A POSITION PAPER ON HUMAN FACTORS APPROACHES FOR THE DESIGN OF VDU INTERFACES TO COMPUTER-BASED RAILWAY SIGNALLING SYSTEMS

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The introduction of computer-based systems for the control and protection of trains has led to the development of a wide variety of control interfaces based on VDU technology. This mirrors trends in other industries, where there is growing concern that changes in the role of the operator coupled with inappropriate display design is resulting in reduced operational safety. In response, HSE has recognised the need to provide companies with practical guidance on the safety related aspects of the design of VDU interfaces. As an initial step, a position paper was commissioned to examine the current status of human factors techniques, standards, guidelines and research relating to operator interface in process control plants. This paper considers how the findings for the process industry apply to the context of railway signalling and control systems. Conclusions are drawn on the practicality of generating human factors guidance on the design of VDU interfaces to computer-based railway signalling systems.

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1.0 INTRODUCTION

1.1 BACKGROUND TO PAPER

The introduction of computer technology into railway industry applications has led to significant changes to the role of the signalman in railway signalling centres. The manual control and scheduling of trains is rapidly being automated for the purpose of improving the reliability and frequency of traffic services. This removes a large proportion of the routine scheduling, routing and control tasks undertaken in less automated signalling systems. As a result, the primary tasks of the signalman are to monitor traffic patterns, resolve any conflicts or problems that arise, act as a communications manager and respond to any malfunctions or incidents that may occur.

The trend towards computer-based systems for railway control applications has inevitably led to the introduction of VDU-based interfaces in a wide variety of control room contexts. In the signalling centre, VDU consoles are rapidly replacing wall-mounted track diagrams for train control and monitoring. VDU-based systems are also being introduced for controlling track current on electrically powered systems, station management and for communications management. The presentation of information on these displays, the facilities provided to enable the user to enter commands and the implementation of VDU technology in the control room environment can have an impact on the effectiveness of user tasks and in some circumstances, on the safety of train operations.

The underlying safety of train operations is maintained by high integrity interlocking systems, which prevent both the signalman and automatic train scheduling systems from setting routes or operating signals that would potentially lead to a collision. Therefore, in the majority of circumstances, the safety of operations is protected from the impact of any human errors made by signalling staff. However, the accuracy of human actions could become vitally important under emergency or system failure conditions. In such cases, operational safety tends to depend upon careful adherence to established operating rules by a variety of personnel, including train drivers, station staff, line controllers, lineside staff and other engineering staff. Whilst such events are limited in number and infrequent, the potential for human error is high. Increasing levels of automation can result in unfamiliarity and information overload under failure conditions. Unless steps are taken to ensure control skills are maintained and information displays are carefully designed, such events can become a serious threat to safety.

The Health and Safety Executive (HSE) recognises that it is important for companies to effectively manage human factors as a part of maintaining safety. The guidance booklet "Human Factors in Industrial Safety" (HSE, 1989) is intended to alert managers to the issues involved by the use of pertinent examples and by suggesting a control strategy to reduce risks. This booklet identifies the need for more specific guidance to address particular human factors issues, including the design of operator interfaces to control systems.

Concerns regarding deficiencies in the design of operator interfaces in computerised process plants, led the Control Systems Group of HSE's Technology Division to request the preparation of a position paper (Cary, 1992). This provides a summary of; the available human factors techniques, relevant standards work, current practices during the design of installations plus recent and ongoing research programmes related to the operator interface on computerised process plants. It was recognised that the findings of this paper may also have relevance to the design of VDU-based systems in railway control applications. Therefore, the Control Systems Group, on behalf of HM Railway Inspectorate, requested the preparation of this additional short paper to discuss how the findings concerning process control systems may apply to the railway context. The HSE intends to utilise this information during the development of practical guidance for industry, in order to ensure that the advice is relevant and does not duplicate work taking place elsewhere.
1.2 OBJECTIVES

The objective of this paper is:

To summarise how available human factor design and evaluation techniques, standards, guidelines, handbooks and research findings as identified in the previous position paper (Carey 1992) can be applied during the development of VDU interfaces to railway signalling systems.

1.3 SCOPE

The focus of this paper is on the various controls and displays utilised in computerised railway control centres. This is taken to primarily involve VDU-based systems and panel-based overview track diagrams. Whilst it is recognised that computer-controlled railway systems may be operated from wall panel displays, this paper does not address the detailed human factors design and layout issues raised by such interface technologies.

This paper provides a brief overview of the issues involved, making particular reference to the detail presented in the previous position paper for the process industries (Carey, 1992). It may be useful to refer to this more detailed treatment of individual issues for additional background information.

It is noted that focusing on the signalling system interface excludes a number of key human factors issues that will also have an impact on the safe operation of a railway system. For example as illustrated by the accident at Clapham Junction in 1988, attention must be given to all aspects of the life cycle of a safety system, from design through installation, and operation to maintenance plus final decommissioning (Hudden, 1989). An overview of the breadth of human factors issues within passenger rail transport has been provided in a recent paper (Wiatley and Carey, 1990).

1.4 SAFETY-CRITICAL ASPECTS OF VDU INTERFACE DESIGN

To assist in the preparation of this paper, a number of visits were made under the guidance of H M Railway Inspectorate to sites where VDU-based signalling systems were in use or under development. This led to the identification of a set of generic signalling tasks where the actions of signalling staff can be important to maintaining safety. Each of these tasks make particular demands upon the detailed design of the signalmen's interface to signalling and other systems. These tasks are as follows:

(i) Manual control of trains following signalling or interlocking failure
(ii) Direction of trains in the event of track circuit failure or short-circuit
(iii) Protecting a track possession (i.e. permanent way staff on track)
(iv) Instructing a train to proceed with caution due to reports of items on track, persons on track or vandalism
(v) Removing traction current (i.e. third rail power when evacuating train, overhead lines blown down on track)
(vi) Handling of train stoppages in tunnels
(vii) Protecting a runaway train
(viii) Setting back an overrun train (i.e., train overrun signal into next block)
(ix) Non-stopping trains through a station
(x) Controlling trains to evacuate passengers from a platform
(xi) Responding to train diagnostic messages

Each of these tasks is described and analysed in Appendix A. The particular task requirements identified cover a wide range of generic issues related to VDU interface design. These include:

(i) Overview displays: In a number of tasks, the signalman requires an overview of train movements in order to plan routes.
(ii) **Detail displays**: Clear displays of system status information are required, such as point settings and signal aspects. The signalman also requires specific details on signal numbers, trackside features, tunnels etc., at various times.

(iii) **Rapid safety actions**: Tasks such as setting signals to red or directly stopping trains may need to be performed rapidly and to a high degree of reliability. The interface operations to carry out such actions need to be simple and consistent.

(iv) **Alarms**: A number of events need to be quickly brought to the signalman's attention. As safety-related events, these are of a high priority. The alarm facility needs to attract the signalman's attention and then provide a means of identifying the alarm.

(v) **Operations**: A limited set of train control and safety-related operations need to be carried out accurately to maintain safety. These include instituting protection for a track possession, setting routes and non-stopping of trains. It is important to ensure that such operations are consistent in their structure of basic input actions and, provide clear confirmatory feedback.

(vi) **Communications**: The majority of the tasks listed in Appendix A involve communications of some form. The quality of communications procedures can have a significant impact on success during such tasks. The detailed discussion of communication systems is outside the scope of this paper, though the key role that communications can play in task success should be noted.

Issues of relevance during the design of VDU interfaces for railway application have much in common with the key issues involved in the design of VDU interfaces for process control applications. As in process applications, there is a need to provide both overview and detailed information on system status. In both cases, dynamic wall-mounted mimic displays can be very useful for the purpose of providing an overview of operations. In general, however, the amount of information that has to be shown on railway signalling displays is far less than that required for an average process plant. The number of pages of information needed in a VDU based system is therefore far less which reduces the problem of navigation between displays.

Similarly, the handling of alarms is an issue for both process control and railway applications. The number of potential messages generated in computerised railway signalling systems is gradually increasing as further sub-systems are added. However, the range of alarms that have a safety significance are relatively few, suggesting that an effective prioritisation of alarms should not be too difficult to achieve in railway signalling applications.

In comparison to process control systems, the input actions required to operate a signalling system can be slightly more complicated, requiring particular attention to be paid to the simplicity and consistency of input operations.

In summary, the design of VDU displays and input mechanisms is of central importance to a range of safety-related signalling tasks. Many aspects of display and control design in railway signalling applications have parallels in process control systems, suggesting that a common set of design principles could be developed to bridge both application areas.
2.0 HUMAN FACTORS DESIGN AND EVALUATION TECHNIQUES

The previous position paper (Carey, 1992) described a wide range of human factors activities that can be carried out during the implementation of a computer-based control system. These were broadly classified into seven main activities:

(i) Defining operational philosophy  
(ii) Assessing task demands  
(iii) Establishing design standards  
(iv) Designing displays  
(v) Designing the workplace  
(vi) Designing user support  
(vii) Consulting users

Each of these activities has potential application in the design of VDU interfaces to computer-based signalling systems. Detailed descriptions and discussions are provided in the previous position paper. The particular areas of application during the design of railway signalling centres are discussed in the following sub-sections.

2.1 DEFINING OPERATIONAL PHILOSOPHY

Within process industry applications, it is important to identify who will use the information and interfaces provided to a control system (e.g. shift process operator, supervisory staff, maintenance engineers) and to define the most appropriate level of process automation to ensure overall plant safety. The same aspects need to be considered for railway signalling applications.

In the majority of cases, the signalman will be the primary user of information displays. However, they may still be occasions where the same display system is utilised by engineering personnel, or in the event of an emergency, by senior supervisory staff. In these cases consideration needs to be given to the specific information display needs of each user group and any security aspects related to granting access and control privileges. There is value, therefore, in precisely specifying the groups, aptitudes and likely levels of experience of the key system users early in the design or system procurement process.

Decisions on the appropriate level of automation for the control of railway traffic is particularly important with regard to train scheduling. Whilst it is clear that automated train scheduling systems can generate much more efficient routing and scheduling of trains, this can lead to problems when such systems fail or need to be overridden for safety purposes. It is particularly important that the signalman builds up and maintains a level of skill in manual train control operations. This may be attained through providing opportunities to operate the system manually (Lucas, 1989). It is essential, therefore, to explicitly consider the allocation of control and safety monitoring tasks between the signalman and automated systems.

2.2 ASSESSING TASK DEMANDS

For both process control and railway signalling applications it is important to assess the level of mental and physical demands likely to be generated by key safety-related tasks. This can be achieved through a combination of methods of describing and formally assessing operational tasks.

Similar hierarchical and tabular methods of task description can be applied to signalling tasks as are applied in the description of process operating tasks (Carey 1992). These are most appropriate for routine or procedural tasks requiring a clear, identifiable sequence of activities. As in process control applications, the main problem lies in the description and subsequent analysis of highly cognitive tasks, such as the planning required to avoid stopping trains in tunnels, to control a runaway train or to control a train for evacuation purposes. Current cognitive task
description techniques can be complex to apply and are limited in scope. However, the range of complex cognitive tasks appears to be comparatively limited, consisting primarily of route planning operations. There is, therefore, greater opportunity for such techniques to be successfully applied.

The assessment of signalling tasks can utilise the same generalised techniques as applied to process control tasks:

(i) Timeline analysis may be used to examine dependencies in time critical tasks, such as removing traction current under emergency conditions. This may include estimates of the time required to locate relevant information, perform critical control actions and communicate with collaborating personnel.

(ii) Link analysis would be applicable where train and control information is distributed across a large number of VDU display pages. This would provide an analysis of the efficiency of the physical and visual movements required to access information over a set of critical tasks, and therefore provide a check that information is suitably located on and between VDU display pages.

(iii) Workload analysis is of importance in ensuring that signalling personnel are not underloaded, overloaded or allocated a disproportionate mixture of task activities. In particular, it facilitates the assessment of the impact of increased automation and reductions in staff numbers.

(iv) Human error analysis can be applied effectively to the types of safety-related tasks described in Appendix A. This may involve the application of human error identification and error cause analysis techniques.

(v) Techniques for analysing task complexity are well-suited to the evaluation of the interaction dialogues implemented for basic tasks such as setting signals to danger and implementing track protections.

2.3 ESTABLISHING DESIGN STANDARDS

The development of company-specific human factors design standards would be of value in both the railway and process industries. It would be useful, for example, to develop in-house standards relating to the control room environment in signalling centres and console ergonomics. Where appropriate, it would also be of value to standardise aspects of screen display design for track layout and other similar displays. Where system implementation is to be carried out by a third-party supplier or contractor, various approaches are under development for the rigorous specification of user requirements. Three particular methods are described in the previous position paper:

(i) The Human Computer Interface Requirement Specification (HCIRS) technique that provides guidelines for generating project specific human factors requirements (Chapanis and Budurka, 1990).

(ii) The definition of usability goals that describe a target level of performance that must be achievable by a signalman for critical tasks (Rengger, 1990).

(iii) The specification of a required human factors development process and key deliverables to be followed by a contractor during the design process (e.g. HUSAT, 1988).

Common design standards should be easier to achieve and to enforce in the railway context than in process control, as all signalling centres are likely to use the same interface equipment and in most cases, will already be operating using similar equipment and procedures.

2.4 DESIGNING DISPLAYS

A number of key issues need to be resolved in the design of VDU interfaces for use in signalling centres:

(i) How many VDU display screens should be provided?
(ii) What level of detail and amount of information should be shown on each VDU display?

(iii) How should the rail network be sub-divided for display purposes?

(iv) How should the VDU displays be structured and linked to provide rapid and easy access to information?

As indicated in the previous position paper (Carey, 1992), a number of these issues require further research in order to provide definitive guidance. However, there are a number of useful techniques that can be applied to resolve some of these questions.

2.4.1 Information Requirements Analysis

An analysis of the information required during safety-related operations can be carried out on the basis of task descriptions as described in Section 2.2. Such analyses are useful to identify key items of information required by a signalman in safety-critical tasks. This may include important information from adjacent signalling sections or from other systems such as the power distribution or timetabling system.

In comparison with process control applications, the ‘mapping’ of derived information requirements onto to appropriate displays should be a comparatively simple process. The majority of information can be shown on track diagram displays.

2.4.2 Utilising Operational Knowledge

Existing signalling staff can provide a valuable source of knowledge and experience for use during the assessment and development of displays. The method described by Van der Schaff (1989) is a comprehensive and structured approach to consulting users during the design of displays in process control applications. The general procedure involves the design of a small prototype set of displays in conjunction with operators, the implementation of the displays in the control room and their evaluation. On the basis of the results, guidelines are produced for the generation of a full set of displays.

The general principles involved when consulting system users would also be valid in railway signalling applications. There may be an opportunity to implement a new display system alongside existing displays and controls in a signalling centre. However, this particular technique focuses on selecting the most important individual items of information for display on overview displays and the most appropriate linking for ‘paging’ between consecutive displays. Such decisions tend to be far less complex for signalling display systems and would not require the detailed approach proposed by Van der Schaff.

2.4.3 Prototyping Interface Designs

Early prototyping of display design concepts may be of particular value in railway signalling applications. Such prototypes can range from static mockups through to fully operational example displays. The value of utilising such displays at an early stage of design is to reveal potential problems in the use and construction of a full set of displays prior to their development. The key aspect of this approach, however, is not the development of such displays, but their systematic evaluation through structured gathering of opinion and performance data. In comparison to process control applications, it is a relatively simple task to simulate rail traffic in order to animate such displays to provide a realistic test of user performance.

2.4.4 Evaluation of the Completed System

Once detailed display designs are finalised, it is possible to apply a number of techniques to evaluate their adequacy, particularly with regard to safety-related tasks.

(i) Checklists may be applied to check the compliance of the completed design with general human factors principles or specific requirements laid down in standards or project guidelines.
(ii) The task descriptions for safety-critical tasks, such as those outlined in Appendix A, may be utilised in a scenario analysis. Most of the tasks described involve a specific series of actions to be carried out, and it would be possible to identify potential error modes, their consequences and their causes.

(iii) Operational personnel may contribute in a number of ways to the evaluation of a full system. As indicated in the previous position paper, a range of approaches can be applied including panel sessions, questionnaires, empirical studies and full simulation trials.

(iv) Aspects that cannot be judged against precise requirements or a task-based evaluation may only be analysed and justified on theoretical grounds. Such evaluations may be carried out by 'experts' or commissioned as an independent peer review of a system (e.g. Lucas, 1989).

(v) Once a new signalling system is installed, it may be appropriate to carry out full operational assessments. This may require a range of data collection techniques to be used such as post exercise questionnaires, debriefings, logging of operator input actions, observation or video recording of activities.

During the operation of a new signalling centre, there may be scope for formalising feedback routes regarding problems and errors in the use of the new interface facilities. This may be achieved by a Confidential Incident Reporting System or by a review carried out after a period of full operation.

2.5 DESIGNING THE WORKPLACE

Aspects of the physical design of the workplace, including workplace layout, console design and environmental factors, are very similar in both the railway signalling and process control environments. The only significant difference between the two environments is the generally more sophisticated nature of the telephone, radio and public address facilities required in signalling centres.

Techniques for control room design are fairly well advanced. Issues of layout can often be resolved 'on the drawing board' utilising link analyses based on task descriptions. Console dimensions can be derived based on anthropometric data (e.g. Invegaard, 1989; Panzer and Zelnik, 1979). Similarly, the design of lighting arrangements and other environmental aspects are covered by existing guidance, analytic and measuring techniques (e.g. CIBS, 1984).

2.6 DESIGNING USER SUPPORT

In common with VDU systems in process applications, the provision of well designed documentation and training can be an important determinant of the effective use of system facilities. A limited amount of guidance is available on the design of effective user documentation (Simpson and Casey, 1988). The theory and practice of training design is a well developed discipline in its own right. In addition, it is possible to formally evaluate system documentation and training during the later stages of design and commissioning.

2.7 CONSULTING USERS

Signalling personnel can provide a valuable contribution to the interface design process in a variety of ways. Whilst signalling staff are unlikely to be directly involved in authorising design decisions, they can make valuable inputs as experts on signalling tasks, they can provide opinions on design options and can evaluate part or finished designs.
3.0 HUMAN FACTORS STANDARDS GUIDELINES AND HANDBOOKS

The previous position paper (Carey, 1992) lists and reviews a wide range of standards, guidelines and handbooks that may be applied during the design of the operator interface for computerised process plants. These cover control room layout, the working environment, console design, VDU interface design and general human factors design approaches. Many of these documents have been developed specifically for the process industries. There does not appear to be similar initiatives in the railway industry. However, there is a large degree of commonality between design requirements for process and signalling applications. Therefore much of the information is applicable to the design of signalling centres but requires some interpretation.

3.1 THE EEC SAFETY DIRECTIVES

Two recently issued EEC directives are predicted to have a major impact upon the implementation of human factors standards across a wide range of commercial and industrial sectors within the UK. These are as follows:

(i) The VDT directive (90/270/EEC) specifies minimum safety and health requirements for work with display screen equipment. This includes the physical attributes of display screen equipment, the working environment, console design and the ease of use of the software provided.

(ii) The Machine Safety directive (89/392/EEC) specifies minimum safety requirements for items of machinery. The scope of this directive includes the interface software between an operator and a machine control system. The term 'machine' is being interpreted widely and may apply to some applications in the railway's industry.

The directives will be enforced via regulations issued and policed by the HSE (HSE, 1992). The impact of these developments upon the design of VDU systems in railway applications remains to be seen.

3.2 CONTROL ROOM AND WORKSTATION DESIGN

The theoretical basis underlying the physical design of workplaces is relatively well developed. Standards and guidelines in this area give explicit advice on the minimum and maximum physical dimensions of operator consoles, the precise visual performance requirements of VDU displays and give measurable minimum comfort requirements for the working environment.

Key standards and guidelines in this area are as follows:

(i) Part 3 of ISO 11064 is currently under development providing a detailed specification for the physical design of control room workplaces.

(ii) ISO 11064 is based upon DIN 33414, a published German standard on the design of control rooms. Not all parts of this standard are available in English translations.

(iii) BS 5940 and BS 3044 address the design of furniture for office environments. This has some relevance to control room applications.

(iv) The visual aspects of VDU's in the workplace are covered by BS 7179, ISO 9241, ANSI 100, Gilmore (1985) and the VDT Manual (Cakir et al, 1980).

3.3 VDU INTERFACE DESIGN

Published standards and guidelines for the design of VDU interfaces are limited. In response to this, considerable effort is being put into the development of ISO 9241, which will represent the main standard for application to the software interface of computer-based systems.
Parts 10 to 19 of ISO 9241 provide an overview of software ergonomics principles stating detailed requirements for the presentation of information on displays, user guidance and particular forms of interactive dialogue. Part 11 is key to the design approach to software ergonomics envisaged for ISO 9241. This defines the concept of a 'usability statement', which may be defined by a developer or by a customer/client organization. This can take the form of a statement of usability requirements for a product, as a statement of the level of usability achieved or as a statement of conformance to particular standards. The remaining parts (Parts 12 to 19) will provide specific design requirements for VDU information presentation.

ISO 9241 is still under development. Based on the level of detail provided in the currently available parts of ISO 9241, it should give a relatively detailed and comprehensive coverage of VDU dialogue design issues. However, the primary focus of application of this statement is in office computing applications. Therefore, it is unlikely to cover all of the specialized design issues that would be faced in the design of a VDU-based signalling system.

The most extensive set of detailed design guidelines available are produced by Smith and Mosier (1986). These have emerged as a standard reference for human-computer interface design, though it is recognized that there can be severe problems in their application, particularly where the advice given is conflicting or contradictory when applied to a specific design. As with ISO 9241, these guidelines do not cover the range of specialised design issues raised by signalling type applications.

A particular area where guidelines would be of value is in the presentation of warning and alarm information on signalling systems. This is an area where some detailed guidance is available in the guideline documents relating to process applications. For example, this area is covered by the Human Factors in Reliability Group Guides (HFRG, 1987 and HFRG, 1991) which provide lists of questions relevant to the design and implementation of process control room facilities. This covers VDU systems in the control room and many aspects of the advice would apply in the railway signalling area.

A complementary approach to the human factors aspects of computer-based systems is taken in the HUSAT Human Factors Guidelines (HUSAT, 1988). The six volume set provides a detailed specification of a human factors design process for computer-based systems. This indicates the activities to be performed at each stage of the design lifecycle, the deliverables to be produced and the managerial control required. The guideline does incorporate some specific advice covering aspects such as workplace dimensions and interaction design. The recommended design process is very rigorous and would be expensive to apply to its full extent. Where a new system is being developed in-house, there are aspects of the recommended design process that could be applied to good effect.

In general, the design issues relating to the design of VDU-based signalling systems are less complex than those encountered in the design of process control systems. The number of display formats, for example, are generally fewer, centering around an interactive version of the track layout diagram. Many of the detailed design issues relating to display density, navigation between displays and alarm system design are common between process control and railway applications. There is a gap in the coverage of such issues by existing standards and guidelines, but there does appear to be scope for producing generic guidance that would meet the needs of both industrial sectors.

3.4 INFORMATION CODING AND PRESENTATION

The careful and consistent design of coding methods on VDU displays is an important component in supporting the task of monitoring train operations and minimising the potential for errors when reading displayed information. Key aspects are the selection of colour codes and the specification of standard symbols for items such as signals and points.

Standards on display coding for signalling applications are very limited. General purpose standards providing colour definitions (e.g. BS 381C) and colour codes for safety-related controls (e.g. BS 4099, BS 5578) are of value in the specification of colours but provide little assistance in the selection of appropriate colour sets. In most signalling applications, some colours will be directly determined by existing colour coding standards for signal aspects and other colour codes utilised on previous generations of panel displays and controls. There is scope for providing additional guidance and suggested standardised colour coding schemes specific to signalling applications (e.g. red indicating occupied track block).
There is notable variation between the symbol coding schemes applied on VDU-based signalling systems. There are a number of ways, for example, of indicating point settings and designating signal locations. Unless it can be shown that there are circumstances when signalling staff would frequently swap between systems from different vendors, there is likely to be little merit in seeking to establish uniform conventions on symbols for such displays. Statements of general principles in the representation of track diagrams and signalling information could be generated and supported by examples from existing systems.

In summary, there is a need and scope for additional guidance on the coding and presentation of information on VDU displays. Many of the basic principles of colour coding and graphic design are general in nature, and could be applied across a range of industrial control contexts. Examples of colour codes and symbol designs specific to each context would also be of value.

3.5 SYSTEM DOCUMENTATION

Standards and guidelines on user documentation design are few in number. BS 4886, for example, is directed towards the standardisation of the content and presentation of technical manuals. The process that should be followed in creating user documentation is currently the subject of standardisation activities by a BSI committee (BSI Technical Committee IST/18). A very limited number of human factors texts are available that address this issue directly (e.g. Simpson & Casey, 1988).

Well-designed documentation can be an important factor in ensuring the effective and efficient use of the facilities provided on a VDU-based system. There would be benefits in stating a set of key principles for user and technical documentation design in the form of design guidelines.
4.0 THE SCOPE AND DIRECTION OF CURRENT RESEARCH

As identified in the preceding position paper for the process industries (Carey, 1992), within many areas of human factors research, current knowledge is sufficiently well developed to provide the basis for clear prescriptive advice and the development of analytic techniques. However, there are particular areas where key research questions remained unanswered, rendering it difficult to provide well-founded and authoritative advice. This is compounded by advances in computing technology continuing to introduce additional areas of uncertainty. Particular areas of research knowledge were identified as high priority in the provision of guidance for process industry applications, including improved models of operator cognition, alarm handling philosophy, VDU format design for monitoring and diagnosis tasks, and navigational requirements within VDU display structures. Many of the conclusions drawn in the previous paper can also be applied to the domain of railway signalling systems. This section therefore concentrates on identifying any common or additional requirements that apply to railway applications.

4.1 IDENTIFICATION OF PRIMARY SAFETY-RELATED TASK REQUIREMENTS FOR RAILWAY SIGNALLING APPLICATIONS

As an initial step in providing guidance on the design of VDU-based signalling systems, it is important to identify the safety-critical aspects of signalling tasks and the resulting display requirements. The descriptions and analyses presented in Appendix A may be useful in this regard. However, these are constructed on the basis of a short survey and further work would be needed to generate a comprehensive definition of task interface requirements. It needs to be clearly established which aspects of the VDU system design are critical for operational safety. This would provide a useful mechanism for prioritising guidance and focusing design effort on those aspects of greatest importance.

4.2 THE TRADE-OFFS BETWEEN PANEL AND VDU DISPLAYS

The predominant trend in display systems for signalling applications is away from track layout control panels towards VDU-based display systems. VDU displays offer more flexibility both in the presentation and integration of a wide variety of computer generated information as well as offering cost savings. However, there is a danger that the move towards VDU-based presentation of signalling information will reduce the signalman's overview of traffic movements, particularly in circumstances when such an overview is vital to taking rapid, decisive actions to prevent a potential accident.

The decision whether to implement a panel track diagram display in a control room depends to a large degree upon the extent to which the section of track covered by a console can be displayed in its entirety on the number of VDU's provided. The IECC (Integrated Electronic Control Centre) system developed by British Rail is in most current applications able to display the area controlled by a signalman on two of its four VDU displays. Such systems are therefore implemented without an additional panel display of train movements. Similarly, the control centre for the light rail system installed at Stanstead Airport utilises VDU displays only, since it is possible to show all of the network on a single display. However, in the event of the failure of the VDU display system, a portable traffic control panel can be plugged in. In comparison, a panel track diagram display was included in the London Underground Jubilee line signalling centre to supplement VDU displays. This was found to be necessary to provide an overview of traffic patterns along the entire line, particularly under failure conditions.

The key issues that need to be addressed are:

(i) What level of overview of traffic movements is maintained or needs to be maintained by signalling staff?

(ii) What are the tradeoffs between alternative methods of providing overview information (e.g. panel vs paged/ fixed VDU's)?

(iii) What is required to cope with console or interlocking failure conditions?
The answers to the above questions are not entirely clear. The need to provide a panel display in addition to VDU displays is likely to depend upon a number of contextual factors. In order to provide appropriate guidance, a clearer understanding is required of the particular information needs of safety-critical signalling tasks.

4.3 ALARM HANDLING PHILOSOPHY ISSUES

Computer-based signalling systems can generate a range of alarms, warnings and messages that need to be brought to the attention of the signalman. The number and potential arrival rate of such messages is likely to be less than that on an average process control plant under failure or deviant conditions. In addition, only a small proportion of the messages will have safety consequences (e.g. failure of an interlocking, signal overrun). In most applications, an appropriate mode of presentation could be arrived at by utilising the existing guidance available in the process control domain. There is no immediate need for further research to underpin such advice for use in railway signalling applications.

4.4 DECISION AIDS AND AUTOMATIC TRAIN SCHEDULING SYSTEMS

The introduction of sophisticated computer programs for the scheduling and routing of railway traffic raises specific human factors issues. For example, it is important to establish the extent to which a signalman needs to be able to monitor and evaluate the quality of advice given by such aids. In addition, it is vital to consider the impact of using such technology on the signalman’s ability to manually schedule traffic in the event of the failure of an automatic train scheduling system. In the majority of cases the consequence of errors in such manual operations are protected against by safety interlocking systems. However, in the event that a signalling area has to be operated manually without the protection of an interlocking, the development and maintenance of the signalman’s skills in traffic control would be vital.

The issues surrounding the support and maintenance of operator skills in highly automated systems are of general importance. There is a justifiable concern that highly automated systems can de-skill their user, thus reducing their capacity to intervene or regain manual control under system failure conditions (Bainbridge, 1987). The impact of such automation in signalling systems is worthy of further study.

4.5 ACCESS TO INFORMATION ACROSS MULTIPLE VDU DISPLAYS

Three primary factors interact to determine the ease of access to information on a VDU-based system:

(i) The number of display screens provided

(ii) The relevance of the information content on each display page

(iii) The ease of navigation through the display structure

These are each critical issues in the design of VDU systems for process plants. Signalling applications, however, are generally less complex for three main reasons; a single form of information representation is appropriate for most purposes (i.e. the track layout diagram), distinctions between critical information (e.g. point settings, signal aspects, track locations) and non-critical information (e.g. track circuit numbers, signal numbers) are self-evident, and the size and complexity of a track section controlled from a signal console is usually limited. Signalling display systems can therefore be designed around an interactive version of a track layout diagram, suppressing non-critical information unless specifically requested. Overview displays can be restricted to showing main lines and station layouts, and are capable of being displayed in their entirety on two or three VDU screens. As a result, it is generally easier in signalling applications to identify the necessary number of display screens and the information contents of each display page.

Navigation between page in the main display structure and access to additional auxiliary displays is also made less complex than in process control applications. However, it is still possible to generate access structures which make information access slow and difficult. Current research findings apply to menu access structures and to some aspects of panning and scrolling across a large track layout diagram. It is still necessary to define the basic parameters of what renders a display access structure easy or difficult to use.
4.6 DETAILED DISPLAY DESIGN

As already stated, signalling system displays are based on a track layout diagram. Important issues are the use of colours, symbols, text codes and general graphical design.

The use of colour is recognised to be a powerful coding medium for identifying and distinguishing between items on a display. However, it is easily misapplied resulting in displays which are hard to read and visually fatiguing. Similarly, graphical symbols of various types are of use to identify signal positions and other trackside features. Textual codes are widely used for identifying trains (header codes), track circuits and signals. Each of these aspects of display design have been subject to a substantial amount of basic research which can form the basis for authoritative guidance.

Graphical design considerations in the construction of a track layout VDU display include decisions such as the simplification of track layouts for screen representation, ensuring the display is not cluttered or confused in particular areas (e.g. major junctions) and the size and positioning of text labelling to clearly identify stations and junctions. Outline guidelines for such design tasks are unlikely to require further detailed research. There are, however, still aspects of graphical design where it is difficult to give precise advice, such as the factors which influence perceived clutter and the resulting effects on user performance. This is a key issue in the design of all graphical schematic displays. Further research work would be of benefit to clearly establish the basic parameters that underly good visual performance when using graphic displays.

4.7 SELECTION OF INPUT DEVICES

As in process control applications, a wide range of input and combinations of input devices can be applied to signalling tasks. The correct selection and implementation of an input device is important. Poorly chosen devices may increase error rate, slow down the response to an incident and frustrate users.

The comparative performance aspects of different forms of input devices have been studied widely and some general conclusions can be drawn (Carey 1985). Continuous technical developments are likely to result in some changes to the tradeoffs currently established. Whilst there is a need for guidance, at present this area does not merit further empirical study.

4.8 INTERACTION DIALOGUE ISSUES

The forms of human-computer interaction in signalling systems can be slightly more complex than those required in process control applications, particularly with regard to interactions with automatic train scheduling systems and manual setting of routes. In the majority of cases, existing guidance and research findings should be sufficient to cover the different types of interaction.

The current move towards the use of windowing and direct manipulation techniques will require careful handling. Whilst standardised windowing environments and interface style guides should assist in ensuring good practice is adhered to, it will still be possible to produce interfaces which are complex and confusing to use. There is also the danger that overlapping windows will result in important information being obscured when it is required. Research specific to control room applications of this technology would be of benefit to ensure such technology is applied effectively.

4.9 SYSTEM RESPONSE TIME

The speed of response of a VDU display system to a user input or request for information may determine the speed and effectiveness of actions in safety-critical tasks. Slow response times can also have a significant effect upon the level of satisfaction of a user with a system.

The majority of empirical studies on this issue have been directed towards office-type tasks. However, it is possible with discretion to extract relevant data to apply to the types of tasks encountered in signalling applications. The current level of research knowledge is generally sufficient to provide both a preferred and an absolute maximum system response time for most operations.
4.10 DESIGN ISSUES FOR PANEL TRACK INDICATOR DIAGRAMS

There is considerable experience within the railway industries relating to the design and use of panel track indicator diagrams for traffic control and monitoring. The role of panel track indicator diagrams in VDU-based signalling control centres is slightly different. They provide overview information on traffic patterns with only limited facilities for manual control of train movements. Key issues relate to the size and positioning of such panels such that their details are visible from a seated console and the design of embedded controls for manual operations. In each of these areas, sufficient information should already be available, so this does not merit further research.
5.0 DISCUSSION

5.1 COVERAGE OF EXISTING GUIDANCE

The preceding sections have summarised the availability of appropriate human factors techniques, standards, guidelines, handbooks and research knowledge for application to the development of VDU-based signalling systems. There is a considerable amount of commonality between the human factors issues raised by VDU display systems in the railway and the process industries. A number of features of signalling systems make the design task significantly more straightforward than that required for process control applications. In most cases, therefore, the breadth of guidance required for process display systems will cover the information required for the design of signalling systems.

5.1.1 Techniques

The majority of the techniques described for use in process industry applications can be applied directly to the design of a railway signalling system. In many areas, their application would not need to be as exhaustive or complicated as that required in some process industry applications. For example, the design of effective track layout displays is simpler in a number of aspects than the design of process mimic displays. Sophisticated approaches to information requirements analysis are therefore not necessary.

5.1.2 Standards, Guidelines and Handbooks

Existing guidance for control room and workstation design is primarily focused on process control applications. Many of the general principles embodied in this guidance will have relevance for the design of VDU interfaces to railway signalling applications. However, in some particular detailed design areas, there is scope for railway industry specific advice. For example, there is very limited specific guidance on information coding and presentation for railway signalling applications. Specific guidance or standards would therefore, be of benefit, covering the symbology and graphics of signalling displays. There would be benefit in carrying out a review of existing guidance to determine its immediate applicability and to determine where there are gaps in its coverage.

5.1.3 Research

There are few additional requirements for basic research beyond those outlined for process industry applications (Carey, 1992). In many aspects, the design of displays for signalling applications appears to be less complex than the design task encountered in the process industries. Generic design issues which encompass both industries include: the provision of panel/VDU overview displays, the impact of automated advisory systems on user skills and capabilities, navigation between displays, the formalisation of graphical display design principles (e.g. to avoid clutter) and the development of principles for applying windowing interface technology to control room applications. There may be a need to carry out research on such issues in railway specific contexts.

An important first step should be to obtain consensus agreement on the scope of those signalling task which could particularly have safety consequences, and the resulting interface requirements. The descriptions provided in Appendix A should provide a useful starting point.

5.2 APPLICATION OF HUMAN FACTORS GUIDANCE WITHIN THE SYSTEM DESIGN PROCESS

The previous position paper (Carey, 1992) included the results of an outline survey of process companies that examine the inclusion of human factors consideration within the plant design process. It was evident that a wide gap exists between the extensive scope of human factors guidance and extent of information and techniques available and its actual application within the process industries. This was not due to a lack of interest in human factors, rather the difficulty of accessing relevant information and concerns regarding the cost-effectiveness of human factors effort.
The limited scope of this project precluded a similar survey within the railway industry. However, there is still likely to be the need for accessible guidance, provided within a framework which is sufficiently flexible to enable human factors considerations to be applied in a cost-effective manner.

Human Factors guidance could be provided at one or more of the following levels:

(i) Guidance on particular design attributes or features, such as the recommended maximum number of colours on a display, standard symbol sets, console dimensions etc.

(ii) Guidance on selecting and applying human factors techniques during system design.

(iii) Guidance that establishes a framework for safety assurance in the design of a VDU-based interface.

In common with the conclusions reached in the position paper for the process industries, it is suggested that appropriate guidance for signalling system design could be based around a set of safety objectives and goals. This would provide a safety assurance framework approach. A suggested set of goals are outlined in Table 5.1. These are identical in content to those outlined for process industry applications.

<table>
<thead>
<tr>
<th>SAFETY LIFECYCLE STAGE</th>
<th>OBJECTIVES AND GOALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCEPTUAL DESIGN</td>
<td>• To describe the safety-related operational philosophy for a railway system covering the level of automation, protection systems and the role of signalling staff in relation to traffic safety.</td>
</tr>
<tr>
<td>OUTLINE DESIGN/ SYSTEM PROCUREMENT</td>
<td>• To describe and evaluate task and information demands of safety-related operations (outline) • To develop the human factors component of a requirement specification for system design or procurement.</td>
</tr>
<tr>
<td>DETAILED DESIGN AND ACCEPTANCE TESTING</td>
<td>• To describe and evaluate task demands of safety-related operation (detailed) • To ensure detailed design meets standards set in requirements specification and is compatible with overall safety goals.</td>
</tr>
<tr>
<td>COMMISSIONING</td>
<td>• To demonstrate commissioned system meets safety requirements. • To ensure user support facilities (e.g. operating rules and training documentation) meet standards set in requirement specification and are compatible with overall safety goals.</td>
</tr>
<tr>
<td>OPERATION</td>
<td>• To ensure safety design intent is being complied with during operation, particularly following any modifications. • To collect operational feedback on system performance to feed into future designs.</td>
</tr>
</tbody>
</table>

**TABLE 5.1 HUMAN FACTORS SAFETY OBJECTIVES IN SAFETY DESIGN LIFECYCLE**

Guidance for the railway signalling industry would also be able to share a common second level of guidance with that for process applications suggesting human factors techniques for achieving each of the primary safety assurance goals. Techniques could be selected to correspond to the level of safety risks and the size of the project to ensure cost effectiveness.

A final-layer of guidance could then be provided to address particular system design attributes. This could involve pointers to the same standards, guidelines and handbooks of use in process control applications. However, there may be benefit in rewriting some of this guidance to create a version specific to railway industry applications. Industry specific guidance would be required in particular areas, such as symbol design for schematic displays.
6.0 CONCLUSIONS

A wide variety of human factors standards, guidelines and handbooks are available, though there is very limited coverage of the specific detailed design issues involved in implementing VDU-based control room interfaces. In many areas, efforts to provide clear and relevant guidance for process companies could be raised to meet the specific needs of railway signalling applications.

In general, the safety-related aspects of VDU interface design for signalling applications are less severe than that encountered in process industry contexts. Safety-interlocking systems provide comprehensive and highly reliable protection against the majority of the possible human errors that could be made during signalling operations. There are, however, a number of very specific circumstances where combinations of equipment and human failures could result in a potential threat to safety. These particular circumstances need to be clearly identified to further highlight key areas of control room interface design.

The research required to support the production of comprehensive human factors guidance is largely the same as that identified for the process industries. For example, additional information is required on the design and evaluation of navigation methods within VDU display structures, and clear principles need to be developed for graphic display design.

The guidance produced must be targeted at the safety-critical aspects of signalling tasks and must be flexible enough to enable it to be tailored to the specific commercial contexts of individual companies. The suggestion of a layered approach to the inclusion of human factors engineering would also be effective in the context of railway signalling systems.
### 7.0 REFERENCES

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APPENDIX A

INTERFACE REQUIREMENTS FOR SAFETY-RELATED SIGNALLING TASKS
APPENDIX A - INTERFACE REQUIREMENTS FOR SAFETY-RELATED SIGNALLING TASKS

A number of generic signalling tasks have been identified where the actions of signalling staff can be key to maintaining safety. These are described in the following sections:

1. MANUAL CONTROL OF TRAINS FOLLOWING SIGNALLING OR INTERLOCKING FAILURE

Whilst both signalling and interlocking systems have a high level of reliability, it is possible for such systems to fail and require the signalman to operate the system under manual control. To cater for the failure of train detection equipment, the signalman needs a means of manually keeping track of the position of trains. The control of movements of manned trains can be maintained through radio or telephone links with the driver.

Without the protection of the interlocking it would be possible for the signalman to direct a train into a section where a stationery train is already standing. To prevent this happening, the signalman needs a clear indication of the position of each train, the setting of all points, the correct identity of each train for communication purposes and clear communication channels to avoid misinterpretations. This indicates the following functional requirements of the control room interface:

(i) The display for manually recording train positions should be clear to read, simple to operate and if separate from the normal screen displays (e.g. magnetic board) should be directly compatible with the screen representation of the rail network.

(ii) The method for displaying the setting of points should be clear (from the seated position) and the mechanism for controlling points simple to operate.

(iii) The coding method for the identification of trains and of signals should be systematic.

(iv) The communication system and method of operation should minimise the potential for miscommunications.

2. DIRECTION OF TRAINS IN THE EVENT OF TRACK CIRCUIT FAILURE OR SHORT-CIRCUIT

There are a number of reasons why a track circuit may fail or short-circuit, such as the placing of an object across the track, an item of rolling stock separated from a previous train or trackside equipment failure. In each of these cases, the interlocking logic should ensure that approach signals are set to danger. However, it is still incumbent upon the signalman to check that the track section is protected. The signalman may also choose to utilise a train passing on an adjacent track to perform a visual check of the section before allowing traffic to proceed over it. In this case it will require an action by the signalman to set a signal to red to stop the required train or communicate by radio with the driver. This leads to the following requirements:

(i) The attention of the signalman needs to be drawn to the track circuit fault, through an appropriate alarm facility. This needs to ensure that the signalman can detect that an alarm has occurred, can establish what the alarm is, and identify exactly where it has occurred. Preferably, there should not be the need for an extensive visual search.

(ii) The display should clearly show whether all approach signals are set to red.

(iii) The mechanism for stopping an approaching train on an adjacent track should be rapid and simple to operate.

(iv) The communication system and method of operation should minimise the potential for miscommunications.
3. PROTECTING A TRACK POSSESSION

The signalman has the responsibility for locking signals to red to protect a track possession. This involves receiving a call from the person in charge of possession requesting that a track possession be taken up. The signalman then designates either the track sections under possession (which locks all signals into the sections to red), or directly locks or ‘collars’ the signals at either end. At the end of the period of work, the process is reversed upon receiving a further call from the possession master.

There are a number of potential errors that could be made during this process, such as applying the protection to the wrong section of track, partly protecting the possession but not locking all the signals that could give access to the section, and at the end of the possession, removing the wrong protection. The potential consequences are that the safety of the trackside gang would be put at risk and where tracks have been removed, there would also be a safety risk to those travelling on the train. Key issues in preventing these types of errors are as follows:

(i) The method for setting and removing a protection needs to be straightforward and give clear visual feedback on the section selected.

(ii) The communications system between trackside personnel and the signalling centre should minimise the potential for mis-communication.

4. INSTRUCTING TRAIN TO PROCEED WITH CAUTION DUE TO REPORTS OF ITEMS ON TRACK, PERSONS ON TRACK OR VANDALISM

In the event that the signalman receives a report of possible vandalism or trespassing, it is his/her responsibility to stop and warn the drivers of trains approaching the section concerned. This has three main steps involved; receiving a report from a train driver or member of the public of the potential danger, setting signals to halt trains entering the section and then informing the driver of the circumstances. With direct radio connections to the drivers’ cab it may not be necessary to stop the train.

In performing this task, there is the potential for a number of errors such as misidentifying the location of the hazard (n.b. particularly if report received from member of public or emergency services from a mid-track section without clear identifying features), failing to stop or inform an approaching driver in time or advising the wrong driver if a number of drivers call in within a short time period. This would result in safety risks to those travelling on the train or to persons on the track. The following interface features are therefore important:

(i) The track diagram display needs to incorporate sufficient landmark features to enable the locations reported to be identified. This also, of course, includes signal reference numbers.

(ii) The operation of the mechanism for setting a signal to danger needs to be rapid to operate and robust against errors.

(iii) The protocol for communicating locations and hazards needs to be clearly established to avoid errors.

(iv) The communication system should minimise the potential for miscommunications.

5. REMOVING TRACTION CURRENT

On railways using third rail or overhead power lines for traction current, there can be circumstances where power has to be removed quickly. This would include train evacuations, derailments or when power lines are brought down on top of a train. The mechanism for removing the current involves firstly recognising the need to remove the current (n.b. the signalman may infer this or may receive a request from the lineside), and then removing the current, either by contacting a separate traction power control centre or directly through the computer system.

Various potential errors may occur during this operation. Firstly, the signalman has to determine the need to remove the current in a section. If the request is received from the lineside or emergency services, it is important that the
signalman does not misidentify the location of the incident. If control over traction current is carried out elsewhere, there is the potential for miscommunication, resulting in the wrong section being isolated. Since power sections generally do not correspond with track sections, there needs to be some way that the signalman can double check that the correct section has been isolated. Throughout this task, any undue delay increases the possibility of electrocution for the persons concerned. As a result, the following aspects need to be considered:

(i) The track diagram display needs to incorporate sufficient landmark features to enable the required area to be identified.

(ii) The procedure for removing the current needs to be quick and feedback provided that enables the signalman to check that the correct area is isolated. It follows that the signalling system should enable the signalman to display the isolated section on the track diagram.

(iii) The communication system and method of operation should minimise the potential for miscommunications or delay.

6. HANDLING TRAIN STOPOAGES IN TUNNELS

Tunnel sections can pose a number of hazards to safety, including suffocation through lack of ventilation and increased dangers from fire or smoke. On underground metro systems (e.g. London Underground), efforts are made to ensure that if traffic needs to be stopped, wherever possible trains are not stopped in tunnel sections. In other systems, where trains have to be stopped or evacuated in a tunnel section, the signalling control centre may have the responsibility for starting auxiliary services such as ventilation fans, tunnel lighting or fire systems.

The task of controlling trains to prevent stoppages in tunnels has planning and action components. Errors or delays in either component could result in trains having to be stopped in tunnel sections. The operation of auxiliary systems within tunnel sections would require services in the right section to be operated without undue delay. The following interface features are therefore required:

(i) To facilitate planning of train stoppages, the signalman needs to possess a clear overview of the positions of trains in relation to a tunnel section. Depending on the density of traffic and frequency of tunnel sections, this may require an overview display of large lengths of line.

(ii) For the implementation of train stoppages, the method of setting signals to red or controlling trains must be quick and accurate to operate.

(iii) The displays concerned with auxiliary safety systems in tunnels need to be particularly clear and the method of operation straightforward, as such systems are likely to be rarely used.

7. PROTECTING A RUNAWAY TRAIN

Should a train start to run out of control, it is vital that the signalman detects the situation quickly and takes immediate action to plan and set up a safe route, stop conflicting trains and alert staff or passengers at stations en-route. Depending on the density of traffic at the time the incident occurs, this can be a particularly difficult task.

Key errors that could affect the ability of a signalman to respond to such a hazard include the delayed detection of an overrun past a red signal, difficulties or mistakes in planning a safe route, delays or mistakes in stopping conflicting trains and making mistakes in setting the required route. Furthermore, passengers and staff on platforms along the route of the train may need to be instructed to stand back from platform edges. The signalman's display and control facilities must therefore meet the following requirements:

(i) A clear indication that an overrun has occurred must be given to the signalman. This must ensure that the overrun is rapidly detected and its location identified.
(ii) To assist in planning a safe route, the signalman needs to possess an accurate overview of train positions and movements across a wide area.

(iii) For the implementation of train stoppages, the method of setting signals to red or directing trains to stop must be quick and accurate.

(iv) The mechanism for setting routes must be simple to operate and not prone to inducing errors.

(v) The communications between the signalling centre and stations in the section concerned must be reliable and effective.

8. SETTING BACK AN OVERRUN TRAIN

Should a train overrun a red signal when stopping, the signalman may need to take action to 'set back' the train into a previous section or to a station platform. Setting back has to be handled with care as the direction of train movement is against the protection normally provided by the interlocking and the train could run back into the path of a following train.

The safety of this operation requires the signalman to detect an overrun when it occurs, to check that the train can be set back without conflicting with other traffic, setting signals to protect the path of the train, instructing the driver and then monitoring the operation to ensure that instructions are complied with (i.e. the train does not run back further than instructed). The following requirements must therefore be met:

(i) A clear indication that an overrun has occurred must be given to the signalman. This must ensure that the overrun is rapidly detected and its location identified.

(ii) The displays must give a picture of train positions, point setting and train routes.

(iii) The mechanism for setting signals to red must be rapid to operate and reliable.

(iv) The communications with the driver must be reliable and avoid miscommunication.

9. NON-STOPPING TRAINS THROUGH A STATION

Under conditions where there is a bomb threat, fire alert, or high platform overcrowding which would be exacerbated by emptying another train onto the platform, the signalman may be required to override the automatic train scheduling system to ensure that trains pass through the station without stopping. A serious error would involve delaying the required action such that a train stops at the platform before the required command can be issued. The following requirement must therefore be met:

(i) The mechanism for instructing the train scheduling program to non-stop trains through a station must be simple and rapid to use.

10. CONTROLLING TRAINS TO EVACUATE PASSENGERS FROM A PLATFORM

In underground stations, it may be necessary to respond quickly to a request for an empty train to be dispatched to a particular station to evacuate passengers where fire or another hazard is preventing escape. To achieve this, the signalman may need to plan complex train movements to gain access to the station for empty rolling stock from a terminus station or depot. Such a task has the following requirements:

(i) The signalman must be able to identify the location and availability of suitable stock.

(ii) The signalman must be able to obtain an overview of potentially large areas of network in order to plan a route.
(iii) The mechanism for setting the route must be easy to use and to check. This may be totally manual or performed via the automatic train scheduling system.

11. RESPONDING TO TRAIN DIAGNOSTIC MESSAGES

Advances in on-board train management and diagnostic systems enable a large amount of information regarding train functioning to be conveyed to the signalman. Some of this information may have safety consequences such as a door failure, or overheating components. In a similar manner, trackside units can detect specific malfunctions in existing rolling stock such as hot axle boxes. In order to respond effectively to those malfunctions with potential safety consequences certain requirements need to be met:

(i) The signalman must be alerted to those messages with potential safety consequences. This information would need to be carefully prioritised to avoid the console being flooded with diagnostic messages.

(ii) The signalman needs to be able to locate the particular train quickly. This may be supported by direct access to displays showing the train concerned.

(iii) The displays must provide enough detail to know where the train can be stopped for attention or to evacuate its passengers.

(iv) The mechanism for setting the route must be easy to use and to check.