
- Displays shall have anti-reflective properties to minimise reflected glare; and
- Displays shall not be obscured from view when the controls are operated.

3.33. Generic requirements such as those in 3.32 above need to be reviewed prior to adoption of the main contractor's project design. However, generic requirements cannot cover all aspects of the design that need to be specified. For new control rooms, the main contractor should deliver a HF study to develop the HMI solution and associated requirements. This will address matters like how the controller's panel will display route layouts and information, which are the aspects that cannot be specified up-front. Therefore, it is essential that user testing forms part of the HF study.

*Audible Alarms and Alerts*

3.34. A holistic approach should be taken to audible alarms and alerts in the control room. The use of sound is a powerful way to convey specific information, however, inappropriate use can severely hamper and frustrate controllers' performance across *all* tasks. As such, a coherent alarms and alerts strategy for the control room is necessary and should include speech based warnings as they can provide clear and detailed information to the operator if used carefully.

3.35. Wherever possible, alarms should convey the meaning of the event to which they relate rather than requiring reference to a screen to understand its meaning. Wherever practicable, alarms should be silenced by the controller taking the action required by the alarm, rather than simply acknowledging to the system that they have understood the situation. Alarms may also benefit from accompanying visual information to provide further information.

3.36. However, alarms should be used sparingly and as part of an overarching alarms and alerts philosophy for the control room. Alarms should not be confusable with one another and perceptibly different sounds should be used on different equipment. With several suppliers providing equipment it is important that the main contractor conducts an alarms and alerts review is undertaken.

3.37. An alarm sound should reflect the priority of the situation to which it relates. Safety critical events such as a signal passed at danger or an incoming emergency call should be accompanied by both unique and distinctive sounds.

*Layout Analysis*

3.38. Layout analysis can help determine how to arrange equipment required at a workstation as well as to individual equipment items. The following steps should be included:

- Group HCI equipment (displays, controls and audio devices) according to function, based on task analysis outputs and input from users;
- Prioritise equipment groups taking into account each task in terms of frequency, order and criticality;
- Create 3D visualisations, scaled drawings or physical mock-ups of equipment; and
- With input from users, experiment with different layout options to determine optimum solution. Taking into account equipment priority, for example, by locating frequent and important items close by, or by locating large CCTV display screen feeds beyond the immediate display screens for the panel.

*Environmental Requirements Analysis*

3.39. Environmental requirements are those aspects relating to the following (not exclusively):

- Lighting;
- Glare;
- Sunlight;
- Noise;
- Temperature;
- Air quality;
- Ventilation; and
- Humidity etc.

3.40. Shortcomings with the items listed above in Section 3.39 can have an all-round negative impact on human performance. For new installations the application of ISO11064[1] should cover these aspects.

3.41. When retrofitting equipment, or upgrading existing facilities, the environmental requirements should be reviewed to ensure they are fulfilled. Considerations include existing structures that can obstruct views to new screens (for example, support posts), or new equipment producing more heat than outgoing systems thus creating additional demand on air conditioning systems.

*Physical Ergonomics Analyses*

3.42. Workstations should be designed to ensure that they optimise human performance, support comfortable working and minimise risk of injury. Anthropometric data should be used to define reach envelopes, level of adjustment, space and vision zones. The way workstation equipment is operated should be considered when performing the ergonomics analysis to make sure that the two elements work together.

3.43. Retrofitting new equipment to an existing workstation can create difficulties as space in the control room is often limited meaning that compromises have to be made. This should not be accepted without a detailed consideration being given to the following:

- Alternative equipment being procured that better satisfies HF requirements;

1 ISO11064: Ergonomic design of control centres — Part 6 Environmental requirements for control rooms

- Modifying the existing workstation to accommodate HF requirements; and
- Developing a set of options to select a preferred solution.

3.44. User input to this process should feature. However it should not be approached with a predefined solution, for example 'is this position ok?'. In addition, although individual users can describe how they use the workstation, they cannot represent the full range of user anthropometry, so this is not a substitute for full ergonomic analysis and option appraisal.

*Collecting Existing User Feedback and Experience*

3.45. Experienced controllers have an important role to play in most human factors analyses and can provide the following input:

- Describe how they perform their role;
- Provide detail on local operating arrangements and instructions;
- Highlight problems in the control room; and
- Test new equipment / layouts.

3.46. However experienced controllers may not be able to provide the following:

- Comment on behalf of other controllers as there may be individual differences in how the roles are undertaken; and
- Represent others in terms of anthropometrics such as reach and visibility.

3.47. In order for control room staff to work as effectively and efficiently as possible, it is important that they are properly briefed and involved in defining how a new system is to function.

3.48. Mapping existing users' knowledge onto new systems can be helpful. However, users may be tempted to try to replicate aspects of existing systems, such as icons, button positions and even task sequences etc. which can create its own problems as even minor differences between old and new systems can create confusion and have an impact. In addition, it is important to be aware that users will have no experience of how a new system will work and they are being asked to imagine and / or start the process of learning whether proposals *could* work.

3.49. It can be helpful to create a user-group for major projects to facilitate the testing of draft solutions assisting by the provision of feedback. Having individuals that understand how the engineered system works and how it is operated can be especially useful and therefore, if creating a user group, it is important to make sure they have the right skills. Human factors specialists if engaged, have a role in bridging the technical, operational and human elements, as well as being proficient in running user tests and trials (refer to Section 3.61-3.67 below).

*3D Visualisations and Walk-throughs*

3.50. Contemporary design work often involves the use of virtual reality systems that create a three dimensional (3D) mock-up of a control room that you can effectively walk through.

This can be very helpful as a way of visualising what the space will feel like and it helps avoid people having to imagine what the layout will feel like from two-dimensional drawings.

3.51. To make the most out of 3D models it is important that reviews consider safety, operability, accessibility and maintainability aspects. The following can help to produce effective 3D visualisations:

- Does the model include space volumes that help provide certainty that accessibility envelopes are guaranteed?
- Make sure that suppliers' equipment is not represented as a box or volume of space. Modelling scaled equipment is important to identify access and interface issues; and
- Does the model enable workstations to be 'moved' to illustrate the full range of adjustment, demonstrating that the $5^{th}$-$95^{th}$ percentile of the user population can safely operate controls and see the displays?

3.52. 3D models are representations of what the control room layout could be and the data that is used to create the model is often based on assumptions in the design. Therefore, as the design evolves and equipment is manufactured and the control room is built / upgraded, the 3D models should be updated and reviewed accordingly.

HF in Control Room Construction, Fit-out and Installation

3.53. HF issues arise during construction even with very detailed designs and construction, fit-out and installation activities often expose HF issues that require resolution. An experienced HF specialist can assist by making checks and observing the construction phase to spot issues and to make sure they are addressed in a timely manner (refer to Section 3.61-3.67 below).

Outputs From Human Factor Studies

3.54. Outputs from the HF analysis will inform design requirements that feed into the wider design. HF analyses should be written up in a report to provide transparency over the work conducted as well as to support subsequent work such as a task analysis being used by other studies.

3.55. It is critical when initiating HF analyses that the form of the outputs are clearly defined at the outset and in a form that can be used by the wider design team. The design team should be regarded as recipients of the HF analyses, and as such, a user-centred approach should be adopted when preparing HF deliverables.

3.56. Most outputs should be expressed in the form of a design requirement as the analyses lead to features in the design that may need to be implemented in a particular way. As a general rule, requirements should be as detailed and specific as possible. Although it can be difficult to specify detail early in the project, requirements can be identified at a higher level, for example 'the workstation shall be designed to be operated by the full range of population anthropometry, from a $5^{th}$ percentile female, to a $95^{th}$ percentile male'. Then as the analyses progress, further detail can be provided.

3.57. These design requirements should be included in relevant tender specifications and / or in the wider operational design as appropriate. However, further work and analysis is often necessary to define design requirements and this is addressed through a suppliers' HF study.

3.58. Analysis requirements (or 'process requirements') should be clear and what issues need to be addressed. One such example could be: 'an analysis of the radio panel HMI is required to determine the optimum layout of the HMI control panel, taking into account the following principles: common sequences of control use and functional grouping, … etc.'.

3.59. Some requirements cannot be specified at this stage and so the output in these circumstances will be a set of issues for subsequent resolution and / or recommendations for solutions. Most projects will have an issues register and it makes sense to centralise these and manage them accordingly. The successful closure of these issues is a prerequisite for project assurance.

3.60. As well as standalone HF reports, integrated deliverables are becoming more common, where HF outputs are incorporated into the deliverables from other project activities. This provides a useful way to ensure findings are embedded in the wider design.

<u>HF Support Activities</u>

3.61. Some projects may require a dedicated HF specialist to perform and oversee work. The role should be embedded in the design team as this provides a smooth mechanism to feed in the HF derived requirements and ensures that HF analyses are informed by the ever-moving system design. The role should participate in the activities of the wider project, including design reviews, engagement with equipment suppliers, stage gate reviews, operational design etc.

**Step 3 – Planning HF Work**

<u>HF Organisation, Roles and Responsibilities</u>

3.62. The level of HF competence required to support a control room design should be shaped by the screening process (refer to Step 1 above). A new tramway system is likely to require comprehensive HF input covering many aspects, including the control room.

3.63. The HF work performed on the project should be overseen by a HF specialist. HF specialists engaged should be fully qualified and chartered, as well as experienced and proficient in determining what analyses are required and in performing them.

3.64. HF work can be provided by an external specialist. However, it is advisable that the has its own HF advisor to support the commissioning and delivery of HF work that is procured. This can help provide the necessary assurance to the client that HF issues are being properly managed.

3.65. Ownership of HF issues should be clearly defined and consistent with the contractual arrangements for the project. In most cases this means ownership lies with the main contractor until the project is handed over. The main contractor should provide clarity on the HF specialist and if this is from a separate HF organisation, the person their nominated HF lead reports to. This is important especially if the HF work is performed by a subcontractor where there can be commercial implications arising from HF work. Some projects have a reporting line between the HF subcontractor and the clients HF advisor, even if the contractual relationship is with the main contractor.

3.66. For larger projects it is good practice to have an HF steering group whose responsibility is to oversee HF work, ensure outputs are used and to help resolve difficult issues. This steering group is important as it provides transparency around HF issues and helps ensure issues are addressed in an effective and efficient manner.

3.67. For smaller projects it is advisable to contract an experienced HF specialist to do a simple screening exercise to identify the HF issues that need to be managed, and to advise how these should be resolved. This can help ensure a proportionate approach is taken to address HF issues as it is likely that a scaled-down version of the above arrangements would be appropriate.

Programme Management and HF Work

3.68. HF work needs to be incorporated into the wider programme management process. Programme delivery plans should draw on the HFIP and set out how HF issues, risks and opportunities will be addressed.

3.69. Project management plans should include HF activities and deliverables as well as their dependencies and successors, such as the following:

- Procurement, including specifications for HF work and equipment and tender reviews;
- User testing;
- Operations input;
- Project stage-gate reviews and milestones, for example, for testing and trialling;
- Development of the operational concept;
- Training needs identification; and
- Construction.

**Step 4 – Delivering HF Work**

3.70. This section includes guidance on how to maximise the value from HF work and to minimise the risks. The guidance is presented as a series of issues and their solutions.

3.71. **Issue 1:** Key stakeholders (including the client, main contractor and equipment suppliers) are not familiar with HF and assume that requirements can be specified without realising that studies and analyses are required.

3.72. **Solution 1:** Clients should appraise themselves of ORR's requirements[2] relating to HF integration as this should really be the catalyst to having a proper approach to the topic.

3.73. It is key that the client incorporates the need for a HF study as part of the tendering process as this then provides the foundation for HF work to be completed. The tender review process should include an assessment of the contractors' HF competence and proposed approach. If improvements in the submissions are required, these should be made before contract award. For oversees suppliers, the approach taken to HF might be a surprise as many designers may be used to working with prescriptive regulatory regimes where risk is managed through prescriptive requirements and application of standards.

2 Human factors integration - Objectives, principles and evidence ORR looks for | Office of Rail and Road https://www.orr.gov.uk/media/15720

Therefore, it might be a new concept that risk has to be managed to as low as is reasonably practicable. Therefore, incorporating the need for a HF study in the tendering process this helps create the right mindset at the start of the project.

3.74. **Issue 2:** Outputs from HF studies do not feed into the wider project.

3.75. **Solution 2:** Main contractors can sometimes take a tick-box approach to HF work, especially if they do not understand how the outputs contribute as HF may be considered as a commercial risk to the project.

3.76. HF subcontractors need to be sufficiently well integrated into the project to progress their work, ensuring that it genuinely contributes to the design. The HFIP is a key document that provides the foundations for proper HF integration and it needs to be a live document and its application is monitored. The client would undertake check for its application as part of its oversight activities.

3.77. Consideration should be given to the unintended consequence arising from pressure and incentives on the main contractor to complete a project in a given timescale as this may inhibit the integration of adequate HF requirements into the system design.

3.78. **Issue 3:** Concerns over the cost and time impacts of the design requirements coming from HF work leads to attempts to restrict HF work.

3.79. **Solution 3:** HF work identifies requirements that need to be implemented and incorporated to ensure a safe and operable system. HF work should be presented as a means to identify potential problems before they are experienced in reality. As well as providing a safe system, it means that operational costs may be reduced, efficiencies gained, and restrictive operational practices can be avoided.

3.80. **Issue 4:** Managing the impact of technical system changes on HF work, and NR work impacting on technical system changes.

3.81. **Solution 4:** The technical systems that are operated from the control room will be updated as the project develops including the potential for HF derived requirements to be a potential trigger. HF specialists need to maintain an awareness of the design parameters that may change and how they may impact on the HF work they are undertaking. This is best achieved through close collaboration between disciplines, supported by a suitable change control process to record the changes.

3.82. Often it is necessary to progress HF analyses on the basis of assumptions about the wider design and as the design develops, assumptions are replaced with decisions. This will necessitate a check on whether HF requirements still stand or require an update in line with the developing design.

**<u>Step 5 – HF Approvals and Assurance</u>**

3.83. The approach taken to HF approvals and assurance should be consistent with the approach taken across the wider project.

3.84. The main contractor should have an internal review and approval process for all HF deliverables. Deliverables should be shared with the wider project for review, including the client's representative and HF steering group.

3.85. The review process should not be used as a way to challenge the intent of design requirements. There should be a separate process in place after the deliverable has been approved whereby the requirements are reviewed and their implementation confirmed.

3.86. The main contractor should ensure that HF issues contained within an issue log are only closed out with approval from a technically competent HF specialist (this could be the client's representative or the HF steering group.

3.87. The main contractor should have an assurance process in place that demonstrates:

- HF work was performed by technically competent HF specialists;
- Robust HF approaches have been used to deliver the HF study;
- How HF specialists were integrated into the project;
- What the outputs of the HF work were, and how they updated the system design and support the safety and business cases for the project, as appropriate; and
- How end-users' feedback contributed to the HF work.

3.88. The client's HF representative should review the HF work against the above points, on behalf of the client.

## Appendix A: Resources Supporting An OCC HFI

### A1: LRSSB Tramways Principles Guidance

1) The main contractor should ensure that HF issues contained within an issue log are only closed out with approval from a technically competent HF specialist, whether this is the client's representative or the HF steering group.

Electric Traction Systems - Central Control Facilities

2) The tramway control room should have provision for the safe and efficient management of the electric traction power supply system. Where the traffic control is located separately from the electric traction power supply control, communication facilities should be provided between them.

3) There should be a monitoring system that clearly shows the actual position or status of all monitored switches, isolators, circuit breakers or other devices controlling the power supply. This system should have provision to record all status indications, alarms and operator actions.

4) Arrangements for control of the traction supply should be such that under all conditions of the control system (whether normal, emergency or failure), a need for the emergency discharge of that supply at a particular location can be met within the response time required by the emergency services.

5) Sufficient information should be permanently displayed, or otherwise immediately available for display in the electric traction supply control facility. This will enable the person in control to:

   - Relate, with sufficient accuracy, the electrical distribution system to the geography of the tramway; and
   - Make safe the area affected by an incident in terms of tramway operations and electrical supply.

Traffic Control Room

6) The tramway operations control room and electrical control room should normally be combined.

7) The design of the tramway control room should provide a working environment that minimises distraction and fatigue to minimise the risk of error by the staff responsible for the control of operations.

8) A HF study should be carried out at the design stage or when there is a significant change to the control room or systems.

9) The integrity of controls and indications should be appropriate to the extent to which safety depends upon their correct operation. Both normal operating conditions and degraded operating conditions should be taken into consideration when assessing the risks and the level of integrity required.

10) The control room equipment essential for safe operation of the tramway should be protected from the consequences of electrical supply failure at the control room. Any loss of power or changeover to battery supplies should not cause a loss of integrity in the ability to control the system.

11) All information necessary to control the system safely should be continuously displayed. Display screens capable of showing the track layout and positions of tramstops should be provided. Display screens for the electrical supply systems should be provided that are capable of showing the locations of feeding points, and the actual position and status of circuit-breakers and section isolators.

12) If any diagram or diagrams respond to the position of vehicles, the lie of points or switches, position of circuit breakers or aspect of tram signals, such information should be clearly displayed.

13) Switching between displays in the course of an operation is not acceptable if this gives rise to a subsequent need to remember the status of relevant items.

14) A fixed line diagram or diagrams should be provided to enable operations to continue in the event that the display screen equipment is unavailable.

15) There should be a high integrity recordable telephone line for use between the local emergency services control room(s) and the tramway control room. Tramway control room staff should be made aware of any incoming calls on such a line, even if other communications systems share the same equipment. A similar line should be provided to the controlling signal equipment of any railway system that crosses or shares an alignment with the tramway. All such, communication lines should continue to function if mains power is lost at the tramway control room.

16) Whenever control room staff pass messages that are critical to safe operation, all messages should be recorded, and the recordings kept for at least 48 hours. Where safety is dependent on communications between control room staff, these communications should be similarly recorded.

Radio Communication Systems

17) An adequate system of radio communication between the tramway operational control room and trams should be provided.

18) A system allowing selective calling and identification of individual trams, or groups of trams, should be provided if instructions that are critical to safe operation are to be passed by radio. The radio system should incorporate the facility for each of the emergency services and tramway staff to use their own portable radios within their own command structure. Any such facility should be functional throughout any running tunnels and within any access shafts and cross passages.

19) Voice communications between control and the tram driver should be kept separate from those between the tram driver and the passengers so as to prevent the latter from overhearing control messages.

**A2: Resources to Support Task Analysis**

20) There are many references available that provide information on how to conduct task analysis, such as the following examples:

- A Guide to Task Analysis: The task analysis working group (1992) Kirwan, B and Ainsworth, LK. CRC;
- Cognitive Task Analysis (2000) Schraagen, JM, Chipman, SF, and Shalin VL. Psychology Press; and
- Hierarchical Task Analysis (2000), A. Shepherd. Routledge.

21) Safety Critical Task Analysis Guidance is available from the Energy Institute[3]. This guidance is especially helpful for topics relating to task screening and safety critical task identification.

Task Identification Using tram Control System Functional Requirements Specification

22) The following function list has been adapted from IEC 62290[4]. The function list should correspond with higher level tasks in the task analysis and therefore can be used to support production of the task analysis.

- Ensure safe movement of trams
  - Ensure safe route
    - Set route (inc. automatic route setting)
    - Protect route
    - Supervise route
    - Lock route
    - Release route
    - Locate trams
      - Determine location
      - Determine direction of tram
    - Determine speed restrictions
  - Permit tram movement
    - Determine limits to movement authority
    - Use signals to authorise tram movements
    - Authorise tramstop departure
  - Regulate tram movements
    - Skip tramstop
    - Restrict tram entry to tramstop
    - Hold tram at tramstop
- Manage traction power
- Manage depots and stabling areas

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3 https://publishing.energyinst.org/topics/human-and-organisational-factors/risk-management/guidance-on-human-factors-safety-critical-task-analysis2
4 IEC 62290: Urban guided transport management and command/control systems Part 2: Functional requirements specification

- Prevent collisions with persons on track
    - Warn passengers to stay away from platform edge
    - React to emergency stop request from platforms
  - Protect staff on track
  - React to tram equipment failure
  - Respond to emergency situations
    - Respond to fire and smoke detection
    - Respond to derailment
    - Respond to broken rail
    - Respond to emergency call (passenger, driver, other)
    - Respond to passenger alarm activation
    - Respond to emergency release of tram door
- Manage tram timetable
  - Select timetable
  - Modify timetable
- Manage tram service
  - Assign journeys to trams
  - Move passenger-less tram
  - Move engineer's (maintenance) tram
  - Turn back within a tramstop
  - Turn back in a siding area
  - Modify dwell time
  - Cancel trams
  - Modify target tramstop of missions or groups of missions
  - Couple and split tram
  - Set in / Set out for a mission
  - Add trams on demand
- Manage operational disturbances
- Supervise passengers and public
  - Supervise passengers on trams
    - Monitor passengers on trams
    - Communicate with passengers on trams
  - Supervise passengers and public on tramstops
    - Monitor passengers and public on tramstops
    - Communicate with passengers and public on tramstops
  - Supervise passengers and public on platforms
    - Monitor passengers and public on platforms
    - Communicate with passengers and public on platforms
  - Supervise passengers and public on the track
    - Monitor passengers and public on the track
    - Communicate with passengers and public on the track

## A3: Resources to Support Workload Analysis

23) The following workload references of analysis techniques are useful approaches for tackling workload issues:

- The Operational Demand Evaluation Checklist. This was originally developed by Network Rail and the approach has been used successfully for several signalling projects. Further details are available from the following link and from Network Rail directly[5];
- The NASA-TLX is a practical workload assessment tool[6]; **Error! Hyperlink reference not valid.** and
- ATLAS[7] was a tool developed by Human Engineering – it used task analysis output to predict workload.Error! Hyperlink reference not valid.

## A4: OCC Design

Control Room Workstation Layouts

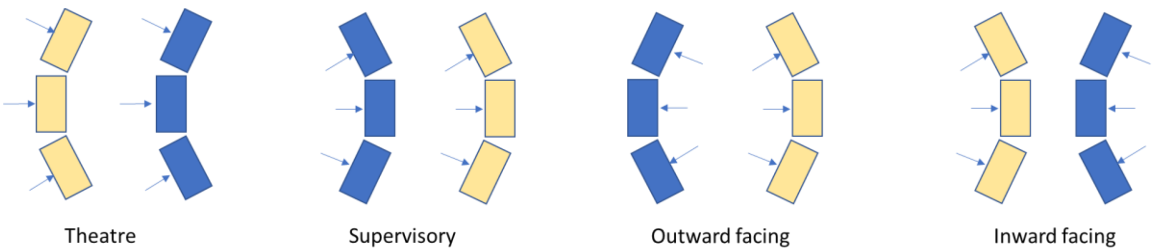
24) The overall layout of the control room should reflect the interactions between operators themselves and the equipment they are responsible for operating.

25) Those needing to communicate frequently should be located in close proximity. Similarly, where equipment is shared, this necessitates co-location.

26) Consideration should be given to non-verbal communication between operators as expressions of surprise or confusion can provide a useful cue to others about the status of the tram system. Designers tend to prioritise operators' sightlines to wall mounted screens, often showing CCTV images. If being able to easily see co-workers is important, it may necessitate duplicate wall mounted CCTV displays.

27) Figure A below Illustrates a typical control room workstation layout. The workstations shown are coloured based on function. Theatre style and inward facing layouts can support person-person interaction, whereas supervisory permits all workstations to be viewed from a single standing position, and outward facing is good for communication between the two functional teams.

Figure A - Control Room Workstation Layout Options




28) The following generic requirements are likely to apply in most situations. They should be reviewed and updated prior to adoption as part of any OCC scheme:

5 https://www.researchgate.net/publication/26881162_The_Operational_Demand_Evaluation_Checklist_ODEC_of_workload_for_railway_signalling
6 https://humansystems.arc.nasa.gov/groups/tlx/
7 https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=19175

- Task analysis should provide the basis for workstation design and equipment layout;
- Workstations should be designed to support the full range of operator anthropometry, ranging from 5th percentile female to 95th percentile male;
- Maintenance access should be considered when designing the workstation;
- Viewing distances to display screens should take into account whether multiple screens are required. If multiple screens are required, viewing distances may need to be increased; and
- Workstation design should support users of all abilities and characteristics, and be suitable for both right and left handed users.

Supervisory Activities and Provisions for Emergency Situations

29) Ensure there is sufficient desk space for supervisory activities and emergency situations, such that additional resources can be drafted in the support the control room team. For example, an additional duty control manager to oversee management of an incident on part of the network whilst the rostered duty controller oversees operation of the remainder of the tram system, including managing any special working around the incident.

30) It is useful to have a well-equipped room in the OCC that can be mobilised for occupation by an incident management team in the event of a major or catastrophic incident. Key equipment includes duplicate radio system, CCTV feeds, telephone and critical tram control equipment etc.

Example Access and Circulation Requirements

31) The following generic requirements are likely to apply in most situations. They should be reviewed and updated prior to adoption as part of any OCC scheme:

- The layout of the control room workstations and equipment should support the operational demands made on the tram system;
- The control room layout should be defined by the application of ergonomic requirements that have been informed by a HF study;
- Consideration should be given to future expansion and new technologies such that there is opportunity to integrate these effectively and efficiently; and
- The layout of the control room and workstation design should be flexible enough accommodate the needs of current and future operators with disabilities.

Example Illumination Requirements

32) The following generic requirements are likely to apply in most situations. They should be reviewed and updated prior to adoption as part of any OCC scheme:

- Lighting should support performance of all tasks in the control room, taking into account both day and night operations;
- Natural and artificial lighting should not be a source of glare within the control room;
- Contrast between display screens and their viewed background should be kept to a minimum;

- Analysis should be undertaken to confirm that distracting reflections are not experienced from the normal workstation operating position; and
- Windows should be used to provide a natural source of light and to allow sighting of the external environment as this can help relax eye muscles.

Example Finishes

33) The following generic requirements are likely to apply in most situations. They should be reviewed and updated prior to adoption as part of any OCC scheme:

- Plain, or small low-contrast patterns, should be provided for the structure, walls and ceilings;
- All finishes should be of low reflectance and preferably be a matt finish;
- Finishes should be of low contrast to any background colour or window;
- Internal glazing should not result in reflections that are visible from workstations and work areas;
- Materials should be selected based on low VOCs (Volatile Organic Compounds) as high levels may impact on human performance; and
- Gases emitted from new materials and new equipment should be allowed to ventilate after installation, and before the control room becomes operational.

Welfare and Comfort

34) The following generic requirements are likely to apply in most situations. They should be reviewed and updated prior to adoption as part of any OCC scheme:

- OCC staff welfare and comfort when away from their main workstation should be considered and incorporated into the design; and
- Access to toilets, kitchen spaces, refreshments, prayer spaces, rest spaces and other facilities that support effective rest and recuperation, and therefore the concentration and focus of OCC staff, should be considered as part of the design.

**A5: Human-Machine Interfaces, Controls and Displays**

35) The following generic requirements are likely to apply in most situations. They should be reviewed and updated prior to adoption as part of any OCC scheme:

- There should be a clear HMI design philosophy that supports all interactions with the system and covering the following: control inputs, system monitoring, visual information, vibration warnings and alarms and alerts etc;
- Interactions with the system should be intuitive and consistent with the design providing suitable guidance during task execution;
- Human error and reliability should be considered when designing control interfaces and displays;
- The design should be error tolerant whereby incorrect control inputs should be identified and fed-back to the user;
- Safety critical control inputs should be accompanied with suitable measures to prevent unintended consequences associated with inadvertent use;
- Requirements around manual data entry from the operator should be kept to a minimum; and

- All information that the operator requires to perform tasks should be available in a timely, effective and efficient manner.

36) Only valid information should be displayed to operators. Where equipment or operational status is not known, older information may be displayed only with suitable indication highlighting that it may have been superseded.

## Appendix B: Source / Related Documents


- EN 50668 (2019) Railway applications - Signalling and control systems for non UGTMS Urban Rail systems
- EN 62290-1 (2014) Railway applications - Urban guided transport management and command/control systems - Part 1: System principles and fundamental concepts
- EN 62290-2 (2014) Railway applications - Urban guided transport management and command/control systems - Part 2: Functional requirements specification
- EN 62290-3 (2014) Railway applications - Urban guided transport management and command/control systems - Part 3: System requirements specification
- ISO 6385, 2016, Ergonomic Principles in the Design of Work Systems
- ISO 11064, 2016, Ergonomic Design of Control Centres; Parts 1-10.
- ISO 9241, Ergonomic requirements for office work with visual display terminals; Parts 1-17
- ISO/TS 18152, Ergonomics of Human System Interaction
- NR/SP/ERG/24017 Control Room Design Specification, Process and Guidance Network Rail (2004)
- NR_L2_ERG_24020 Engineering assurance arrangements for Ergonomics within design and development projects Network Rail (2012)
- NR_L2_MTC_PL0175_04 Daily and weekly visualisation control room meetings Network Rail (2018)
- NR/L2/SIG/11201; Module A5-5 Signalling Control Centres Network Rail (2018)
- Near miss of two track persons by a tram on the Manchester Metrolink, Radcliffe 8 November 2005 RAIB (2006) https://assets.publishing.service.gov.uk/media/547c906ced915d4c1000019f/R092006_060717_Radcliffe.pdf
- Derailment at Phipps Bridge, Croydon Tramlink 21 October 2005. https://assets.publishing.service.gov.uk/media/547c9073ed915d4c0d0001bb/R042006_060329_Phipps_Bridge.pdf RAIB (2006)
- Fatal accident near David Lane tram stop 15 August 2016. https://assets.publishing.service.gov.uk/media/58e4defce5274a06b30000dc/R062017_170405_David_Lane.pdf RAIB (2017)
- Embedding good human factors in complex, multi-disciplinary engineering projects, Hillier Gemma; Wright Karen; Grimes Elaine Mott MacDonald March (2009)