Understanding Human Factors
a guide for the railway industry

Rail Safety & Standards Board

Understanding Human Factors/June 08

About this document

In an industry with multiple stakeholders, Rail Safety and Standards Board (RSSB) builds consensus and facilitates the resolution of difficult cross-industry issues. RSSB provides knowledge, analysis, a substantial level of technical expertise and powerful information and risk management tools and delivers this unique mix to the industry across a whole range of subject areas. Working with our industry partners our purpose is, therefore, to:

- continuously improve the level of safety in the rail industry;
- drive out unnecessary cost; and
- improve business performance.

RSSB continues to manage an extensive programme of research and development on the industry's behalf. This work addresses a wide range of operational and business issues of common concern to Members. Its outputs feed into collective industry planning, the formulation of safety standards and safety decision-making from individual Members.

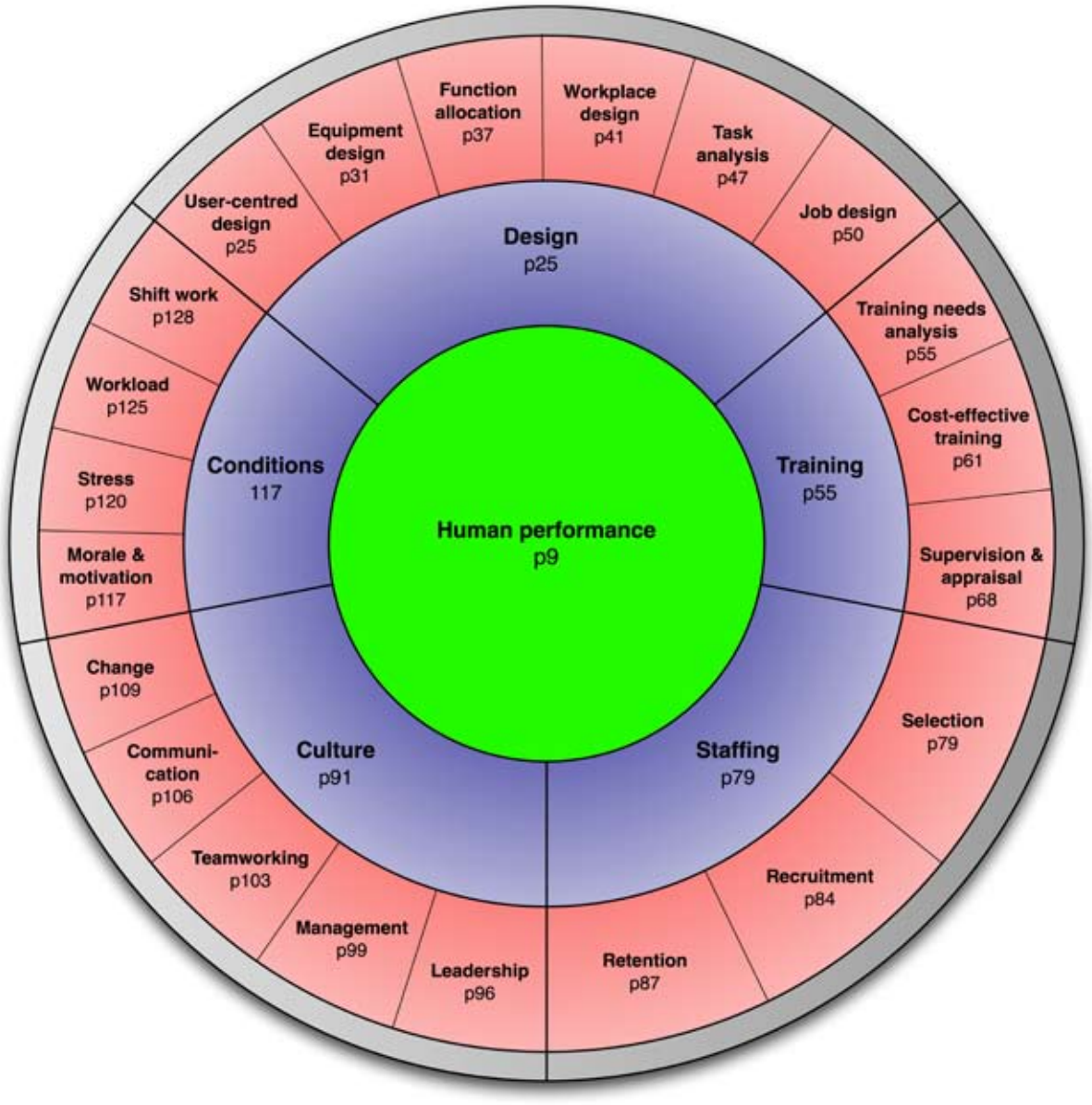
How was this Guide developed?

This guide is the culmination of a process that started in 2003, when the Health and Safety Executive (HSE) and RSSB's Human Factors Team identified the need for a comprehensive human factors guide for the railway industry in Great Britain. Industry stakeholders endorsed the development of the Guide in January 2004, when they identified it as a priority project for RSSB.

In developing the Guide, RSSB adopted a user-centred design approach and interviewed a representative sample of the Guide's end users early in the project. The results of these interviews were used to inform the content and style of the Guide. End user representatives, as well as the Railway Industry Advisory Committee (RIAC) Human Factors Working Group and RSSB's technical advisers, reviewed the Guide at various stages of its development.

This Guideis available in both print and searchable, hyperlinked pdf formats.

The scope of this human factors guide



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Who is this Guide for?

This Guide has been created for designers, suppliers, managers, supervisors, trainers and Health & Safety (H&S) staff who work in the railway industry. Its main purpose is to answer the question *'what practical advice can a human factors approach offer to railway staff without requiring them to be experts in the subject?'* Accordingly, this Guide is not written as a text book, or a step-by-step process. Instead, it uses a Frequently Asked Questions (FAQ) format, addressing questions that are relevant to railway staff, and which human factors research has had some success in answering. The answers we give are in sufficient detail to tell you what a human factors approach involves, why it's important and what you can do. The questions are not presented in any particular order. Each one represents a potential channel of communication between rail industry and human factors professionals. The Guide will have met an important goal if it encourages railway professionals to seek more frequent, more timely, and more informed dialogues with their human factors colleagues. This Guide will also be of interest to front-line staff who would like to know how some of the decisions that affect their working lives should be made.

How should you use this Guide?

This Guide has been made for browsing. The best way of using it is to scan the questions covered and dip into those which seem of particular interest to you. We hope you are rewarded by insight, information and signposts to further sources of advice. If this Guide causes you to ask questions that you would not otherwise have asked, it will have done its job.

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Part 1: Getting started

What are human factors?

Human factors is another term for ergonomics. It has traditionally focused on ensuring that employees have safe and easy-to-use equipment and a place in which they can work efficiently. However, we use the term 'human factors' in this Guide in a much broader sense.

This broader focus is necessary because of several interconnected trends:

- Technical systems are becoming more wide-reaching and complex, making it necessary to consider their effect on the larger work group and, indeed, the total organisation
- Work is placing increased demands on people's knowledge
- Organisations are increasingly regarding employees – as well as technology – as valuable investments.

Instead of just focusing on the relationship between the individual and their equipment and working environment, we need to ensure there is a good balance between the organisation as a whole, its people, working practices and technology. Consequently, this Guide is based on a definition of human factors as:

> *'all the 'people' issues we need to consider to assure the lifelong safety and effectiveness of a system or organisation.'*

If an organisation attends successfully to all human factors, the organisation and its people will get the best out of each other. The whole of the railway industry will only operate at its best if it attends to all the human factors that can affect its performance – that is, its safety and profitability.

In particular, the timely application of human factors knowledge and techniques:

- reduces the potential for error
- increases the margin for safety
- reduces the potential for expensive re-design
- increases the efficiency and effectiveness of training
- reduces the potential for expensive staff turnover
- increases the productivity of the whole organisation.

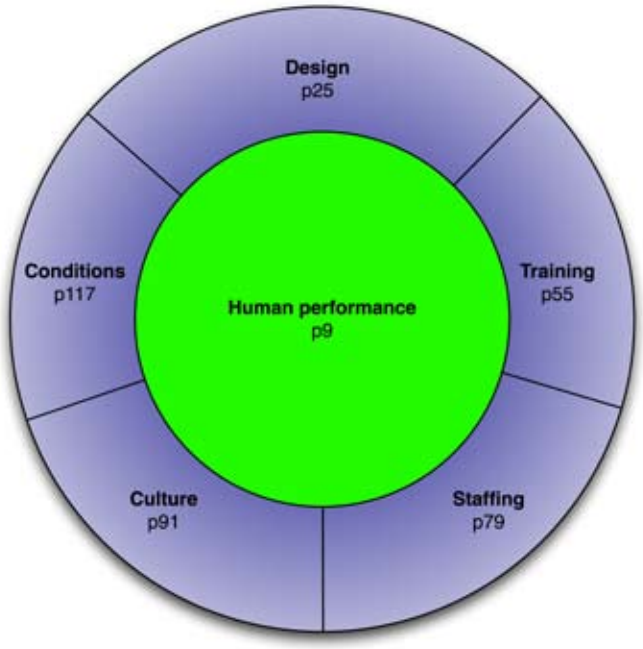
Where are human factors important?

The diagram on this page shows the five areas of human factors that are critical to human performance in the railway industry.

Design

Everything manufactured, supplied and brought into service in the railway industry has been designed. The products of design must be fit for purpose. Here, we use 'product' quite widely to include equipment, processes, procedures, rules and rule books etc. Fitness for purpose means adequately defining at the design stage both the way products are to be used and the technical problems they are intended to solve. The usability of a product depends on several important human factors issues, including:

The critical areas of human factors



- how easy it is for the user to understand the function of the product
- how straightforward and safe the product is to operate
- how well the product supports the user's task
- how well the use of the product fits with related organisational products and their users.

Ignoring the human factors of design does not simply miss a major performance improvement opportunity: it can lead to a severe decline in performance, loss of staff or customers through accident or wastage, and often substantial financial cost (eg failed IT systems).

Training

People need to be developed in ways that fulfil their own potential as well as the needs of the organisation for which they work. Training should be seen as a continuous process by which organisations get the most out of people – and vice versa. In order to be cost effective, organisations need to gauge the right time to train the right skills in the right people in the right way.

Staffing

Organisations need the right numbers of people doing the right jobs at the right time – and once they've got them, they need to keep hold of them. Recruiting, selecting and retaining the right people are all crucial to the success of an organisation. Getting it wrong is very expensive and can lead to organisational weakness and even collapse.

Culture

Each organisation automatically develops its own culture. Culture is both a product and a cause of the way people behave with each other. An organisation's culture is apparent in the behaviour of its leaders, its teams and its managers, and in the style and expectations with which its people communicate with each other. It's also responsible for how easily, or not, an organisation can change. An organisation can't change culture directly. But it can find ways of influencing people's behaviour – which then influences its culture and (hopefully!) encourages more of the desired behaviour.

Conditions

Of course, standard conditions of work are usually defined in appropriate detail by legislation and employment contracts. The human factors approach is concerned with the impact of workload, shift work, morale, motivation and stress on performance and well-being.

What is the organisational payoff?

When a safety-critical organisation works on human factors in all five critical areas described above, a new possibility emerges – that of becoming a high reliability organisation (HRO). An HRO is one that has learned to manage the unexpected by being chronically uneasy. It grows suspicious 'if things get too quiet around here'. As a result, it is able to notice the unexpected in the making and then halt – or at the very least, contain – its development. And if some of the unexpected breaks through the containment, the HRO focuses on keeping the errors small and quickly getting the system to function again.

You can find out more about *HROs* on page 95 in the section on *Culture*. Striving towards being an HRO means addressing human factors in all five critical areas described above. These five areas are important because they all influence human performance.

'If eternal vigilance is the price of liberty, then **chronic unease** is the price of safety.'
James **Reason**, psychologist

Performance

Within an organisation, human performance is directed behaviour that takes place for some measurable purpose.

How well this purpose is achieved will depend on both external and internal conditions. By external conditions we mean environmental, cultural and organisational factors that affect people's behaviour from outside. By internal conditions we mean the set of psychological, physiological and anatomical factors that shape people's behaviour from within. Many external conditions, such as ambient temperature and noise, can be controlled. Some internal conditions, such as muscular power and the trainability of individuals, must be taken as 'givens'.

However, there are some enduring features of the nature of human performance that are very difficult for managers, designers and trainers to deal with. People at work make mistakes. They take risks. They break rules. They have accidents.

In any particular organisation, it may be appropriate to address these fundamental aspects of human performance by any arbitrary mix of the five critical areas – design, selection, training, culture or conditions. While we cannot offer guidance about the best mix for your organisation – since each context will be different – we can offer some insight into the nature of these aspects of human performance.

This we do in the first section of Part 2.

How should I navigate this Guide?

Each of the sections in Part 2 begins with a wheel diagram, based on the main wheel diagram at the beginning of this Guide. Each wheel diagram identifies the relevant human factors topics and questions dealt with in the section it introduces, together with relevant page numbers. The topics are illuminated by examples, case studies and other explanatory panels.

Text that appears in *italicised blue* signifies the title of other topics in Part 2 of the document. Text that appears in *italicised green* signifies a technique for which more detail is provided in Part 3. At the end of each section, you will find a set of selected references that will be useful if you wish to delve further into the topics raised.

In Part 3 you will find an extensive bibliography, a jargon buster section and a set of representative human factors techniques. Looking through them will give you a good sense of what is involved in collecting and analysing human factors information.

If you are using the on-screen (pdf) version of the Guide, you will find that the coloured text and page numbers are also links which you can click for fast access to other parts of the document. In addition, website references and red text (ie references) are also clickable links which will access the Internet if you are connected. For best results, please familiarise yourself with the navigational controls provided by Acrobat Reader. These controls will also allow you to quickly navigate around the document, including going back to the page you just came from.

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Part 2: Guidance

Human performance

The diagram below focuses on what is at the core of human factors – human performance. It focuses on four fundamental questions about humans at work. This part of the Guide deals with each of these questions in turn. At the end of each question you will find a list of sources of further information that will provide more detail.

Questions of performance

Why do people make mistakes?

'An expert is a person who has made all the mistakes that can be made in a very narrow field.' Niels **Bohr,** physicist

People get things wrong all the time. Even the most straightforward task, such as reading numbers from a display, is not error-free. People simply must make mistakes. It is a crucial part of our nature. A mistake is something that gives us information about how near our goal we are. Without mistakes there can be no learning. Errors are at the heart of our ability to adapt to, and master, new situations. On the other hand, some errors have such dire consequences compared with their learning value that they simply need to be prevented wherever possible. In the 1889 Armagh train disaster, 88 people were killed, most of them children, when their overloaded train stopped, was divided by railway staff, and then rolled back down a hill colliding with the train behind. In those days, signallers separated trains by the clock: they sent trains into the next section on the basis of how long it had been since they sent the last one. After Armagh, interlocking and absolute block working were made compulsory. In addition, automatic brakes were fitted so that split trains could not lead to runaways.

'Making **mistakes** simply means you are learning faster.' Weston H. **Agor,** Professor of Public Administration

This accident was not due to a mistake by the signaller, or anyone else on the day. Rather, it was a consequence of the design decisions taken by people who had not anticipated the particular combination of circumstances that occurred at Armagh. See *Why do accidents happen?* on page 18 for more about the real relationship between accidents and human error.

What sorts of mistakes do people make?

There are three types of performance that can lead to errors:

- *Skill-based performance* – where we routinely perform highly practised activities with little conscious effort, eg replacing a rail clip or setting a route on an NX panel
- *Rule-based performance* – where we have more mental involvement and apply previously learned rules to tasks we have usually been trained for, eg planning a route in a signal box before setting it, talking a driver past a red aspect, or evacuating a station
- *Knowledge-based performance* – where we have even more mental involvement, often in novel situations, eg attending an accident scene, or counselling a staff member.

Errors in skill-based performance

Errors in skill-based performance are generally regarded as slips or lapses. They typically occur when our attention is diverted and we fail to monitor our actions. There are several types:

- *Familiarity slips* – where something we frequently do 'takes-over' a similar but less familiar action. For example, we might dial a frequently used telephone number when intending to dial a similar one
- *Similarity slips* – where the intended action is similar to other actions we do a lot, so that we perform the right action on the wrong object. For example, a signaller might normalise the wrong points switch on a panel because it is close to similar switches

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- *Memory lapses* – where we forget the goal in the middle of a sequence of actions or omit a step in a routine sequence. An example is forgetting why we entered a particular room. Another is the driver who forgets to use their AWS 'sunflower' display to remind them that they have overridden a warning to slow down. Yet another is the signaller who is distracted during arrangements for a possession and fails to use a reminder appliance as required

AWS design – a problem of association

The Automatic Warning System installed on all passenger trains in the UK is an example of a system that was not designed with limitations of human attention in mind. It is a device fitted in the train cab, based on the now obsolete mechanical system of signalling that used to signal either STOP or PROCEED. It sounds a bell when a clear (green) signal is passed and a buzzer when caution or danger is signalled. The AWS is a useful safety system in that if the buzzer is not acknowledged by the press of a button, then the train begins to stop automatically. However, times have changed since it was designed. In today's commuter traffic, most signals will be at the 'caution' aspect, and given the frequency of signals (spaced 1km apart), most drivers will face two signals per minute. Since people 'automate' highly repetitive behaviour, drivers can lose focus on the reasons for carrying out this repetitive task, and act in reflex whenever the buzzer sounds. The end result is that drivers often hear the buzzer and press the button reflexively without thinking about train speed and location.

Source: Davies (2000), reproduced with permission from POSTNOTE, Jun 2001, Parliamentary Office of Sci and Tech.

- *Association slips* – where the brain makes a faulty connection between two ideas, often when one is an external stimulus that typically provokes a certain action. An example is a driver reacting to one alarm as if another was going off. Another common driver error arises from the design of the AWS (see Panel, *AWS design – a problem of association*).

Errors in rule-based performance

These are mistakes we make in applying known rules. For example:

- *Misapplying a good rule* – that is, applying the rule in a situation where it is not appropriate. This is often a rule that is frequently used and seems to fit the situation well enough
- *Applying a bad rule* – so that in certain situations the job gets done, but with unwanted consequences
- *Failing to apply a good rule* – that is, ignoring a rule that is applicable and valid in a certain situation.

Errors in knowledge-based performance

Knowledge-based performance is especially prone to errors, often of a complex nature. They arise from a lack of knowledge, uncertainty, lack of concentration, or a misapplication of knowledge, particularly in novel situations. Examples are:

- *Availability bias* – choosing a course of action because it is the one that comes most readily to mind. For example, the Armagh railway disaster was a result of a train movements procedure that was straightforward to implement, but fundamentally flawed
- *Confirmation bias* – looking for information that confirms belief about the situation, while ignoring or filtering out anything which disagrees. This can arise through over-confidence, or as a way of making short-cuts and reducing complexity

'If everything seems to be going according to plan, you've obviously **overlooked** something.'
Commercial Pilot

Either of these biases can lead us into making faulty conclusions about a situation, and so drawing up and executing a faulty plan to accomplish the task.

What causes errors?

Errors are not random events. Rather, they are a consequence of what normally goes on in our mind, arising because of inattention, incomplete knowledge, sparse sensory data, mis-perceptions, forgetting something, problems in our relationships with colleagues, friends and family, and so on (see Panel, *Errors are consequences – not causes*). In turn, many of these factors

Errors are consequences – not causes

A major study of over 100 rail accidents and near accidents over three years in Australia found that driver inattention was the most important factor – especially inattentiveness to railway signals. Significantly, the report concluded that *'the problem of sustained attention amongst drivers rests with the higher levels of the organisation where work conditions are designed and controlled.'* In other words, the real cause of many of these accidents was not driver error, but the conditions in which drivers had to work. Driver error was seen to be a consequence of the problem, not the cause of it.

Summarised from research reported in Edkins and Pollock (1997)

are shaped by the operational context in which we work, including the social climate, the management culture, our working conditions and the fitness for purpose of the tools we work with.

One of the key causes of human error is having our attention diverted. Attention can be diverted by environmental factors, such as alarms, telephone conversations and demands by other people; by physiological factors, such as fatigue, sleep loss, alcohol, drugs and illness; and psychological factors, such as having to juggle multiple activities, stress, boredom, frustration, fear, anxiety, anger and personal worries.

'Reducing human error involves activity in **every area** of human factors - just tackling one is never enough.'

How can you reduce errors?

Error management should be tailored to suit specific contexts in particular organisations. The challenge for organisations is to create environments in which people can make their mistakes without dire consequences. This means using the most cost-effective combination of techniques across the five areas of human factors explored in this Guide, as follows.

Design – is used either to ensure that people cannot make certain sorts of mistake (eg by installing signal interlocking), or else to help users to review their decisions before enacting them (eg a dialogue box that asks *'Are you sure you want to delete the selected file?'*). Automation may seem attractive because it designs the human out. But automation is as much 'fools gold' as the elimination of error is. At best, it simply changes the problem to one of how to create the best possible interface between people and the automated component. At worst, it creates even more problems when the automation fails in front of a bored, de-skilled user. See *function allocation* on page 37.

Training – is used to ensure that people are rehearsed in their skills and knowledge and therefore less likely to make mistakes, and are better able to recover from mistakes when they do make them. However, thought needs to be given to the type of training required. More training on skills, rules and knowledge is of little benefit to people who commit deliberate violations. See *rule-breaking* (page 12) and *risk taking* (page 15). Violations are better dealt with by showing people the consequences of their actions.

Staffing – is used to ensure that the right people are placed in the right jobs. More importantly, it ensures that people are recruited who can be trained in the skills and responsibilities to the level that will be required of them.

Culture – is developed by the organisation, through its *leadership* (page 96), *management* (page 99) and *teamwork* (page 103) so that people work in a supportive, blame-free atmosphere. As a result, everyone develops a responsible approach to managing the detection and correction of mistakes, reducing their consequences and preventing their re-occurrence.

Conditions – are considered with the aim of identifying and reducing the mistake-making consequences of *motivation and morale* (page 117), *stress* (page 120), *workload* (page 125) and *shift work* (page 128). The reduction is achieved mostly through effective design, training and management (including self-management).

What error reduction techniques are available?

The majority of the techniques for human error reduction require you to evaluate individual task performance (actual or predicted) in terms of natural mental process (eg a person sees something because they expect to see it, overlooks something that is present, or focuses on one area of the display to the exclusion of everything else). The techniques also require you to evaluate the influence of performance-shaping factors. These are sources of influence on our behaviour such as fatigue and noise.

Several of the key techniques are listed below. You can find out more about them in *Part 3*.

- *Fault trees* are used to depict system failures and causes, and to estimate their probabilities.
- *Human Error HAZOP* (HAZard and OPerability) is thorough and insightful – but very resource intensive.
- *HEART* (Human Error Assessment and Reduction Technique) is well established in the railway industry, is relatively simple to understand and use, and focuses on factors that have the most influence on human error.
- *Murphy diagrams* are very similar to fault tree analysis in that errors or failures are analysed in terms of their apparent causes.
- *SHERPA* (Systematic Human Error Reduction and Prediction Approach) is a human error prediction

technique that also enables tasks to be analysed and potential solutions to errors to be presented in a structured manner.

RSSB is currently developing a rail specific human reliability assessment technique. This is initially driver based, but will be extended to other operational groups in due course.

Further information about human error

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9 Reason J. & Hobbs (2003) Managing maintenance error, Ashgate Publishing

10 RSSB (2008) Good Practice Guide on Cognitive and Individual Risk Factors, RS232, Rail Safety and Standards Board

11 Vanderhaegen F. (2001) A non-probabilistic prospective and retrospective human reliability analysis method – application to railway system, Reliability Engineering and System Safety 71 (2001) 1–13

12 Williams J.C. (1986) HEART – a proposed method for assessing and reducing human error. In 9th Advances in Reliability Technology Symposium, University of Bradford

Why do people break rules?

Sometimes people break a rule because they don't know it exists, or they don't understand it well enough, or they fail to recognise that a situation demands it. Or perhaps they simply forget that the rule exists. In all of these cases, rule breaking falls into one or another of the categories of human error discussed in the section on *Why do people make mistakes?* on page 9.

Sometimes, however, people break a rule deliberately. This means that the rule-breaking is not really an error, but a violation. Why do people deliberately break rules?

Overwhelmingly, people do not break rules maliciously, but for entirely rational reasons. In general, violations result from the conflict between an organisation that is attempting to control the behaviour of the workforce, and the individual who is attempting to carry out their task as easily as possible.

The UK railway industry classifies violations in the following way:

- Routine violations
- Situational violations
- Exceptional violations
- Personally optimising violations
- Sabotage

Lawton's (1998) research into Rule Book violations on the UK railway system has revealed four main reasons why staff break rules deliberately.

- *Unusual circumstances*. These can lead to exceptional violations and usually arise when a rare combination of events gives rise to a novel response. An example is the shunter who fails to show a hand danger signal to the driver to instruct them to remain stationary, before walking between carriages. These are high-risk but low-frequency violations – the violations most often associated with shunting accident fatalities. They occur when someone encounters a novel problem and needs to use their knowledge to find a solution, eg when a train needs to be coupled together on a bend.

- *Situational short-cuts*. Some types of short-cut can lead to situational violations and usually arise in difficult conditions where someone sees an economical way to keep the job going. An example is the driver who does not stop even though they have lost sight of the shunter during a movement. These violations are high-risk and high-frequency and are the result of the employees' immediate work environment. Violations are inevitable in conditions where the work area or equipment is poorly designed or under-staffed. Such conditions make it difficult or impossible for staff to remain within the rules. While the job keeps moving forward effectively, this type of violation is often ignored. Such violations may even be expected or endorsed by managers. It is another story when an accident happens and violators find themselves the subject of disciplinary investigations. Historically, industrial life in the UK has often revealed the operational difficulties created when staff 'work to rule': such action typically highlights the way in which rules within a system are often impractical in everyday practice.

'Overwhelmingly, people do not **break rules** maliciously, but for entirely rational reasons.'

- *Routine short-cuts*. Other types of short-cut lead to routine violations and occur when short-cuts are regularly taken. An example is the shunter who gets on and off the pilot engine while it is moving. Routine violations are usually high frequency but low risk. They often go unnoticed or unremarked, and contribute greatly to productivity. People usually assume that the skill of the individual more than offsets any risk they might be taking. In such cases, individuals may also believe that the rules they are ignoring no longer apply to them. These routine transgressions end up being part of the normal way of working within a particular work group.

- *Ineffective supervision*. This can lead to various types of personally optimising violation - or even sabotage in extreme cases (although no supervisory system – however effective – can prevent a determined saboteur). Ineffective supervision can lead to an individual's misjudgement, eg someone who breaks rules to prove to themselves, or others (probably mistakenly), that they have the additional skills needed to be in control of the risks. Alternatively, an environment with no recent accidents may be seen as proof that the way people work is safe – which then produces complacency and a false sense of security. Finally, people who are not fully held accountable for safety are more likely to adopt non-approved methods of working than those who are fully accountable for the consequences of an accident or incident. Uncertainties in the allocation of authority, responsibility and accountability will increase the likelihood of violations.

'Uncertainty about who is in charge or accountable **will increase** the likelihood of violations.'

Rule breaking usually has rather different outcomes for the individuals that do it and the organisations they work for. People tend to break rules deliberately when the benefits of doing so appear to outweigh the costs (as long as they remain inside their own risk comfort zone. See *Why do people take risks?* on page 15). For the organisation as a whole, however, rule-breaking on a large scale may cause serious disruption to productivity and other losses due to the accidents that result overall. Take the example of car drivers who exceed the speed limit. For society the economic and social costs of road traffic accidents are huge. But from an individual's perspective the personal costs appear unlikely and distant.

What can be done to reduce rule breaking?

- *Make sure the rule is necessary.* Before trying to persuade people to follow a rule you should first see if you can simplify the task or remove opportunities for error, and therefore the need for the rule.

- *Make sure the rule is credible*. Safety rules should be about safety. If the main purpose of a safety rule is to protect an organisation rather than the safety of the individual, its credibility will suffer (see Panel, *Rules must be credible*). It must be clear that the focus of the rule is on safe behaviour, not compliance. Credibility will

Rules must be credible

In one accident in a process industry, a valve had to be changed on a line carrying corrosive chemicals. The line was emptied but a few drops of liquid remained. The permit asked for goggles and gloves to be worn. The fitter did not wear them and was splashed in the eye by a drop of the chemical. At first sight this seems like a violation, a deliberate failure to follow clear written instructions. However, a look at the permit book showed that every permit asked for goggles and gloves, even for jobs on low pressure water lines in clean areas. The maintenance crew therefore ignored the instruction, deeming it to be more about management covering itself rather than about their own protection.

Source: Kletz (unpublished), reproduced with permission

also suffer if it is out of date or out of sync with new procedures – it needs to be reviewed at appropriate intervals. Not doing so will increase the number of routine violations.

- *Make sure the rule is understood*. People must be aware of the rules themselves, how they fit with related rules, the hazards that they are attempting to avert, and the consequences of not observing them. This means you need to pay serious attention to rule description, training and dissemination.

- *Make sure the rule is practicable*. If the wrong method is easier, or if the right method is impractical, people will use the wrong method. You need to make it possible for staff to plan their work to take the rule into account, and provide the equipment necessary to perform work according to instructions. You also need to ensure that targets are achievable without short cuts.

- *Make sure the rule is consistent with both organisational and team goals*. When the goals of a work group conflict with the goals of the organisation this may give rise to informal ways of doing things that encourage infringements of the rules. The supervisor, being close to the work group, may share the norms of the group and therefore support such infringements. The aim of the organisation should be to foster informal norms that do not go against its goals.

- *Make sure the rule is rehearsed right after training*. Failing to practice new rules soon after training – either operationally or via simulation – simply wastes the training resource. Either the rule itself will be forgotten, or its perceived importance will be reduced.

- *Make sure the rule is enforced*. Rules must be supported by effective monitoring of the work practices and enforcement. You need to apply sanctions consistently and fairly when non-compliance occurs. Increasing the costs of violating will increase compliance.

Tools and techniques to reduce rule-breaking

A rule compliance toolkit has been developed by RSSB. This toolkit helps railway managers identify the sources of rule compliance problems – including violations – and their solutions. The toolkit is available from the RSSB website at www.rssb.co.uk (as of May 2008)

The first document listed below in *Further information*, commissioned by HSE, reports on the development of a package of easy-to-use, but comprehensive, methodologies that enable the non-specialist to identify the underlying reasons behind violations. The project also aims, as far as possible, to identify the best management practices for reducing the potential for violations. The methodologies were developed for the offshore industries, but may be useful in other industrial sectors.

Further information about rule-breaking

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Why do people take risks?

'Nothing will **ever be** attempted, if all possible objections must be first overcome.' Samuel **Johnson,** essayist

Everything we do is a risk, since there is always uncertainty involved – however small. We may be uncertain about the information we are using to make our decisions, or about whether our chosen action will lead to the goal we wish to achieve and what the cost will be. Fortunately, in most aspects of our lives, we can use feedback about our actions – especially our errors – to give us a better idea of the risks involved in future actions. In any event, we don't want to avoid all risk, for risk adds excitement to what we do. It removes boredom and adds perspective to our decision making. It makes us conscious of our own learning, growth and capabilities.

What affects risk taking?

People differ in the levels of risk they are prepared to tolerate. Most of us actively seek to maintain our activities within a 'risk comfort zone'. If things get too boring or too risky, we modify our activities to compensate. A good example of this is the motorist who becomes more familiar with a particular route and starts to drive it more quickly. The risk arising from their uncertainty about the route is released for use elsewhere – in this case in the form of speed – so maintaining their exposure to risk. Risk compensation theory helps to explain why safety measures such as antilock braking systems, air bags, seat belt laws and speed regulations have not resulted in an overall reduction in accidents. Instead, people use the reduced risk these safety enhancements bring to drive faster and closer to the car in front than ever before (see Panel, *Do organisations compensate for risk?*).

'Everything is **sweetened** by risk' Alexander **Smith,** Scottish poet

Some people appear to seek higher levels of risk than others. They are particular personality types, who are also characterised by:

- reduced levels of self-control
- reduced long-term planning ability
- sensation seeking behaviour
- higher self-esteem
- high activity levels
- preference for personal freedom over adaptation of social norms
- need for independence

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Whether we are risk seekers or risk averse, a key problem for all of us is that our perception of risk and the actual level of risk is usually quite different. This gap is due to any number of a wide range of factors that seriously distort our estimation of how risky something is (see Panel on page 16, *Factors affecting risk perception in the railways*).

Do organisations compensate for risk?

It seems that individuals operate their own 'risk economy' in which they conduct their activities within a self-defined risk comfort zone (see *What affects risk-taking?*, this page). Does something similar operate for whole industries? The aviation industry has suffered what appears to be the same accident rate since the early 1970s. This is allowing for increased flights, and in spite of major advances in technology (eg Ground Proximity Warning System and Airborne Collision Avoidance System) and in training (eg Line Oriented Flight Training and Crew Resource Management) as well as reliability improvements in manufacture and maintenance. As safety professionals discover more about the complexities of accident causation and safety management, it may be that they need to guard against a new risk: that the organisational focus is on a 'same for more' risk economy (ie same accident rate for more productivity) rather than a concerted effort to reduce the accident rate in absolute terms.

Further information in Keinen et al (1984)

How can you reduce risky behaviour?

Reducing risky behaviour is quite difficult. This is partly because people conduct their activities in a way that makes them feel safe – even if they are not. But it is also because of the large number of factors that affect people's perception of risk. Together, these factors mean that it is rarely effective to simply explain the real risk to people. Instead, if people are not naturally sensitive to risks (sometimes called being risk averse), we need to use our knowledge of the factors to find effective ways to persuade them.

Human performance

Factors affecting risk perception in the railways	
Factor	**Effect**
Age	Both younger and older people often underestimate risk. They also overestimate their ability to deal with it.
Gender	Men tend to take more risks than women. They also perceive what they do as less likely to result in an accident.
Experience	More experienced people develop an increased awareness of risk and reduces the likelihood they will be involved in an accident. However, habitual response to 'routine' hazards can reduce risk awareness.
Reward system	Payment by piecework may be good for productivity, but also increases risk-taking and accidents.
Overconfidence	Humans are naturally overconfident and unrealistically optimistic – probably a basic survival mechanism – which often leads us to underestimate risk. A majority of us, for example, consider ourselves less likely than average to get cancer, get sacked from our job, or get mugged. Obviously, only 50 percent can be 'less likely than average' to do anything.
Controllability	If we think activities are under the control of others, we think they are they are relatively more risky. For example, releases of toxic chemicals by industrial facilities are judged to be riskier than activities under our own control eg driving, walking on the line.
Availability	Facts that readily come to people's minds are usually rated as more probable than those less easily recalled from memory.
Anchoring	People often base their judgements on recent information that may be quite unrelated (see Panel on page 17, *Vlad the Impaler*).
Familiarity	Risks from unfamiliar activities (eg a radiation leak) are judged to be greater than risks from familiar activities (eg your job).
Fairness	Risks from activities believed to be unfair (eg the unpopular siting of a community incinerator) are judged to be greater than risks from activities judged to be fair (eg vaccinations).
Benefits	Risks from activities that have questionable or indirect benefits (eg nuclear power stations) are judged to be greater than risks from activities that have clearer, more personal benefits (jobs, monetary benefits, car driving).
Catastrophic potential	Risks from activities that can cause a significant number of simultaneous deaths and injuries (eg a rail crash) are judged to be greater than risks from activities that cause deaths and injuries scattered across time and space (eg car accidents).
Understanding	Poorly understood risks (such as bad health due to exposure to radiation) are judged to be greater than risks that are well understood or self-explanatory (such as slipping on ice).
Cause and effect proximity	Perception of risk is reduced by the failure of the risk to manifest, eg an individual may indulge in a particular risky behaviour, like red zone working, many times without suffering any apparent consequences.
Conflict avoidance	People underestimate risks that question their earlier decisions, eg cigarette smokers underestimate the risks associated with tobacco compared with non-smokers.
Dread	Risks from activities that evoke fear or anxiety (eg exposure to cancer-causing agents) are judged to be greater than risks from activities that do not arouse such emotions (eg accidents at work).
Trust	People or organisations which lack trust or credibility (eg companies with poor environmental track records) are judged to be greater than risks compared with those that are trustworthy (eg effective regulatory agencies).
Accident history	Risks from activities with a record of major accidents or frequent minor accidents (eg level crossing incidents) are judged to be greater than risks from those with little or no such history (eg new rules).

Three lines of approach to reducing risky behaviour involve *selection*, *targeted communications* and *behaviour modification* programmes. You can find out more about these in the paragraphs below.

Selection

It may be helpful to consider people's propensity for risk as part of an organisation's selection process. In this way, organisations can screen people who are less inclined to take risks in the first place. For example, the Zuckerman Sensation Seeking Scale does this by asking people about their thrill-seeking behaviour and boredom levels. This psychometric test identifies those people who favour risky activities in real life and who often intentionally expose themselves to danger. Research at Loughborough University showed that high scorers on the test are also more likely to gamble and expose themselves to new sensations eg through volunteering for novel activities.

Sensation seeking and risk taking are closely related. Research among car drivers has shown that the Sensation Seeking Scale can identify people who will commit more moving traffic violations. Psychometric tests such as this may form a useful decision aid – as part of a comprehensive selection process – in making sure the right people are available for safety-critical jobs.

Targeted communications

Communications designed to alter people's attitude to risk are likely to be ineffective unless they are guided by the factors known to influence our perception of risk (see Panel, *Factors affecting risk perception in the railways*). O'Neill (2004) says that people fall into different groups according to their sensitivity to risk, as follows.

Vlad the Impaler

When did Vlad the Impaler die? Before asking the person next to you, ask them to write down the last three digits of their telephone number. Now ask them for the date of Vlad's demise. Chances are, there will be a strong relationship between the two numbers, and your colleague will have assumed that he lived in the first 1,000 years AD. (In fact, he died in 1476, at the ripe old age of 45). Why should this be? It turns out that if people have little basis for judgement, they will tend to use something from a recent activity – even though it is completely unrelated. This is the phenomenon of *information anchoring*, and it can enormously (and unwittingly) alter a person's perception of risk.

- *Risk averse* people are the most easily influenced by communications about risk. They may be regarded as natural risk managers who are ready to hear about new risks and are likely to mobilise resources to deal with them.
- *Risk tolerant* people tend to be ambivalent about risk. Their response will depend on their personal experience of the risk being addressed.
- *Risk deniers* are unlikely to take any form of action in response to a communication. This may be because they are in denial, or will not (or cannot) commit the resources to deal with it – unless an incident occurs.
- *Risk seekers* are deeply convinced that are effective risk managers. They see risks as a source of personal challenge and adventure. Raising awareness of a risk in such people may result in the probability of the risk increasing rather than reducing.

Behaviour modification programmes

Safety behaviour is more influenced by the consequences of such behaviour than by general attitudes to safety or instructions to behave safely. The influence is stronger if the consequences are positive rather than negative, sooner rather than later, and certain rather than uncertain. Behaviour modification programmes can provide a framework for presenting these consequences in a structured way. It does not really matter which programme is used. However, to be effective, the organisation's safety culture must be capable of supporting the programme (we cover safety culture in more detail in the section on *Culture* on page 91). Evidence from experience with behaviour modification techniques in a range of industries confirms that they can lead to safer behaviour, and can result in reductions in accident/injury rates. Behaviour modification programmes have been most successful when they have used a combination of all the principles of behaviour modification (see Panel, *Principles of behaviour modification*).

Principles of behaviour modification

- *Behaviour can be measured.* To make measurement possible, the behaviour you wish to change must be carefully defined and observable.
- *Behaviour is a function of its consequences.* People continue to behave as they do either because the consequences reinforce this behaviour or the consequences do not reinforce doing things differently.
- *Behaviour can be changed by providing appropriate reinforcement and feedback.* Positive reinforcement – such as thanks, praise and support from colleagues and management – promotes behaviour change, whereas punishment in an organisational context – such as blame, criticism and disciplinary action – is almost always counter-productive.
- *People whose behaviour you want to change need to be involved in goal-setting.* When people are involved in setting challenging and achievable targets for changing their behaviour, this adds to the positive effects of reinforcement and feedback.

Successful behaviour programmes have not only improved safety. They have also led to improved productivity and business performance. The following conclusions have emerged from the experience of safety-critical organisations with behaviour modification programmes:

- Behaviour modification programmes should not focus exclusively on the behaviour of the individuals in the workplace. They need to be sensitive to the demands of the job and normal work practices.
- Much of the benefit comes from the engagement process in identifying goals, setting targets, working to achieve them, and measuring and providing feedback on performance. The processes used to select and implement a behavioural modification programme are more important than the specific programme selected.
- It is also true that different behaviour modification programmes may be suitable for organisations or work-sites at different levels of maturity. It is important to select a programme that is appropriate for the maturity of the work-site.

Human performance

Several companies in the UK Oil and Gas Industry have used many of the available behaviour modification programmes. These include Time Out For Safety (TOFS), Advanced Safety Auditing (ASA), STOP and Care Plus - see Fleming & Lardner (2000).

Further information about risk

1 Fleming M. & Lardner R. (2000) Behaviour Modification Programmes: Establishing Best Practice, The Keil Centre, Edinburgh. (Research performed for the HSE)

2 Keinan G. Meir E. & Gome-Nemirovsky T. (1984) Measurements of risk takers' personality. Psychological Reports 55:163-167 © Psychological Reports 1984

3 Loughborough University, Ergonomics Ltd & Aston Business School, (2004) Recidivist risk takers who work at height. HSE.

4 O'Neill. P. (2004) Developing a risk communication model to encourage community safety from natural hazards. Discussion Paper Jun 2004 for State Emergency Services, Australia

5 Wilde G.S.J. (1998) Risk homeostasis theory: an overview. Injury Prevention 4, 89-91 British Medical Journal Publishing Group

Why do accidents happen?

If you were employed by the railway industry in the year 2002–03, there was around a 1 in 50 chance that either you or one of your colleagues was involved in a workplace accident requiring at least three days off work to recover. Over the same period, you would have been twice as safe working in the construction industry and three times as safe in the agriculture industry (*HSE*).

Aren't accidents due mostly to human error?

The number of workplace accidents on the railways reflects the fact that it is a relatively dangerous place. But why do these accidents happen? Obviously people make errors – see *Why do people make mistakes?* on page 9. And just as clearly, human errors are intimately involved in accidents. In fact, they are so involved that it seems reasonable to blame them for the accidents that happen. However, human errors don't provide anything like the full story of how accidents happen.

Before 1947, investigations of military aviation accidents had concluded that pilot errors were the cause of crashes. But then two psychologists, Fitts and Jones, looked more closely at what pilots did in the cockpit. They realised that the design of the instruments and controls was producing misreadings and actions that had never been intended by the designers. The pilot errors were not random events. Rather they resulted from understandable, regular and predictable aspects of the designs they were faced with. What is more, the errors occurred much more often than accidents did. Significantly, disasters and near misses usually occurred only when these human errors occurred in combination with other factors or other circumstances.

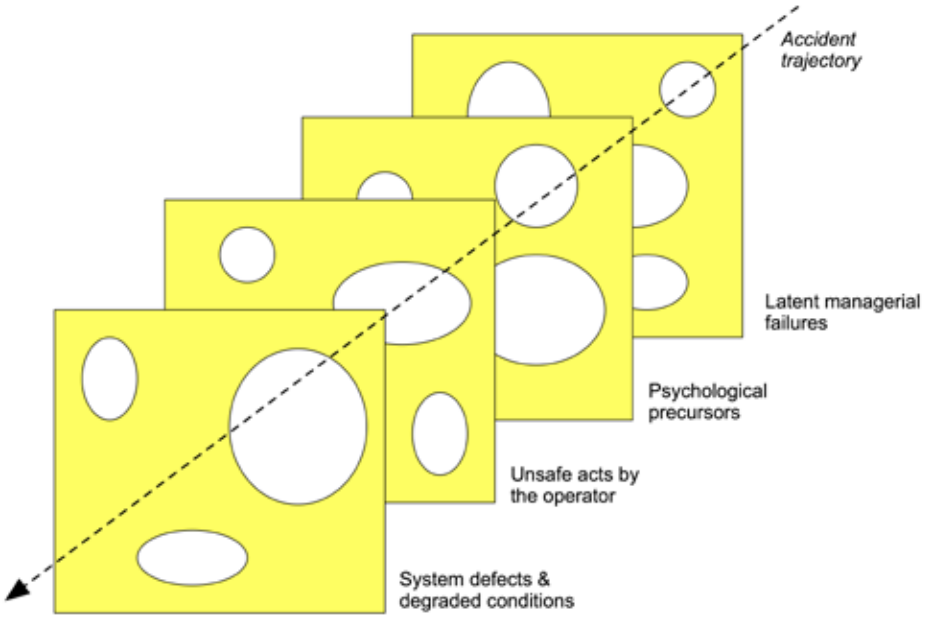
> 'Rather than being the main instigators of an accident, operators tend to be the inheritors of **system defects** … Their part is that of adding the final garnish to a **lethal brew** whose ingredients have already been long in the cooking.'
> James **Reason,** psychologist

One solution was re-design. This means that modern approaches to *user-centred design* (page 25) are essential to avoiding the kind of error discovered by Fitts & Jones. But it is not enough. And neither are better *training* (page 55) and *selection* (page 79) – vital as these are to a comprehensive solution. While there is a place for all of these approaches, they all centre on the user. The breakthrough in understanding accidents came when they were seen not just as something bad that happened to users, but as products of the way in which the whole system worked.

Not only was it recognised that accidents tend to be the result of a complex chain of contributory events, but also that some of the factors contributing to an accident are permanently present in normal working conditions. So the question became 'What are all of these contributory factors, and how do they all come together sometimes to create an accident?'

To answer this question, James Reason came up with his now widely-known 'Swiss cheese' model.

Reason's (1990) 'Swiss cheese' model of accident causation



Reason (1990) says that systems have multiple layers of defence against hazards and errors. It is only when the failures in these defences line up with each other that an accident or incident results. The last line of defence is a person's ability to compensate for *mistakes* (page 9) (eg those arising from bad *interface design* (page 33) or *workplace design* (page 41)) and adverse events (eg those arising from increasing *workload* (page 125) or poor working conditions, resulting in *stress* (page 120) and even more errors).

The involvement of a human being is a positive benefit to the normal functioning system as well as being a source of increasing weakness as abnormal or degraded conditions nibble away at their ability to cope. Skilled and motivated operators of equipment can be very effective last-line defences under surprisingly adverse conditions as they search to prevent a bad situation getting worse. To see this happen, you only have to watch an experienced signaller at a busy panel in the rush hour having to cope with a track circuit failure.

Some of the 'holes in the Swiss cheese' are active failures of human or mechanical performance, and others are 'latent' conditions, such as management factors or poor system design. However, it is clear that if steps are taken in each case to reduce the defensive gaps, the overall chance of accidents occurring will be greatly reduced.

Latent failures at the managerial level can be reduced by organisational planning. Psychological failings can be reduced by paying attention to the types of task that are required of workers, eg through *task analysis*, (page 47). Unsafe acts can be reduced by good workplace, equipment and interface design.

'To err is **human**; to blame it on the other guy is even more human.' Bob **Goddard,** rocket scientist

How can you identify the 'holes in the cheese'?

It's never possible to identify all the 'holes' that may develop in the future. But paying attention to all the areas outlined in this Guide, together with the best engineering, management and health and safety practice, will do a lot to stop the holes all lining up catastrophically.

Looking back, it is possible to discover a great deal about the size and origin of the holes – and how they came to be lined up – through informed accident investigation.

A key tool in accident investigation is root cause analysis. There are a number of methods for this, including *Fault Trees* and *Why-Because analysis* (see Part 3). An important human factors tool in this area is HFACS (Human Factors Analysis and Classification System). Based on Reason's approach, the HFACS framework provides investigators with a comprehensive tool for identifying and classifying the human causes of incidents. This tool is relatively easy to use, though its designers have assumed that its users will be human factors experts. (For this reason we give the key reference (Shappell & Wiegmann, 1997) but not a detailed summary in Part 3 of this Guide.)

The use of tools such as these in support of rail accident investigations is being guided by the new Railways (Accident Investigation and Reporting) Regulations 2005, in which human factors considerations are required to cover specifically the 'man-machine-organisation interface'.

A guide to the human factors aspects of rail incident investigation has been incorporated into formal SPAD investigation guidance (see *Further information*). (For an overview, see Panel, *HF checklist for accident investigations).*

Human performance

HF checklist for accident investigations

Personal factors

- Fitness and health (illness, disability, medication, drugs and alcohol etc)
- Lifestyle (financial worries, births, marriages, deaths etc)
- Morale and motivation
- Competence (task demands, assessment, training, complacency etc)

Mental factors

- Perception
- Vigilance and attention
- Memory
- Decision-making process
- Situational awareness

Team factors

- Communication
- Leadership
- Teamwork

Working condition factors

- Management (supervision, rules, procedures, planning etc)
- Environmental aspects (noise, light, etc)
- Equipment (design, training, maintenance, malfunction etc)
- Fatigue (shift work schedule, overtime, breaks, etc)
- Workload (too much, too little etc)

In 2002, a SPAD Hazard Checklist was developed for use across the railway industry (revised in 2004). This identifies both working practices and communications procedures that should be adopted by both signallers and drivers to help prevent SPADs occurring. Over and above these guides, it may be helpful to consider more general human factors guidance on how to get the most from accident investigations.

Best practice in conducting interviews following an accident

Preparation

Investigators must be prepared to deal with details of a more private nature concerning the interviewee, if these relate to the accident. Interview preparation is very important, not only to avoid the need for re-interviewing but also to obtain full co-operation and good-quality human factors information without having to go into too much detail at a private level. It helps to gather as much information as possible before the interview, listen to any voice recordings, look at other records and plan the questions to ask. Explaining the interview structure to the interviewee may also help them to understand the aims and phases of the interview.

Duration and atmosphere

Interviews ought not to be too long (two hours maximum) and performed as soon as possible, as the interviewee may forget the details of the incident. What is more, the interviewee's 'rationalisation bias' (the tendency to find a plausible explanation or justification of the facts) will increase if there is a long time between the event and the interview. During the interview, it is important to set a tone that creates confidence without causing confusion about the role of the investigator. The place should be comfortable, with style and vocabulary adapted to the interviewee. However, it is important to maintain a professional approach.

Note

This general guidance is complemented by a specific recommended procedure for use by Driver Standards Managers in interviewing drivers following a SPAD. (see *Further Information*).

Eliciting and storing information

An effort should be made to ask open questions and use leading (or closed) questions to get confirmation of details. Open questions start with the words 'what', 'who', 'when', 'why' or 'how' (*'How was your stress level at that time?'*). In comparison, closed questions prejudge the response, can usually be answered by yes or no, and start with a verb (*'Didn't you feel that you were quite stressed?'*).

Active listening is another key element in interviewing technique. It implies paying attention both to what is said and to body language, and consists of repeating or re-wording the interviewee's answer in order to avoid misunderstanding and to obtain as much information as possible. It is also worth considering the use of some means to prompt recall – such as a track layout diagram, transcripts of communications, or photos (or a video) of the reconstruction.

Human factors checklists (see Panel, *Checklist of human factors issues for investigations)* may also be used for guiding the discussion. It is important not to jump to conclusions and to search for elements that might disprove the hypothetical explanation of what happened rather than confirm it. It could be useful to keep track of interviews by tape recording them or taking notes. However, this may change the atmosphere and even be counterproductive as interviewees may express themselves less easily. When recording or note-taking, it is important – if a climate of confidence is to be created – to give the interviewee right of access to the recorded material. National legislation may cover this point in the case of a serious accident.

Things to remember about causes

- The investigation must go far deeper than the human error that is often the last thing to happen before an accident.
- There is a chain of elements/factors that precede the accident, and all of them have contributed to it.
- No single contributor sufficiently explains the accident.
- Each contributor has by itself increased the probability of the accident.
- Some contributing factors are instantaneous (eg track circuit failure) while others have existed for a long time (eg shortage of experienced signallers).
- Many factors exist all the time and do not normally lead to an accident.
- Some permanent factors (eg the shortage of experienced signallers or the high density of train movements) may become very critical in degraded operations.
- Human error can take place at any hierarchical and organisational level of the system – not just on the track, train, station or in the signal box.
- Understanding why the incident happened is much more instructive, and allows a wider range of remedial actions. than focusing on the 'final' human error.

How do you get the most from accident investigations?

Post-incident interviews

The interview remains the most appropriate technique for gathering behavioural and circumstantial data (see Panel on page 20, *Best practice in conducting interviews following an accident).*

Establishing causes

A key part of accident investigation is to use what we know about the multiple contributing factors that are generally responsible for accidents. It is not just about human error. In fact, as the Guide says elsewhere, it is better to think of errors as consequences, rather than as causes (*Why do people make mistakes?* page 9). (Also see Panel, *Things to remember about causes.)*

'Being blessed with both uninvolvement and **hindsight** it is [tempting] to wonder how these people could have been so blind, stupid, arrogant, ignorant or reckless.' James **Reason,** psychologist

Investigator biases

Investigators need to remember that decisions and actions that have a negative outcome will be judged more harshly than if the same process had resulted in a neutral or positive outcome. Unfortunately, we can expect this result even when judges are warned about the phenomenon and have been advised to guard against it. Investigators must also be aware that it is a natural human tendency to form hypotheses and then seek confirming evidence. It is much more efficient to seek disconfirming evidence. It has been famously said that you cannot prove that there are no black swans by counting the many thousands of white ones.

Investigators also tend to believe that people involved in an incident knew more about their situation than they actually did (see Reason's tongue-in-cheek quote on this page). They will tend to think that people should have seen how their actions would lead up to the outcome failure.

People's behaviour should be assumed to be rational (though possibly mistaken) from the point of view of their knowledge and mindset and the multiple goals they were trying to balance at the time. If we can understand how these factors guided people's behaviour, we can see how they were likely to make an error given the demands of the situation they faced.

Investigating consequences

Very often, you can learn much of value from an accident, not just by establishing its causes but also by investigating its consequences. For example, root cause analysis can just as easily be applied to each effect of the accident as well as the accident itself. Doing so will aid prevention by focusing on the wider issues of workplace organisation and regulatory failures.

Taking care of incidents

A near-miss is a situation where an error occurred but was recovered before it developed into an incident or accident. A near-miss is therefore an opportunity to improve safety practice based on a condition, or an incident with the potential for more serious consequences (see Panel on page 22, *How to make the most of near-miss data*). In the UK railway industry, CIRAS (Confidential Incident Reporting and Analysis System) has been set up to log reports of unsafe situations. Confidential reporting systems can be an essential source of information for aspiring High Reliability Organisations, but it is not used as much as it might be (see Panel on page 22, *All's well that ends well?*).

Near-miss reporting is only really successful in an organisation that wishes to develop a problem-solving rather than penalising culture. Senior management needs to be committed on a continuous basis to the issue and make a point of publishing success stories. In addition, whoever is responsible for the problem needs to be involved in analysing it, for they will frequently have the

Human performance

How to make the most of near-miss data

1 All reported near misses should be assessed for seriousness. This is best done under the leadership of a project manager who reports to a steering committee responsible to the top management.

2 Why-Because Analysis is useful to capture the root causes of the incidents and to identify effective countermeasures.

3 The analysis is best performed by a focus group, and should include the person responsible for the problem as well as other stakeholders, eg subcontractors

4 Each countermeasure's implementation status should be available to users and senior management.

Based on research by Braband & Brehmke (2002)

best ideas on how to prevent it recurring. This is only effective in a positive 'no blame culture'. The final thing to get right is identifying the right countermeasure to implement, through the right analysis. *Why-Because Analysis* (a form of root cause analysis) is useful here.

Techniques for accident/incident investigation

HFACS (Human Factors Analysis and Classification System) provides investigators with a comprehensive tool for identifying and classifying the human causes of incidents – but you need to be a human factors expert to use it (see Shappell & Wiegmann, 1997). HFACS helps to determine whether the individual, the line supervisor and/or management had the responsibility for preventing the error. It has been applied to the analysis of human factors data from approximately 1,000 military aviation accidents.

Fault trees. A form of root cause analysis – but be careful that the technique does not lead you to stop the analysis at the inevitable human error(s) that immediately preceded the accident/incident.

All's well that ends well?

Confidential reporting schemes are essential for safety-critical organisations. But how well do they work? A study of a chemical processing plant revealed why safety-critical workers do not report recovery from self-made errors to the near-miss reporting system. The main reasons were that they made and then totally recovered from the mistake themselves, that they didn't think the near-miss system was for reporting *their* particular errors; and that there was no bad consequence to their error. Surprisingly, failures to report these errors were shown not to be due to staff worrying about being blamed or shamed – they just didn't think reporting it to be worthwhile or relevant. These results represent a fundamental problem for organisations: how to communicate their interest in successful operator recoveries and so move away from an 'all's well that ends well' philosophy that helps no one. The secret probably lies in management demonstrating genuine pride and value in the expertise of their operatives through appreciation and continuous training schemes.

Based on research by Van der Schaaf & Kanse (2002)

Why-Because Analysis. This is an easy-to-use form of root cause analysis recently simplified for use by line managers in the railway industry. It has been applied to the analysis of near-misses in the railway industry in order to identify effective countermeasures.

'The point of learning about **human error** is not to find out where people went wrong; it is to find out why their assessments and actions made sense to them at the time.'

Sidney **Dekker,** Professor of Human Factors & Aviation Safety

Further information on accident investigation

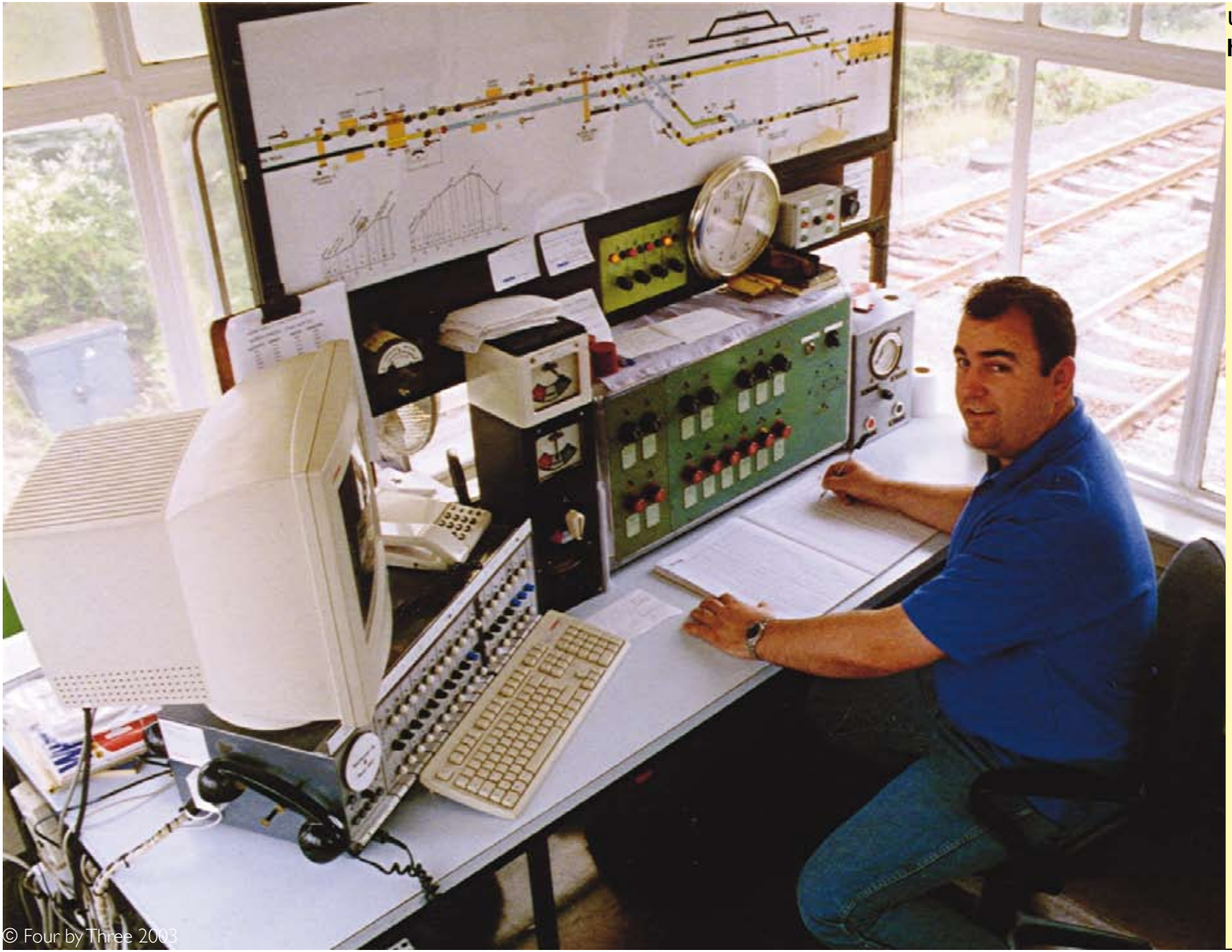
1 HSE Enforcement Statement/Quality Statement for Continuing Aim 2: Document G - Major Incident Response And Investigation Policy And Procedures, April 2001

2 Human Engineering Ltd, (2004) User Guide for Human Factors SPAD Hazard Checklist: Issue 2 HEL/RSSB/041123/RTB02, RSSB

3 Park, L. (2004) Work-related deaths - Investigators Guide, HSE. Produced to assist those tasked with investigating deaths in the workplace

4 The Railways (Accident Investigation and Reporting) Regulations 2005, Statutory Instrument 2005 No. 1992, www.opsi.gov.uk/si/si2005/20051992.htm#6 (as of May 2008)

5 Reason J. (1990) Human Error. New York: Cambridge University Press

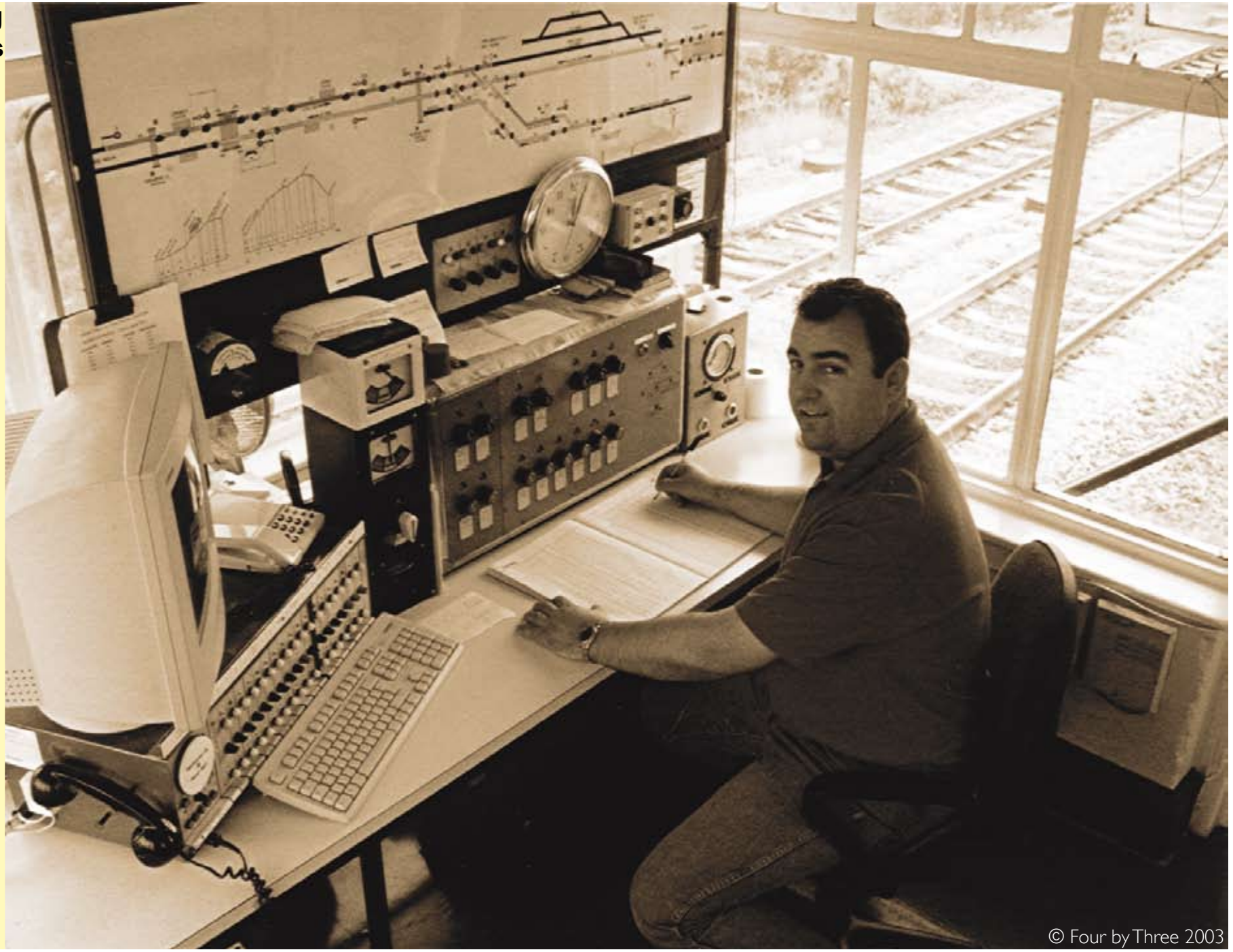


understanding
human factors

Design

understanding
human factors

Design



Design

Design is by far the cheapest and most effective way for a system or organisation to benefit from paying attention to human factors. If a system delivers exactly the results required by an organisation, it represents a happy convergence of user requirements, designers' intentions and practical implementation.

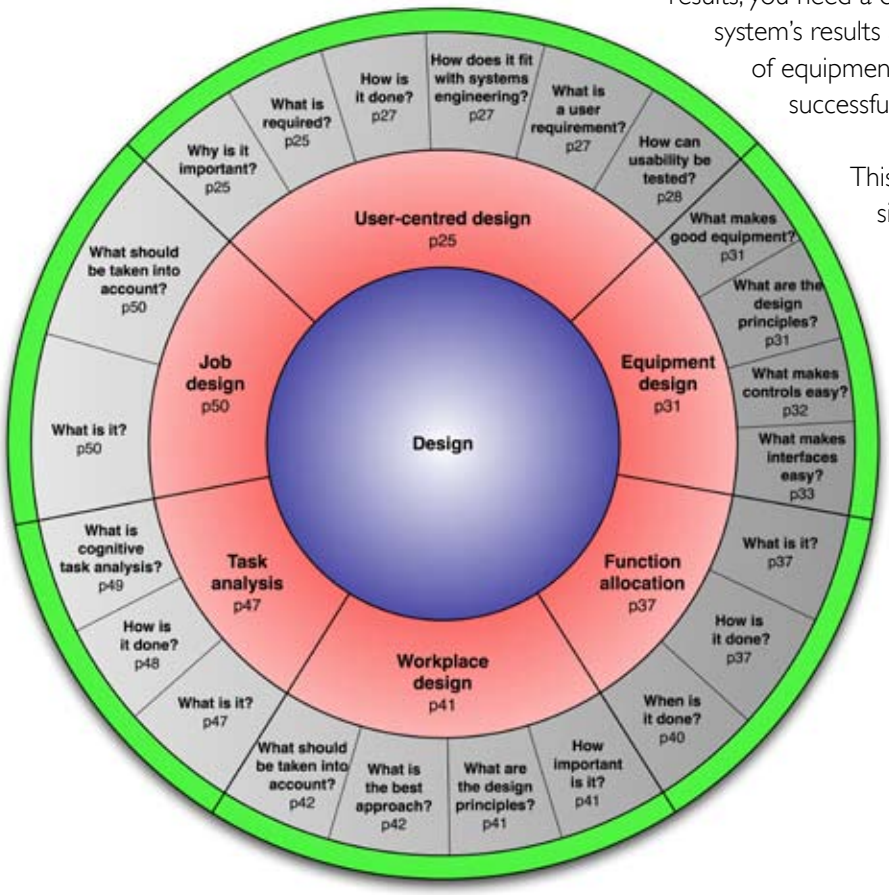
'Every system is **perfectly designed** to achieve the results it gets.' Don **Berwick**, MD

Often, a system's results are less than satisfactory. However, no matter what they are, they will always flow directly from the way the system is configured – whether this configuration is intentional or not.

There are two implications. First, if you want different results, you need a different design for it. Second, since a system's results are produced by the joint behaviour of equipment and its users, designers need to successfully account for both.

This diagram focuses on design. It shows six topics (in the middle red ring), and identifies the main human factors questions that this part of the Guide answers (in the outer grey ring). At the end of every section, you will find a list of sources of further information that will provide more detail. In addition, Part 3 gives further detail on key human factors techniques that are mentioned throughout this Guide.

Focus on design



User-centred design

Why is user-centred design important?

Both individual users and the organisation as a whole will perform better if users are involved in the design of their equipment, tools and working environments. Involving users in evaluating the design product at an early stage in the design process will help to ensure that the product is best suited to its purpose. It will also minimise the time, effort and costs associated with making subsequent design changes. Once a system is in development, correcting a problem can cost an estimated ten times more than fixing it during design; once a system is being used, it can cost 100 times more.

What is required to do user-centred design?

The users are the people (eg drivers) who use the product (eg a cab design), whether frequently or just occasionally. They may also be the people who are affected by the use of the product (eg passengers) or make decisions about its purpose (eg TOC managers). They don't all have to be represented on a design team, but the team must take all their views into account if a product (ie anything that is designed) is to be user-centred.

For design to be both user-centred and sound, the design team must ensure that:

- the end users (those who will actually use the product) take part in the design process
- data on the needs of all types of user – ie all stakeholders – is collected and analysed (see Panel on page 26, *What is a stakeholder analysis?)*

What is a stakeholder analysis?

A stakeholder is a person or organisation with an interest or concern in something – such as a to-be-designed system (the project). Stakeholder analysis is a tool for understanding a project's potential impact by identifying the stakeholders and assessing their interest in the project. Keys steps of a stakeholder analysis are:

1 Establish the objectives of the project

2 Draw up a stakeholder table that identifies stakeholders and their interests (both overt and hidden). Each stakeholder should be asked:
What are your expectations of the project?
What benefits are there likely to be for you?
What resources do you wish to commit (or avoid committing) to the project?
What other interests do you have that may conflict with the project?
How do you regard other stakeholders?

3 Assess the likely impact of the project on each of the interests (plus, minus or unknown). A *workshop* is a good way of doing this. At the workshop, it is often helpful to use something like *cognitive mapping* to capture how the stakeholders cluster by role and interest, plus the degree and direction of influence they have on each other regarding the project.
It's worth remembering that the likelihood of a stakeholder being noticed and involved will be down to their relative power to influence the project, the urgency with which they regard the project, and the relative legitimacy of their interest in the project.

4 Define options for managing the interests.

Adapted from: Department for International Development (1995)

Approaches for involving stakeholders in design and development

Approach	Resulting information	When to use
Background interviews, questionnaires and checklists	Information about the purposes and constraints of the target users; prototype evaluation. Questionnaires should not be used for primary data capture, but to confirm requirements – also useful as a checklist to help structure interviews.	Beginning through mid-point in the design cycle
Analysis of organisational and business requirements	Organisational policy that is understood and transferred to the design project. A key benefit is translating from the abstract to the specific, eg 'make a test system for signalling equipment' becomes 'support on-site testing by maintenance staff'.	At the beginning of the design project
Task sequence interviews (eg heuristic analysis) and questionnaires	Information about the target sequence of activities within the system's operational contexts and conditions.	Early in the design cycle
Observational analysis	Information about the physical environment in which the product will be used, eg Japanese auto engineers spent significant time in the homes of typical customers to understand user needs and values.	Early in the design cycle
Analysis of user problem reports for existing systems	Information about the negative aspects of related existing systems through problem reports and user suggestions – most useful if the new product is an evolution rather than an innovation. Statements like 'the display is too bright at night' or 'the rules conflict with each other' are very revealing.	Early in the design cycle
Analysis of existing systems	Information about the existing elements of similar systems to the one to be developed. Investigate different industries if necessary – don't be afraid to ask for access. Ask users what they like and dislike.	Early in the design cycle
Previous user modifications	Information about the way in which users have developed ad hoc fixes through engineered solutions to original equipment. These modifications will often give strong clues about previous design shortcomings and better understanding of user needs. They can often be reverse engineered into new design requirements.	Early in the design cycle
Focus groups and workshops (eg using brainstorming, hexagons, cognitive mapping)	Information about requirements and prototype feedback from representative stakeholders, including operators, supervisors, managers, trainers, engineers and maintainers.	Early through mid-point in the design cycle
Role playing, walk-throughs, and simulations	Information about the effectiveness of different designs and further insight into user needs and expectations – particularly useful for brand new, rather than evolved, systems.	Early through mid-point in the design cycle
User group meetings	Information about the use and operation of existing systems - most useful if the new product is an evolution rather than an innovation.	All through design cycle
Usability testing	Information about the usability of the system	At the end of each prototyping stage and as the final stage of the design cycle

Sources: Stevens et al (1998) reproduced with permission; also summarised from research by Preece et al (2002)

- data on the tasks that users (both operators and maintainers) perform in using the product is collected and analysed
- the wider technical and economic system to which the product belongs is considered
- the process involves user feedback and re-design where necessary
- the best possible outcome for the greatest number of people is achieved within reasonably practical limits.

How is user-centred design done?

A 'user-centred design' approach requires that the design of equipment and systems is based on understanding the needs and characteristics of its users. The design process needs to involve stakeholders in a continuing process of consultation and testing, which draws on all the available data on the purposes, needs, capabilities and limitations of humans. The Panel on page 26, *Approaches for involving stakeholders in design and development*, sets out techniques for involving users in the design and development of a product at various stages in the design cycle.

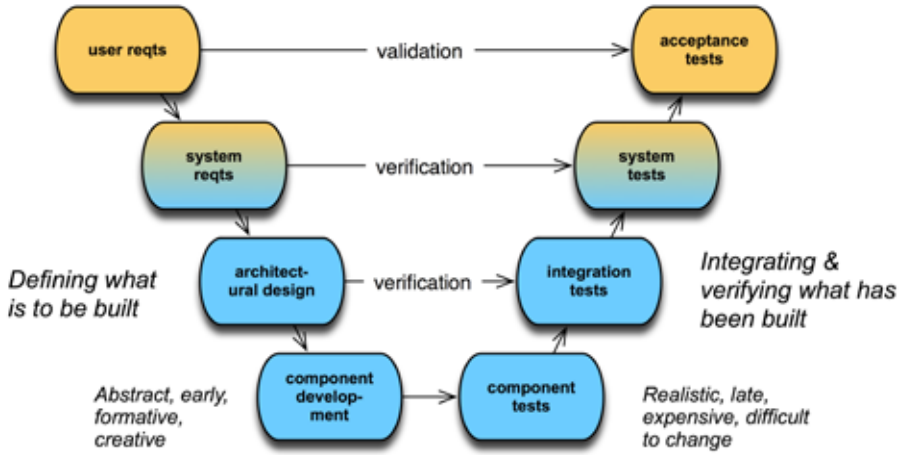
'We often don't notice **good usability**, but we almost always notice poor usability.'

How does user-centred design fit with systems engineering?

Many designers will be familiar with the systems engineering process, which is a structured way of creating effective solutions and managing their technical complexity. The diagram on this page illustrates the main stages of the process. The earlier stages of the systems engineering process are concerned with defining the requirements and the product to be built. Later, the emphasis switches to integration (where the product is assembled) and verification (where the assembled product is tested) before delivery to the users. The blue boxes show where hard science-based research (eg physics, engineering, chemistry, materials) development, design and manufacturing must take place. The amber-coloured boxes show where human factors considerations need to be plugged in – via the techniques outlined in the table.

To ensure the most effective use of these techniques, a Human Factors Integration Plan (HFIP) needs to be constructed (see Panel on page 28, *What's the plan?*).

The systems engineering process
From Stevens et al, 1998 reproduced with permission



An important part of defining user requirements is to remember that there is always more than one type of user with a stake in the system to be designed. The end users are the people who actually use the system, and their operational, physical and mental capabilities must be accommodated. However, the end users and the new product must together deliver a solution that is usable by other parts of the organisation (or perhaps by the organisation's customers). It is a good rule of thumb that designers fully understand the requirements of both the product's end users and the end users' 'customers' if their design is to be effective. In fact, it is very important for designers to understand the interests of all the stakeholders in the system. This underlines the importance of carrying out a proper stakeholder analysis (see Panel on page 26, *What is a stakeholder analysis?*)

What is a user requirement?

Designers need to distinguish between three different types of user requirement. The first type is to do with *user aims*. Designers must understand what users need the product for, and how it needs to fit with their general workflow and that of the organisation as a whole.

The second is to do with *user characteristics*. This means that designers must understand what the capabilities, limitations and expectations of the users are, including:

- visual capabilities
- degree of task and system-specific expertise

What's the plan?

Below are the main elements of a Human Factors Integration Plan (HFIP). If you operate your design project along these lines, you will go a long way towards effectively integrating human factors into your systems engineering process.

1 **Responsibility** – Who is in charge of HF for the project?
2 **Stakeholders** – How are they to be identified and consulted?
3 **Contractors and sub-contractors** – How will they ensure sufficient attention to HF? (What and where is *their* HFIP?)
4 **Coordination** – How are HF aspects to be coordinated across all parties involved? How will decisions made be followed up and HF issues closed off?
5 **Management** – How will HF considerations be incorporated into the regulatory consultation and approvals processes?
6 **Operational concept** – When will it be required and what will it contain?
7 **Legacy information** – What can be utilised from existing/similar systems to identify key aspects of users, processes, equipment, working conditions, and safety?
8 **Design options assessment** – How will it address user requirements, including capabilities, limitations, reliability, workload, health and safety, and hazard prevention?
9 **Standards** – What HF standards and principles will be used during detailed design?
10 **Operability trials** – What criteria will be used and how will performance be measured? What is the end user trials schedule? How will trials feedback be captured and used?
11 **Support** – How will documentation, help, training development and delivery be implemented and when?
12 **Evaluation** – How will data on the performance of the system in use be collected, analysed and used?

Adapted from London Underground Ltd (2002) with permission

- extent and regularity of system use
- experience with similar equipment
- user stereotypes and expectations of what the product is for and how it works
- expected maintenance schedules and required levels of maintainer expertise.

The third type of user requirement is to do with *user values*. If a new piece of technology is to be successfully adopted, it must take account of what motivates users and what can just as easily turn them off:

- *usefulness* – how far users perceive the innovation as being better than its predecessor
- *compatibility* – how far users perceive the innovation as being consistent with their existing values, needs and past experiences
- *ease of use* – how far users perceive the innovation as being difficult to use
- *self-image* – the extent to which a person's image is enhanced by the innovation ie how far it fits with (and promotes) a person's self-concept in the eyes of their peers (its 'coolness')
- *trialability* – the degree to which users can try working with the innovation (eg by a trial period) before having to make a total commitment to adoption
- *clarity* – the degree to which the results of an innovation are clear and communicable to others.

(See Panel, *Checklist for user requirements analysis*.)

'It is **vital** to collect feedback from users as an ongoing process.'

Checklist for user requirements analysis

You may find it helpful to use the following questions in documenting each user requirement.

- *Absolute reference* – what is the unique code that identifies the requirement?
- *Source* – who asked for the requirement?
- *Ownership* – who needs this requirement?
- *Priority* – how important is the requirement?
- *Performance* – how well must this requirement be met?
- *Urgency* – how soon is the requirement needed?
- *Stability* – is the requirement clear and accepted enough for design work to start?
- *Verifiability* – how will the final product be tested against this requirement?
- *Acceptance criteria* – what test(s) will satisfy the user that the requirement is met?

Source: Stevens et al (1998) reproduced with permission

How can usability be tested?

A key technique of user-centred design is assessing the designed product's usability – ie the extent to which it allows the user to reach their task objectives. Good usability is a conscious and deliberate design goal. We often don't notice good usability but we almost always notice poor usability. The idea of usability is highly relevant to the design of human-machine interface, hand tools and equipment, as well as the design of workplaces.

In assessing the usability of any product, we need to consider who the specified users will be, what the specified goals will be and what environment(s) the users will be using the product in.

The usability assessment process

The assessment process should:

- involve real users - both operators and maintainers (see Panel, *Maintainers are users too!*)
- give the users real tasks to carry out – including normal, degraded, abnormal and emergency conditions
- enable testers to observe and record user actions
- enable testers to analyse the data that is collected and make changes in response.

The three key criteria for assessing usability are:

1 *Effectiveness* – how well does the product do the job? Does it enable users to: complete the task?; do the task well?

2 *Efficiency* – how easy and/or fast can users get things done with the product? Does it enable users to: complete the task quickly?; complete the task reasonably easily?

3 *Satisfaction* – are users satisfied by the way in which the product supported their work? Do they like it?

In practice it is very difficult for designers to know or imagine all the usability criteria that are important to users. This is why it is so important to collect feedback from users as part of an ongoing process to improve the operability and maintainability of the product.

Maintainers are users too!

Maintainers are a key group of stakeholders in any new or updated system. Attention to design from the maintenance perspective will involve many interdependent decisions about modularity, accessibility, maintenance working conditions and inspection schedules, maintainer knowledge and skill demands, training requirements and staff availability, as well as safety. Research has produced good human factors guidelines for the kinds of problem that afflict the maintenance environment. As well as providing a handy checklist for maintenance workers and their managers, they are also a useful resource for designers. Anything that can be done at the design stage to avert the more common maintainer problems will substantially increase the usability and effectiveness of the system (see Panel on page 30, *The Dirty Dozen).*

Techniques for usability testing

Among many techniques for usability testing are:

- think-aloud techniques – in which the user is asked to describe all the steps they take in carrying out a task
- videotaping – so that designers can review what users do, and see where the problems are in their designs
- interviews and usability questionnaires – enabling designers to evaluate what users like and dislike about the design and increase their understanding of any problems
- testing and data logging – where the tests require typical users to perform typical standardised tasks in a typical task environment so that the following data can be collected:
  - time for users to learn a specific function
  - speed of task performance
  - type and rate of errors by users
  - user retention of commands over time
  - subjective user satisfaction.
- walk-throughs – in which a group of users step through tasks, and problems are noted for discussion
- focus groups – to discuss aspects of the product both before and after it is in use.

Recommended usability testing techniques

- *System Usability Scale (SUS)*
- *Software Usability Measurement Inventory (SUMI)*
- *User trials*
- *Focus groups*
- *Workshops*
- *Interface surveys*
- *Questionnaire for User Interface Satisfaction (QUIS)*
- *Cognitive Walk-through.*

The Dirty Dozen: Common maintainer human factors problems – and solutions	
Problem	**Solution**
Lack of communication	• Use logbooks, worksheets, etc, to communicate and remove doubt • Discuss work to be done or what has been completed • Never assume anything
Complacency	• Train yourself to expect to find a fault • Never sign for anything you didn't do [or see done]
Lack of knowledge	• Get the relevant training • Use up-to-date manuals • Ask a technical representative or someone who knows
Distraction	• Remain focused on finishing the job • Mark the uncompleted work • Lockwire where possible or use torqueseal • Double inspect by another or self • When you return to the job, always go back three steps • Use a detailed check sheet
Lack of teamwork	• Discuss what, who and how a job is to be done • Be sure that everyone understands and agrees
Fatigue	• Be aware of the symptoms and look for them in yourself and others • Plan to avoid complex tasks when you will be tired eg at end of shift • Sleep and exercise regularly • Ask others to check your work
Lack of parts	• Check suspect areas at the start of the inspection and ensure parts availability • Order and stock anticipated parts before they are required • Know all available sources of parts and arrange for pooling or loaning • Maintain a standard and if in doubt do not sign off the job
Pressure	• Be sure the pressure isn't self-induced • Communicate your concerns • Ask for extra help • Just say 'No'
Lack of assertiveness	• Only sign for what is serviceable • Refuse to compromise your standards

The Dirty Dozen: Common maintainer human factors problems – and solutions	
Problem	**Solution**
Stress	• Be aware of how stress can affect your work • Stop and look rationally at the problem • Determine a rational course of action and follow it • Take time off or at least have a short break • Discuss your problem with someone • Ask fellow workers to monitor your work • Exercise your body
Lack of awareness	• Think of what may occur in the event of an accident • Check to see if your work will conflict with an existing modification or repair • Ask others if they can see any problem with the work done
Norms	• Always work as per the instructions or have the instruction changed • Be aware the 'norms' don't make it right
Adapted from: Dupont (1997), reproduced with permission	

Further information about user-centred design

1 BS 6548-2:1992, IEC 60706-2:1990. Maintainability of equipment. Guide to maintainability studies during the design phase

2 BS EN ISO 13407:1999. Human-centred design processes for interactive systems

3 BS ISO/IEC 15288:2002. Systems engineering – System life cycle processes.

4 CAA (2002) An Introduction to Aircraft Maintenance Engineering Human Factors for JAR 66, CAP 715, www.caa.co.uk (as of May 2008)

5 Dumas S.J. & Redish J.C. (1993) A practical guide to usability testing, Norwood: Ablex Publishing Corporation

6 Dupont, G. (1997) The Dirty Dozen Errors in Maintenance. In: proceedings of the 11th Symposium on Human Factors in Aviation Maintenance

7 As of May 2008, www.usabilityhome.com/ Summarises several usability evaluation methods organised under the three types of: Testing, Inspection, and Inquiry

8 As of May 2008, http://jthom.best.vwh.net/usability/usable.htm is a very useful 'how-to' website for usability testing

9 ISO/TR 16982:2002. Ergonomics of human-system interaction – usability methods supporting human-centred design

10 London Underground Ltd (2002) Manual of Good Practice in Human Factors Integration, Rev A1, M 1035 R2.

11 Nielsen J. (1993) Usability Engineering. Morgan Kaufmann

12 Norman D. (1988) The Psychology of Everyday Things. Doubleday, New York

13 Preece J. Rogers Y. & Sharp H. (2002) Interaction Design: Beyond human-computer interaction. John Wiley, New York, NY

14 Stevens R. Brook P. Jackson K. & Arnold S. (1998) Systems engineering: coping with complexity, Prentice Hall, Europe

Equipment design

What makes good equipment?

Essentially, a good piece of equipment is one that is *fitted to its purpose*. This usually means that it is easy for people to operate and maintain. No doubt you frequently come across, and suffer from, numerous examples of poor equipment design in your everyday life, ranging from high-tech items such as video recorders and computers to basic items such as taps. The design of equipment for the workplace is often no better. In fact, poor design – particularly poor control room equipment design – has contributed to many major air traffic, marine, military and industrial accidents.

Much has been known for a long time about what constitutes good and bad equipment design. But there continue to be many examples where designers do not apply good human factors principles. One dramatic example was the accident at the Three Mile Island nuclear power plant in 1979 in which the nuclear core came close to a catastrophic meltdown. The accident resulted in permanent closure of the facility and sweeping regulatory and operational changes involving emergency response planning, reactor operator training, human factors engineering, radiation protection, and many other areas of nuclear power plant management. The main cause of the accident was that the control room was poorly designed, with problems that included:

- controls positioned too far from the instrument displays that showed the system's condition
- cumbersome and inconsistent instruments that often looked identical and were placed side-by-side, even though they controlled very different functions
- instrument readings that were difficult to read, obscured by glare or poor lighting or actually hidden from the operators
- inconsistencies in the meaning of lights and the operation of levers or knobs (ie pushing a lever up may have closed one valve, while pulling another lever down may have closed another one).

What are the principles for equipment design?

The fundamental principles of good equipment interface design are:

- *Visibility* – placing the controls where the user can easily see them, with adequate lighting for doing so
- *Feedback* – telling the user when their input has resulted in the system doing something, as when route lights illuminate on an NX panel in response to the signaller setting a route – but see Panel, *Too much user feedback!*

Too much user feedback!

Designers of the railway 375 stock made the AWS and CSR audible levels loud enough to cater for the worst case scenario to ensure they attracted attention. But drivers reported that these were excessively loud, resulting in earache and headache by the end of a shift. Design modifications had to be set in motion.

- *Natural mapping* – helping the user to understand how something works by mapping the relationship between controls and their effect. A good example of this is the way signallers' NX panels are laid out (for the most part!) to mimic the track and signal layout

- *Affordances* – using the shape and other characteristics of an object to suggest how it can be used. For example, buttons 'afford' pushing and pulling, knobs and switches 'afford' turning, 'slots' afford the insertion of suitable objects

- *Constraints* – limiting the way an object can be used and so reducing the possibilities for making errors. For example, the design of floppy disk drives only allows the disks to be inserted in the correct way

- *Conventions* – employing design practices that have become conventions because they work well, as in the case of handles that are pulled to open objects. When conventions are used, people can learn quickly how to use the system. When conventions are broken, they can become confused and frustrated.

- *Environment* – considering the environment in which an item of equipment is to be used. This means, for example, putting switches in positions where it won't be easy to activate them by mistake. It also means protecting and supporting the human under severe environmental demands (eg temperature, noise, vibration) – but this can be over-done! (see Panel, *Learning to ignore alarms!*).

Learning to ignore alarms!

AWS alarm activation occurs frequently when drivers travel over magnets for signals in the opposite direction on the Maidstone Relief Line. This is because the alarm is not suppressed on the bidirectional line. It is possible that drivers who keep being subjected to false AWS activation will become desensitised to the sound and they may learn to ignore the AWS alarm at this location.

- *Workflow* – considering the tasks that the users will undertake with the equipment. Effective analysis here will mean that the displays and controls necessary for more frequent and more critical tasks are readily available. For example, an important status display may be shown by default, and emergency shut down will be directly to hand.

- *Workload* – considering the capabilities and limitations of the users, and designing the interface so that they are never overloaded – either mentally or physically. For example, excess mental workload can occur with multiple alarms, or if an interface requires users' attention to be in several places at once – especially at critical times (see Panel, *Too much to do!*). Similarly, excess physical workload will occur if equipment is designed without proper regard to the way muscles and joints work. Designs that require heavy tools to be pushed against a surface, or held in a precise position or tight grip, will quickly cause fatigue.

What makes controls easy to operate?

Several factors affect how easy – or difficult – a control is to operate. Sanders & McCormick (1993) include these:

- *How easy it is to identify the control.* Shape, texture, size, colour, location, activation method and labels all help with distinguishing between different control types. Identical labels should be placed above both the control and its corresponding display.

- *Direction of control movement and its relationship with its corresponding display*[1]. When a control is moved or turned to the right, it should mean 'more' or 'on' and its display pointer must move right over a round or horizontal display.

1. Expectations about the direction of movement of controls is not the same in all cultures. For example 'on' in the US is reflected by a switch up position – the reverse of the UK.

Too much to do!

Class 175 Drivers have reported that they are required to answer alarms, communicate with passengers via intercoms and operate doors, as well as concentrate on driving and keeping to the line speed. On occasions, Drivers have been distracted by the acknowledge (ACK) alarm and, while trying to ignore a multitude of 'active' TMS (Train Management System) alarms, have sometimes found it difficult to differentiate the in-cab radio telephone. When TMS was first introduced, it was not unknown for the 'toilet full' alarm to sound, thereby providing an unnecessary driver distraction at potentially safety-critical moments.

- *Control/response (C/R) ratio* – the relationship between the movement of a control device by the operator and the movement of the system in response, often fed back to the operator via a system display. Low C/R ratio control devices are 'sensitive' in nature, in that a very small movement of the control results in a marked change (as in the case of helicopter pilot controls). This can lead to operators 'overshooting' the precise location required. Conversely, high C/R ratio devices are 'insensitive', requiring larger operator movements.

- *Resistance in the control* – elastic, spring-loaded or in some other form. This provides most of the feedback for users of such electro-mechanical controls.

- *Deadspace* – the amount of control movement around the null, home or neutral position that does not make the controlled system device move. In some control devices, significant amounts of deadspace may affect performance adversely. Deadspace is less important with less sensitive C/R relationships.
- *Location and arrangement of components.* As far as possible, displays should be placed close to the controls that affect them. Components should be grouped by function and those that are important and/or frequently used should be in a prominent location. Components should be positioned to reflect commonly used sequences, and sequences should be arranged logically eg from left to right.

Summarised from Sanders & McCormick (1993)

Some of these recommendations may seem obvious, but you need to remember that long or monotonous work can cause boredom and fatigue which, in turn, lead to reduced alertness, fatigue and errors. It's important to have a logical layout of controls and displays that assumes people will fall back on long-established habits.

'Style guides are an **important resource** for interface designers. Does your organisation have one?'

What makes interfaces easy to use?

It is often assumed that new technologies create an operating environment to which people will adapt easily. But this is not always the case, and designers of systems involving human-computer interaction (HCI) have to put a lot of work into getting the interface between users and computers right. In working on this interface, designers need to draw on several disciplines, particularly psychology. Studies by psychologists of sensation, perception, attention, memory and decision-making provide valuable guidelines on:

- screen layout
- information grouping
- use of colour and highlighting in interface design
- use of animation and shading
- menu length
- depth and breadth trade-offs in menu design
- alarms design and layout[2].

An important resource that many interface designers rely on is a *style guide* that is used across the whole organisation or industry. This ensures that all user-equipment interfaces are internally consistent and promote a consistent look and feel. It can also ensure that design guidelines are developed for specific classes of equipment where components may be relatively unique.

2. RSSB are developing definitive best practice on alarms arrangements for drivers' cabs – see RSSB website.

What should a style guide include?

An interface style guide should cover all components of the user-equipment interface. Information about the organisation and the target audience – such as language preferences and colour conventions – should also be taken into account. Remember both stakeholders and equipment designers will need to approve it.

The guide should consist of design principles stated as rules (eg colour codes for alarms or equipment status) and examples of user-equipment design components (display layout, window design, button shape and appearance, and so on.). It should be used to check and enforce compliance during the design process.

You need to structure human factors style guides in accordance with existing standards and current style guides approved elsewhere in the organisation (see Panel, *What should a style guide include?*).

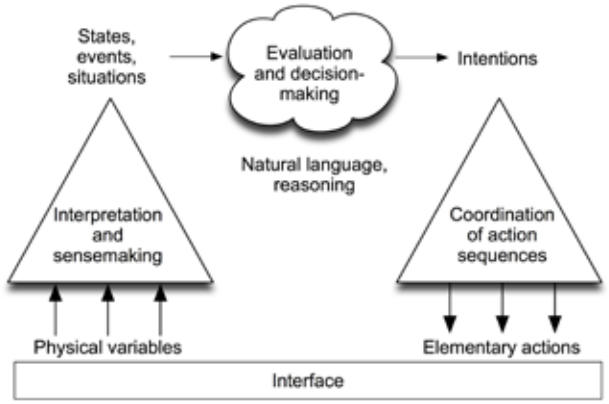
What's the most important interface design issue?

The common theme of all interface guidance is helping the user to cope with complexity. The diagram on page 34 emphasises what users need to accomplish through an interface.

Essentially, users need to structure information at a high enough level so that they can hold the situation in their heads and reason about it. They can then decide what they want to achieve and plan how they will do it. Finally, they must use the interface to carry out their plans.

It follows that a successful interface is one that first allows users to maintain an accurate moment-to-moment mental picture of the situation (usually called 'situation

Interfaces must help users filter complexity



awareness'). It then needs to support the actions the user must take to exert control over the situation. This has powerful design implications for the way information is structured and controls/displays are grouped. It also highlights how important it is for designers to employ a *user-centred design* approach (page 25).

What is situation awareness?

Put simply, situation awareness means knowing what is going on around you – and what is likely to go on in the future. For example, a signaller needs to know about current train positions and routes, and they need to predict future states so as to avoid possible conflicts. In operational terms, situation awareness means continuously extracting environmental information, integrating this information with previous knowledge to form a coherent mental picture, and then using this picture to direct further perception and to anticipate future events.

Most signallers – and other people too, like air traffic controllers – have experienced the feeling of suddenly losing 'the picture' when their *workload* (page 125) has become too much. An important way in which this picture is used is to create expectations for future events. This allows operators to develop plans and manage the complexity of situations. It follows that when these expectations are wrong – due to an inaccurate or failing picture – there may be severe safety-critical consequences. The design of interfaces with appropriate displays, annotations and feedback can do much to allow operators to develop and maintain an accurate mental picture.

'Situation awareness is what you need to know so that you are **never surprised**.'
Air Traffic Control Instructor

Jeannot (2003) says that three different levels of information processing are involved in good situation awareness:

1 *Perception*. This is the first fundamental step in situation awareness and involves perceiving and attending to important cues in the environment.

2 *Comprehension*. This step goes beyond mere perception and involves integrating different pieces of data and information and deciding on their operational relevance.

3 *Projection*. This step involves being able to anticipate future events and their implications based on comprehension of the environment. Projection allows for timely decision making. It is what gives experts apparently lots of time to carry out their tasks when compared to novices, who are much more 'trapped' in their immediate situation.

Source: Jeannot et al (2003), reproduced with permission

The two tables about situation awareness on page 35 give good clues to interface designers on how their products can support this vital aspect of user performance.

How do you measure situation awareness?

There are several measures of situation awareness, of which SAGAT (Situation Awareness Global Assessment Technique) is the most widely known and certainly the best publicised. SAGAT involves a user and a simulation of the task. Jeannot explains that the simulation is frozen at randomly selected times and the user is asked about their perception of the situation at that instant. SAGAT queries are on specific data or data criteria corresponding to the three levels of situation awareness described earlier. The screen and all information sources are blanked/hidden. Computerised versions of SAGAT exist, but paper versions are probably more easy to use (and modify). This technique could be used as part of user training and appraisal programmes.

What challenge does situation awareness present?

Interface designers need to work out how to present relevant information so that it's easier for users to integrate information from different sources (eg timetables, weekly notices, NX panel information) and using different channels (eg Concentrator, Panel, VDUs, talking to colleagues). Users need to understand the situation – not only what has been happening, but also what this situation means for the immediate future.

Indications of good and bad situation awareness	
Indications of good situation awareness	**Indications of impaired situation awareness**
• Anticipating events • Being able to predict the next task demand requiring attention • Managing resources (technical system, team demands, communications etc) • Managing time • Feeling of being in control • Taking the right decision at the best moment, eg managing traffic in a safe and expeditious way • Detecting mismatches and uncommon events	• Increase in delay in communication response times • Inconsistency in communications with colleagues • Sudden and unexpected variation in workload • Confusion • Need to check the same information several times *Source: Jeannot et al (2003), reproduced with permission*

Factors affecting situation awareness, and strategies people use to recover it	
Factors leading to the loss of situation awareness	**Strategies used to recover situation awareness**
• Time pressure • Focusing on non-pertinent, or less pertinent information • Focusing on a subset of relevant information, but missing the evolution of other information • Becoming reactive rather than proactive • Reduced room to manoeuvre • Increased occurrence of non-safe situations • Noise/distraction from other people • Mental and/or physical fatigue • Volume of train movements; sudden variation in traffic load • Number of phone calls • Lack of timetable/head code information at the right time • Lack of adequate feedback • Too much happening and having to process too much information • Traffic building up • Unusual or unexpected events, eg unexpected communications with colleagues, suddenly degraded working	• Increase delays between telephone calls and answering • Checking consistency between panel displays and timetable updates • Forcing oneself to speak slowly and precisely; return to strict phraseology • Request help to decrease load • Scrutinise all movements information more closely • Force oneself not to spend too much time on a single problem • Reorganise task strategy, eg change method of prioritisation • Prioritise work and 'forget' less important tasks • Always prioritise new information as it arrives

Expert users deal with the present by understanding how current events might develop in the future – and taking specific action now to simplify things later. It is worth noting in passing that the main reason that the TRUST system is unpopular with many signallers is because it is only concerned with historical events. Unlike signallers, it is blind to all the much more undesirable events that the signallers manage to avoid through effective action. The results that skilled operators achieve can only be fully appreciated in terms of what could have been.

Exclusively focusing on historical events without this context (as TRUST does) simply transforms highly skilled performance into a thankless task.

A particular design challenge is to support the user's need to project into the future, while preventing them from acting on false expectations. As the discussion on investigator biases revealed (*Why do accidents happen?* page 18), people have a strong tendency to form hypotheses and then try to confirm them. Interface designs need to help users maintain an accurate understanding of the big picture as much as they need to help them operate according to what it tells them. There are currently no rules on how to do this, apart from the guidance provided by *function allocation* (page 37).

What are the design principles for effective interfaces?

An interface design must connect the user's purposes, needs, capabilities and limitations to the task's demands for the key principles for interface designers (see Panel on page 36, *Ten principles for good interface design*). Remember – many design problems arise from poor communication between the design team and the target users, so make sure you use a *user-centred design* process from the outset (page 25).

Wilson and Rajan (see *Further information*) give a very comprehensive checklist of the interface design factors that need to be taken into account.

Ten principles for good interface design

1 Ensure consistency and adhere to agreed standards and conventions
2 Structure tasks and information intuitively and reflect the real world experience of the job holder
3 Support user control (make sure the user feels in charge)
4 Provide user help
5 Reduce short-term memory load (eg support recognition as opposed to recall)
6 Provide visibility of system status
7 Provide informative feedback for all user actions
8 Provide simple error handling, prevention, recognition and recovery – allow easy reversal of actions (undo)
9 Design dialogues to yield closure (ie to ensure a task is completed)
10 Provide short-cuts for frequent/expert users

Specific equipment interface guidance for the railways

There is a Railway Group Standard that sets out the requirements for external visibility from inside driving cabs for control facilities and other interior arrangements. This Standard is designed to ensure a working environment in which drivers of traction and rolling stock vehicles and on-track machines can carry out their operational duties safely and effectively.

In 2004, RSSB published human factors guidance relating to GSM-R cab design. This provides a set of human factors principles for the human-machine interface within the cab. It also recommends an analysis technique based on software manikins to assess alternative cab fitment locations against human factors principles.

RSSB is developing detailed human factors guidance on alarm design and layout. In addition, HSE has published fact sheet guidance on alarm handling – see *Further information*. Further work by RSSB has resulted in a CCTV toolkit which aims to ensure that the system design can meet a variety of industry needs and support operator capabilities.

Tools and techniques

- *Design Scenario Analysis*
- *Heuristic Analysis*
- *Layout Analysis*
- *Link Analysis*
- *Keystroke Level Model*

See *Usability testing* on page 28 for recommended evaluation techniques.

Further information on equipment/interface design

1 Bailey R.W. (1982) Human Performance Engineering: A Guide for System Designers, Prentice-Hall, NJ.

2 Boff K.R. & Lincoln J.E. (1988) Engineering Data Compendium: Human Perception and Performance. John Wiley

3 HSE (2000) Better Alarm Handling. Fact sheet www.hse.gov.uk/pubns/chis6.pdf (as of May 2008)

4 Jeannot E. Kelly C. & Thompson D. (2003) The development of Situation Awareness measures in ATM systems. EATMP report. HRS/HSP-005-REP-01. © European Organisation for the Safety of Air Navigation EUROCONTROL

5 Kroemer K.H.E. & Grandjean E. (1997) Fitting the Task to the Human (5th Ed), Taylor & Francis

6 Pheasant S. (2001) Bodyspace. Anthropometry, Ergonomics and the Design of Work. 2nd Edition, Taylor & Francis

7 Railway Group Standard GM/RT2161 (1995) Requirements for Driving Cabs of Railway Vehicles, Aug 1995

8 Salvendy G. (1997) Ed. Handbook of Human Factors and Ergonomics 2nd Ed. Wiley-Interscience Publishers

9 Sanders M.S. & McCormick E.J. (1993) Human factors in engineering and design (7th edn), McGraw Hill, NY

10 Wilson J. & Rajan J. (1995) Human-machine interfaces for systems control. In Evaluation of Human Work: A Practical Ergonomics Methodology, Eds J.R. Wilson and E.N. Corlett, Taylor & Francis

11 Woodson W.E. Tillman B. & Tillman P. (1992) Human Factors Design Handbook. 2nd Edition, McGraw-Hill

Function allocation

What is function allocation?

When designing equipment for use by human operators, it's often necessary to decide what parts of the system (ie the equipment or the operator) are going to do what. This is known as function allocation. Function allocation may be fixed, where each system component remains dedicated to the role it is given. Alternatively, allocation may be dynamic, meaning that it is designed to be done during 'live' operational time. Quite often, system and job designers are able to arrange for a mix of fixed and dynamic functional allocation approaches.

'The basic problem is that for a system to be operated safely, an intelligent human operator **is necessary**. However, the human operator is an intrinsically unsafe component of the human-machine system.' Maarten **Boasson**, Professor of Computer Science

In broad terms, function allocation can take place:

- between people – where it is called '*teamwork*' (page 103) and is usually a mix of fixed (role-based) and dynamic function allocation
- between machines – where it may be fixed, with each machine programmed to fulfil its own – and only its own – function; or else dynamic, with a redundant system component taking over from another component that has overloaded or failed
- between people and machines – where newer dynamic approaches are taking over from the more traditional fixed approaches used in the earlier days of computers and before.

'The more advanced a control system is, so the more **crucial** may be the contribution of the human operator.'
Lisanne **Bainbridge**, Professor of Psychology

How is function allocation done?

There are three main strategies for fixed function allocation between people and machines:

- the capability strategy
- the automation strategy
- the economic strategy.

The capability strategy

This involves assigning each function to the most capable agent (either human or machine). This is the traditional approach (see Panel, *Fitt's list*) and relies on what we know of the differences between human and machine capabilities. For example, humans are better able to sense unusual and unexpected events, generalise from observations, develop entirely new solutions and detect stimuli when there is noise or clutter. By contrast, machines are better at monitoring for pre-specified events, storing and retrieving information, exerting considerable physical force and performing repetitive activities accurately, rapidly and reliably.

One problem with this strategy is that machines and software are evolving all the time and what is true at the design stage may not be true when the system is fielded, let alone later in its life. A second problem is that functional allocation is rarely left entirely to the designer. In practice,

Fitt's List – a traditional approach

In 1951, Paul Fitt concluded that humans appear to surpass machines with respect to:

- Ability to detect small amounts of visual or acoustic energy
- Ability to perceive patterns of light or sound
- Ability to improvise and use flexible procedures
- Ability to store very large amounts of information for long periods and to recall relevant facts at the appropriate time
- Ability to reason inductively and exercise judgement

And in 1951, machines appeared to surpass humans with respect to the following:

- Ability to respond quickly to control signals, and to apply great force smoothly and precisely
- Ability to perform repetitive, routine tasks
- Ability to store information briefly and then to erase it completely
- Ability to reason deductively, including computational ability
- Ability to handle complex operations, ie to do many different things at once

Summarised from Fitt et al (1951)

design decision making may be severely constrained by earlier management decisions (eg based on policy or union agreements) and system considerations (eg the need to fit with legacy systems – ie older systems still in use). This first strategy has been used a great deal, but is of limited value and is no longer recommended.

The automation strategy

This involves allocating to the machine every function that can be automated. It is favoured by many engineers as a way of reducing the risk of error, but it is dangerous in practice. First, not everything can be automated, and leaving unrelated bits and pieces of functions to people leads to boredom, inattention, de-motivation and overall poor performance. Second, machines are not perfectly reliable, and the more complex they are, the more they fail. This usually means employing higher skilled, better trained and more expensive operators, who – with not enough to do – suffer from even higher levels of boredom etc. This strategy has been used often, but is also of limited value and is not recommended (see Panel, *Ironies of automation*).

The economic strategy

This involves finding an allocation scheme that ensures economical efficiency. Here, designers start by allocating functions that clearly *must* be done by humans or machines – for mandatory organisational, political or safety reasons. They then distribute the remaining (probably most) functions between humans and machines in a number of alternative configurations. The actual configuration finally chosen needs to be an economic trade-off between the following factors:

Ironies of automation

1 Designers may assume that humans should not be included in systems because they are unreliable and inefficient. But many operating problems come from designer errors.

2 Automated systems are implemented because they can perform better than the operator, yet the operator is expected to monitor their progress.

3 The operator is reduced mostly to monitoring, leading to fatigue and ineffectiveness.

4 In the long term, automation reduces physical and mental skills of workers, yet these skills are still required when automation fails. In fact, the skills may be in more demand than usual when automation fails, because there is likely to be something wrong, requiring, takeover, diagnosis and recovery. De-skilling also affects workers' attitudes and health adversely.

Adapted from Bainbridge (1987), reproduced with permission

- developmental and operational costs
- maintainability over the planned system lifetime
- portability to different departments or organisations
- producibility (ie how easily they can be manufactured)
- safety
- staffing and training costs
- ability to meet defined user requirements
- ability to satisfy human needs.

This third, economic, strategy for functional allocation is the one recommended in this Guide, as part of a *user-centred design* process (page 25).

What are the rules for fixed function allocation?

The golden rule to remember is that machines must be made to support human purposes, not the other way round. There are three other key rules.

1 Allocate all clear-cut functions – where there are mandatory reasons for allocating a function, or portions of it – to either humans or machines.

2 Locate all remaining functions in a matrix that sets human performance against machine performance (both axes should use a simple scale of Unsatisfactory to Excellent) (see Panel on page 39, *What are our basic mental capacities and limitations?*).

If a function is in the unacceptable region of the matrix (it cannot be satisfactorily performed by either humans or machines), then the function must be re-defined or the system requirements must be modified.

If the function is shown to be unacceptable *either* for humans *or* machines then it should be treated as a clear-cut function and assigned accordingly.

If a function is in the region that is better performed by humans, then it can be tentatively allocated to the human alternative. Correspondingly, if it is better performed by machines, then it should be allocated to the machine alternative. However, these allocations may be changed by the third key rule (below).

3 Refine the preferred allocations according to:

- *Utility*. A function may be allocated to humans simply because their presence is required, or there is a compelling reason why they should perform the work eg it requires judgement
- *Health and safety*. A function may be allocated to humans or machines to reduce the risk to health and safety. The designer can prepare a list of potential injuries (cuts, bruises, fractures, amputations, burns, internal ruptures, eye penetration, asphyxiation, etc) and hazardous risks to health eg damage to sight, hearing, exposure to noxious substances etc). This can then be used as a checklist for human-machine allocation decisions.
- *Cost*. Consider the relative cost of human and machine performance and allocate on the basis of least cost. You will need to consider all the aspects of cost that are relevant to you. These are likely to include developmental and operational costs; maintainability costs over the planned system lifetime; costs of portability to different departments or organisations; cost of manufacture; and associated staffing and training costs.
- *Emotional needs*. A function may need to be allocated to humans because they need to know that their work is recognised for its value, to feel personally secure, or to feel that they are in control.
- *Information needs*. A function may need to be allocated to humans because they need information in order to be ready for actions and decisions that may be required.

What are our basic mental capacities and limitations?

Attention

- Attention on a task can only be sustained for a fairly short period of time, depending on the complexity of the task. The usual figure cited is around 20 minutes, after which fatigue sets in and errors are more likely to occur.
- People can only pay attention to a small number of tasks at once. For example, if a signaller is focused on handling a particular train, then it is likely that they will be less attentive to other aspects of safety, or other alarms.
- If a task is repeated often enough, we become able to do it without conscious supervision, although this 'automation' of repetitive behaviour can force us into mistakes. In 1979, an operator at Oyster Creek Nuclear Power Plant intended to close off two pump discharge valves. Through an attentional slip, he accidentally closed off two other valves as well, and in doing so, closed off all cooling to the reactor core.

Perception

- We do not have direct access to the world around us. Instead, we must interpret information we sense. The more visual information available to the perceiver, the less likely it is that errors will be made. Bearing this in mind, systems that include redundant information in their design may cause fewer accidents. An example of this was the change in electrical earth wire colour coding in the 1970s to include not only colour, but also a striped pattern. At the same time the live wire was changed from red to brown to overcome problems caused by red-green colour blindness, a condition which affects 1 in 10 of the male population.
- The more intense a stimulus (such as a light or a noise), the more powerful the response elicited (such as brain activity or a physical movement). This has implications for the way danger signals and alarms should be presented at work.

Memory

- *Capacity* – short-term memory has an extremely limited capacity. In general, people can remember no more than around seven recently presented individual items at a time. This has safety implications in areas such as giving new workers a set of instructions to follow from memory or attempting to remember the correct sequence of procedures within a new task. However, trained individuals are able to retain larger chunks of information in memory. For example, chess grandmasters can remember the location of more pieces on a chess-board because they see the pieces not as single units, but as parts of larger conceptual units
- *Accessibility* – even when items are stored in memory, it is sometimes difficult to access them. People are much more likely to remember information if they are in similar conditions to when they encoded the information. For example, signalling staff trained in a classroom may not be able to remember relevant details in a signal box.
- *Levels of processing* – another way in which information can be more reliably remembered is to learn it at greater depth. For instance, if it is necessary to remember items from the Rule Book, then it helps to understand more about the conceptual framework behind the rules. If only the words that express the rule – rather than its meaning and purpose – are remembered, then there is a higher chance of important information being forgotten.

Logical reasoning

- Humans are not very good at thinking logically, but in technological situations, logical procedures are often necessary (for example, troubleshooting an NX panel which has developed a fault).
- A common source of error in industry is the behaviour which arises from design which may be logical in a formal sense, but which is inappropriate to the way people think about their jobs - especially when they are under stress.. During the Three Mile Island incident in 1979, two valves which should have been open were blocked shut. The operators incorrectly deduced that they were in fact open, by making an assumption about the instrument display panel. The display for the valves in question merely showed that they had been instructed to be opened, whereas the operators took this feedback as an indication that they were actually open. Following this, all other signs of impending disaster were misinterpreted with reference to the incorrect assumption, and many of the attempts to reduce the danger were counterproductive, resulting in further core damage.

Adapted from Managing Human Error, POSTNOTE, June 2001, Parliamentary Office of Science and Technology, reproduced with permission

Note
Where adequate information for allocation is not available, human factors judgements by human factors experts based on partial information will result in better design decisions.

When is function allocation done?

Function allocation is one of the first sorts of human factors issues you need to consider when designing a system. Once you have made the necessary decisions about function allocation, you are ready to consider the human factors topics of *task analysis* (page 47) and *job design* (page 50).

Fixed function allocation

For fixed function allocation, all of the decisions are necessarily taken fairly early in the design process. However, while the decision to use dynamic function allocation needs to happen early, the actual allocations take place during operational activity.

Dynamic function allocation

Dynamic function allocation takes place all the time within human teams. Here, people are able to understand what they are trying to achieve as a team, what each other's responsibilities are and when to step in to help out other team members. (See the section on *teamworking*, page 103). In more recent years, machines and computer software have become sophisticated enough for something along these lines to happen between humans and their equipment. Known as adaptive automation, it involves the control of functions shifting between people and machines dynamically in response to environmental factors, operator workload and performance.

Human-triggered dynamic function allocation

At present, dynamic allocation is most commonly human-triggered and involves the human operator either engaging or disengaging some kind of automation. A classic example is when an airline pilot engages/disengages autopilot. An obvious rail example is when an IECC signaller uses Automated Route Setting (ARS) software.

Factors that influence when the operator will engage automation include:

- *their own current state* – the extent to which their *workload* (page 125) and ability allows them to perform the function that could be allocated to the machine
- *the cost of allocation* – the adjustments they will have to make (eg extra communications) in order to allocate the function to the machine
- *the machine's ability* – whether the machine can carry out the function, given the current situation and problem conditions (eg whether the machine has enough processing capability)
- *confidence in the machine* – whether the machine will perform the function well enough.

> 'Dynamic function allocation takes place all the time between humans – where it's called **teamwork**.'

Machine-triggered dynamic function allocation

Increasingly, dynamic allocation is being arranged via machine or software triggers. One example is the Airbus's ability to prevent the human crew from putting the aeroplane into a stall.

Railway examples (in increasing order of sophistication) include the Automatic Warning System (AWS), the Train Protection and Warning System (TPWS), Automatic Train Protection (ATP) and the European Rail Traffic Management System (ERTMS).

All of these machine-triggered allocation systems use *measure-based triggers*, ie machines take over functions on the basis of an automated detection or assessment of procedure violations or human workload. An alternative approach, which is presently only at the research stage, is the *model-based trigger*. The idea here is that an automated system is able to recognise or predict human states that indicate the need for function re-allocation. The system then shifts tasks away from the affected operator, either to another human or to the system.

Highly capable automated systems can make important contributions to system safety, precision and efficiency. But they also impose system costs in the form of new opportunities for error, which occur when human-machine coordination breaks down. The human operator is increasingly responsible for ensuring cooperation and resolving conflict between human and machine intentions and actions. However, if you dig a little deeper, you find that many of these joint systems only perform adequately because the human agents are resourceful and adaptable in the face of uncommunicative and uncooperative

machines. Time pressure, workload, and problems with situation awareness can reduce the operator's ability to coordinate properly with others.

Users need to be able to see what automated agents are doing and what they will do next. Users also need to be able to re-direct machine activities fluently when they recognise a need to intervene. Under manual control, human operators often obtain enough feedback about the results of their actions within a few seconds to correct their own errors. But there are many examples of human operators making the same types of error in setting up and monitoring automatic equipment that does not give adequate feedback. The design needs to take this into account and, for example, provide displays to help operators who have been interrupted in mid-sequence.

These problems must be addressed with an appropriate mix of *equipment design* (page 31), *job design* (page 50) and *training* (page 55).

Further information on function allocation

1 Bailey R.W. (1982) Human Performance Engineering: A Guide for System Designers, Prentice-Hall, NJ

2 BS EN 614-2:2000. Safety of machinery. Ergonomic design principles. Interaction between the design of machinery and work tasks

3 Bainbridge L. (1987) New Technology and Human Error, chapter 24, 271-283. John Wiley

4 ISO 10075-1:2000. Ergonomic principles related to mental workload: General terms and definitions

Workplace design

How important is it?

Designing the work environment or workplace to meet users' needs is as important as the appropriate design of equipment and human-machine interfaces. Poorly designed work environments can have serious consequences, such as schedule delays, recurring discomfort, a decrease in performance or output, and possibly permanent injury or death. Human beings are remarkably adaptable and we can adjust to whatever task, furniture or equipment we are given – but we sometimes do so at great cost. Problems such as Repetitive Strain Injury (RSI), for example, are often a specific result of the body adapting to a repetitive task or an inappropriate posture.

What are the principles of workplace design?

The overall aim of workplace design is to create a comfortable and stress- and hazard-free environment, which is compatible with performing tasks over time. More specifically, it aims to:

- decrease the number and cost of accidents, injuries and disabilities
- improve the responsiveness of the organisation as a whole to its customers
- ensure that organisational systems work as well as possible
- decrease physical and mental stress on personnel
- increase job satisfaction and productivity.

Four principles of workplace design

Four principles govern the broad arrangements of workplace design. They may seem like common sense, but are often overlooked.

1 *Importance.* Components that are essential to safe and efficient operation should be in the most accessible positions. 'Accessible' refers not just to ease of reach, but also to visibility, audibility etc.

2 *Frequency of use.* Components that are used frequently should be the most accessible.

3 *Function.* Components with closely related functions should be located close to each other.

4 *Sequence of use.* Components that are often used in sequence should be located close to each other and their layout should be consistent with the sequence of operation.

Source: Pheasant, in Wilson & Corlett (1995) (following original work by Sanders & McCormick, 1993), reproduced with permission

There is extensive information about our physical capabilities and limitations; about typical (and not so typical!) body measurements; and about likely user perceptions and behaviour (see *Further information* at the end of this section). Workplace designers can draw on this information in focusing on comfort, performance and health & safety. These criteria are related: case studies show that increased comfort and well being will improve productivity (and vice versa). The amount of improvement is typically in the order of 25% (not counting the longer term value of reduced sickness due to workplace conditions such as back and neck pain, and RSI). Many aspects of the three criteria of comfort, performance and health & safety should be served well if

you pay attention to four key design principles (see Panel on page 41, *Four principles of workplace design*).

How is workplace design best approached?

Once you have analysed the relevant *user-centred design* data (page 25) and developed the initial concept, it is good practice to create a succession of mocked-up workplace prototypes. You then need to evaluate these under representative conditions using typical user subjects. User trials should be designed to investigate the spatial arrangements for the avoidance of discomfort, inadvertent hazard potential etc. Observations should be recorded and appropriate design modifications made where necessary.

You can create preliminary, reduced-scale mock-ups with foam or toy bricks. At later stages, it's better to use full-scale wooden models. Workspace and clearance estimates should be assessed using a range of representatives of the user population wearing their likely clothing. More conveniently, precision graphical CAD environments using manikins, eg SAMMIECAD, can be used.

It's important to note that documentation of human factors during the design process is becoming more urgent as legal aspects of design-induced injuries place the burden of safety on the designer as well as the manufacturer.

What should be taken into account?

In designing a workplace that meets human factor requirements, designers need to take the following factors into account.

Analysing body size and postural requirements

Traditionally, body size and postural considerations have been investigated via a fitting trial in which an experiment is conducted with a range of possible users and an adjustable prototype. The aim is to investigate where the 'just right' point is for the majority of users. An alternative approach is to use the method of limits technique. This is a pencil and paper technique that uses body size data to predict what the results of a fitting trial would have been had it been performed. A third technique involves the use of simulation and modelling. Here, body size data drives software models which are allowed to interact to produce overall task timings or error rates (eg as in the Integrated Performance Modelling Environment - *IPME*) or else as three-dimensional manikins that can move around within an accurate simulation of the prototyped workplace (eg SAMMIECAD). Whichever technique is used, body size and postural considerations are generally addressed with three different sorts of measurement:

- *clearance* (eg head room, knee room, elbow room etc). Here the limiting user will (usually) fall into the largest 5% of the population (referred to as the 95th percentile)
- *reach* (eg location of controls with respect to the seat). Here the limiting user will (usually) be someone who falls into the smallest 5% of the population (referred to as the 5th percentile)
- *posture* (eg height of working surface which supports a particular task such as manual assembly or computer work). Here the limiting user will be the average user (the 50th percentile).

For each category, user adjustability of workplace components (eg seats, desk height etc) should be built around the 5th and 95th percentile points.

Based on work by Pheasant, in Wilson & Corlett (1995), reproduced with permission

Body size

Manufacturers of furniture and equipment sometimes base their designs on the measurements of the 'average' user. But more often they design with all sizes in mind, from the smallest to the largest. For example, the height of storage space might be set so that 90% of a typical office population can reach it, or a doorway might be designed so that 99% of the entire population can pass through it without stooping (see Panel, *Analysing body size and postural requirements*).

Postural requirements

The structure and arrangement of furniture and equipment should not only help people to maintain a healthy posture, but also allow them to vary or alternate pressure points and body positions at will. It's a good idea to provide spaces for people to walk short distances, adjust their chairs or alternate between seated and standing tasks.

Personal space

People need enough space to move about and perform various tasks. They also need 'personal space' (into which they allow only people with whom they want to have a personal discussion), 'social space' (in which they expect to make purely social, temporary contacts), and 'public space' (in which they don't expect to have direct contact with others). They can become tense or anxious when

Guidance on lighting

- Avoid lighting levels that are too low or too high for the amount of detail or contrast of the task – they will cause the operating mechanisms of the eye to operate at their limits, causing visual fatigue.
- Prevent glare and surface reflections wherever possible. Reflections can obscure parts of the task that are necessary for effective performance, and can often lead to headaches or postural discomfort. In interior environments, glare is most often caused by sunlight or improperly diffused artificial lighting.
- Prevent flicker wherever possible. Flicker (for example, from artificial lighting or reflected movement) causes discomfort, and usually causes distraction from the task at hand.
- Avoid wide variations in lighting levels across the working area. If two or more parts of the task have very different lighting levels, the eyes are forced to adapt continually between the different levels, causing visual fatigue and discomfort. Large contrasts in the user's environment have a similar effect (eg a daylight window directly behind a display screen can cause discomfort as the eyes adapt between the two. For interior environments, lighting ratios no greater than 5:1 should be used. In an office where, for example, the task illuminance is 500 lux, the minimum illuminance in adjacent areas should be no less than 100 lux.
- Aim for lighting ratios for task-to-immediate surround of 3:1. Task performance is reduced and concentration is more difficult to maintain if the task lighting is lower than the immediate surround.
- To aid maintenance, lift-off back panels should be completely removable to reveal light-coloured interiors designed to assist the spread of light within.
- Ensure that emergency lighting is powered by an independent source, will be immediately effective and will provide sufficient light to enable people to do what is necessary to ensure their health and safety.

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the boundaries between these different types of space are breached. These boundaries are best confirmed in user trials.

Shape (generally proportion)

If a space is out of proportion (too narrow, wide, high, etc), people will consider it distracting or oppressive. If the space contains distortions – such as curved surfaces, acute wall junctures, and too many projections or surface changes – people will consider it confusing and difficult to manoeuvre in.

Lighting

A space that is too dark tends to make people less active, or feel anxious. A space that is too bright may make them feel overly exposed, or they will complain of glare or thermal discomfort. The only way of deciding how to light a workplace is to test it with observers in tasks and conditions equivalent to the operational environment.

The main British Code of Practice on lighting is published by the Lighting Division of the CIBSE. The CIBSE Code for Interior Lighting (1994) gives more detailed guidance (see *Further information*) and should be consulted for further information on:

- the effect of lighting conditions on the performance of tasks in a wide range of interiors
- the appearance of an interior
- general and specific lighting design criteria for a range of interior and exterior applications
- the cost-effective use of energy.

Lighting design in both interior and exterior environments should aid:

- task performance, by providing enough light to make details of the task easy to see, so enabling high levels of speed and accuracy
- safety, by allowing people enough light to see hazards or potential hazards
- visual comfort, by providing the light needed for comfortable and effective working (see Panel, *Guidance on lighting*).

Colour

Strong colour can be a distraction, but can also have attention-holding properties and help people locate critical information. Generally, the tones chosen for a workstation should be neither excessively bright nor excessively dark. Different colours have particular

The psychological effects of colour in the workplace

Colour	Distance effect	Temperature effect	Mental effect
Red	Closer	Warm	Very stimulating, Danger! Stop!
Orange	Much closer	Very warm	Exciting, Attention! Look out!
Green	Further away	Cold to neutral	Very restful, Exit, OK
Blue	Further away	Cold	Restful, Information available
Yellow	Closer	Very warm	Exciting
Brown	Much closer	Neutral	Restful
Violet	Much closer	Cold	Aggressive, tiring

Developed from Kroemer & Grandjean (1997), reproduced with permission

psychological effects. Kroemer & Grandjean (1997) say that broadly speaking, all dark colours tend to be oppressive and tiring: they absorb light and are difficult to keep clean. All light colours tend to be bright, friendly and cheerful: they scatter more light, and encourage greater cleanliness. Some colours transmit strong safety messages (see Panel, *The psychological effects of colour in the workplace*).

'The choice of colours, tones and contrasts within a workstation is of greater **operational importance** than you might expect.'

Noise

Kroemer & Grandjean (1997) say that noise is any unwanted sound. Disturbing noise may arise from the job in hand (eg track machinery, rolling stock, engine noise) or from external sources (eg general office noise, general depot noise). Some human activities are much more noise-sensitive than others (eg concentrated mental work or tasks where understanding of speech is important vs hand signalling or some trackwork). Some people are much more sensitive to noise than others. This sensitivity does not just affect people's comfort levels, but can also make physiological damage more likely.

High noise levels experienced over a period of time can lead to hearing impairment or loss. High frequencies are more damaging than low frequencies. Intermittent sounds like hammering are more damaging than continuous noise. A single very loud noise, such as a shot or explosion, can cause instant permanent damage. Usually loss is only temporary at first, but the more often it is repeated, the more permanent the damage is. Hearing loss tends to occur in the mid-range frequencies first, and then extends gradually to the lower frequencies. In addition to physical damage, noise may result in impaired alertness, disturbed sleep, increased stress levels and irritability.

A special problem on the railways is that the ambient noise in many environments (eg track, driver's cab) and communication channels (eg radio, mobile phone) can make it difficult to understand what people say (see *Why is communication so difficult?*, page 106).

Designers can deal with noise by planning for no noise. Methods include:

- using noiseless components and tools
- re-locating noise emitting equipment
- reducing the noise at source, eg through engine baffles or using less noisy materials
- reducing noise propagation, eg sound insulation or using buffer rooms between noisy and quiet places
- paying attention to personal noise protection, eg wearing ear plugs or defenders.

'A special problem on the railways is making sure that **critical communications** are heard.'

Unfortunately, many workers object to personal ear protection because it might mean that they miss some vital information from the environment or they cannot hear other people speaking. One possibility here is to use active defenders. These can block ambient sound by generating exactly the opposite sound at the same levels (so called 'anti-noise'), while boosting important sounds such as speech or alarms. Since 2003, European Regulations have been in effect to control exposure to noise at work. EC Directive 2003/10/EC reduces limits on personal noise exposure to a limit value of 85 dB(A) and an action value of 80 dB(A).

Vibration

Kroemer & Grandjean (1997) say that vibration is felt as an imposition and a burden, ranging from minor, to unbearable annoyance. The extent of the nuisance depends on several factors, of which frequency is the most important. In the short term, unacceptable levels of vibration cause breathing problems, pains in the chest and vital organs, backache, nausea and vomiting. In the longer term, vibration can cause degenerative changes in the spine (from power tools), prostate and intestinal ailments, arthritis, bone atrophy and 'dead finger'. Spinal damage tends to occur in people who suffer vertical vibration – usually via seated positions. Finger, hand and arm problems tend to occur in people using power tools. The effects of vibration on human performance and comfort are well understood. Designers can address vibration issues by paying attention to suspension systems and seating in vehicles, and by engineering damping solutions in power tools. EC Directive 2003/10/EC places limits on worker's exposure to whole-body and hand-transmitted vibration.

Indoor climate

Indoor climate refers to the temperature of the air and surrounding surfaces, plus humidity, air movement and air quality. The effects of all of these factors on human performance and comfort are well understood and controllable for a wide range of activities, from sedentary through to heavy indoor work (see Panel, *How to maximise comfort for indoor workers*).

The most common problems for people working indoors arise from the combination of physical work and air temperature. Kroemer & Grandjean (1997) say that overheating leads to weariness and sleepiness, reduced physical performance and increased liability to make errors. Overcooling induces restlessness, which in turn reduces alertness and concentration – particularly on mental tasks. Sedentary workers are vulnerable to both overheating and overcooling. For obvious reasons, manual workers tend to be more vulnerable to overheating.

Windows

Generally, most people don't like to live and work in a space that does not have windows. They seem to need some sort of contact with the outside world to feel safe. On the other hand, too many, or oversized, windows can make people feel vulnerable and anxious. Windows are also a key source of natural light, which promotes visual comfort as well as being useful for tasks where good colour rendering is important.

'The most common physical problems for people **working indoors** arise from the combination of physical work and air temperature.'

As most people prefer to work in natural daylight, it's important to make full use of it wherever possible. At the same time, you need to ensure that the use of daylight does not cause discomfort through glare or heat gains for other users of an interior space. The Workplace (Health, Safety and Welfare) Regulations 1992 state that every workplace shall have suitable and sufficient lighting, and, so far as is reasonably practicable, lighting should be by natural light. In most circumstances, suitable and sufficient lighting for both interior and exterior environments can be provided by a combination of natural and artificial lighting.

How to maximise comfort for indoor workers

Sedentary workers	Manual workers working in hot environments
• Ensure the air temperature in winter is between 20°C and 21°C and in summer between 20°C and 24°C. • Ensure surface temperatures are within 3°C of the air. • Ensure the relative humidity does not fall below 30% in winter and does not move outside 40% - 60% in summer. • Ensure draughts between the head and knees do not exceed 0.2 metres/second *Source: Kroemer & Grandjean (1997), reproduced with permission*	• Ensure workers can acclimatise to heat in stages. New or returning workers should start by spending 50% of the working time in the heat and then increase by 10% per day. • Ensure that cooling periods increase with physical effort and/or heat load. • Ensure that workers have the opportunity to drink little and often. A cupful every 10-15 minutes is recommended. • Encourage the consumption of plain water with only occasional tea or coffee. Lukewarm drinks are absorbed faster than cold drinks. • Encourage workers to avoid iced drinks, fruit juices and milk-based drinks since they put more stress on the digestive organs. • Ensure that drinking water is always available close to the workplace and that workers can drink whenever needed. • Where radiant heat is excessive, eg from industrial heat sources, ensure the provision of eye protection, screens and protective clothing. • Ensure everything is done to reduce the impact of heat on workers, eg through increased ventilation and/or dehumidification.

Attractiveness

Attractive surroundings not only help people to feel comfortable and in control, but also improve their self-esteem. It has even been found that a luxurious setting has the psychological effect of making people speak more quietly!

Proximity to others

People enjoy watching other people, but they do not like to be in situations where they can be directly observed. Generally, they like to sit where the entrance to the room is still within their line of sight and will seek out a seat that is not next to an occupied one. These sorts of issue have implications for the design of open plan areas.

Circulation

In effective circulation spaces, people can move efficiently from place to place. The most efficient routes are in a straight line and offer an unimpeded view of the destination. If a route is too complicated, people will react to it with frustration and instinctively resist using it. For information specific to the design of train driver cabs (see Panel, *Cab design guidance for the railways).*

Cab design guidance for the railways

The 1995 Railway Group Standard sets out the requirements for external visibility from inside driving cabs for control facilities and for other interior arrangements (see *Further information*).

In 1998, the US Department of Transportation published comprehensive human factors guidelines for locomotive cabs. The key topics covered include:

- Cab environment (heating, ventilation, air conditioning, noise, toilet facility, and vibration)
- Cab layout (general design, access, visibility and seating)
- Workstation design (controls, electromechanical displays, auditory devices, general principles, automation, electronic displays and computer input devices).

Summarised from: Multer et al (1998)

In 2002, the International Union of Railways revised detailed guidance on the ergonomic layout of train drivers' cabs. The topics covered include:

- Number and arrangement of seats for drivers and other staff
- Dimensions and layout of the driver's cab
- Visibility from the driver's cab
- Driver's desk and main operating equipment and control systems.

Summarised from: International Union of Railways (2002)

Tools and techniques

SAMMIECAD is a computer-based human modelling tool. As of May 2008, it is fully described at www.lboro.ac.uk/departments/cd/docs_dandt/research/ergonomics/sammie/home.htm The system allows designers to carry out a 3D analysis of fit, reach, vision and posture. It runs on the Windows NT/2000/XP platform and is particularly appropriate for the design and layout of equipment and furniture in public areas, offices and homes; cockpit, cabin and interior evaluations for all types of vehicles; design of control panels; field of view, reflection and mirror evaluations; and safety and maintenance evaluations.

We are grateful to Taylor & Francis for permission to reproduce portions of Kroemer & Grandjean (1997) in the foregoing section.

Further information on workplace design

1 Boff K.R. & Lincoln J.E. (1988) Engineering Data Compendium: Human Perception and Performance, John Wiley

2 BS 5940 Part 1 (1980) Design and dimensions of office workstations, desks, tables and chairs

3 BS EN ISO 11064-1:2001 Erg. Design of Control Centres. Principles for the Design of Control Centres

4 BS EN ISO 11064-2:2001 Erg. Design of Control Centres. Principles for the Arrangement of Controls

5 BS EN ISO 11064-3:2001 Erg. Design of Control Centres. Control Room Layout

6 BS EN 349:1993. Safety of machinery. Minimum gaps to avoid crushing of parts of the human body

7 BS EN 547-1:1997. Safety of machinery. Human body measurements. Principles for determining the dimensions required for openings for whole body access into machinery

8 BS EN 547-2:1997. Safety of machinery. Human body measurements. Principles for determining the dimensions required for access openings

9 BS EN 60598-1:2000. Luminaires. General Requirements and Tests

10 BS 5266-1:1999. Emergency Lighting. Code of Practice for the emergency lighting of premises other than cinemas and other premises used for entertainment

11 CIBSE Code for Interior Lighting (1994) Chartered Institution of Building Service Engineers

12 CIBSE Lighting Guide 3. (LG3) (1996) The visual environment for display screen equipment use

13 EC Directive 2003/10/EC (2003) on the exposure of workers to the risks arising from physical agents (noise and vibration)

14 International Union of Railways (2002) Layout of driver's cabs in locomotives, railcars, multiple-unit trains and driving trailers, UIC leaflet 651, 4th edition

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19 Pheasant S.T. (1991) Ergonomics, Work and Health, Macmillan

20 Pheasant S.T. (2001) Bodyspace. Anthropometry, Ergonomics and the Design of Work. 2nd Edition. Taylor & Francis

21 PP 7317. Ergonomics Standards & Guidelines for Designers, by Stephen Pheasant, BSI

22 Railway Group Standard GM/RT2161 (1995) Requirements for Driving Cabs of Railway Vehicles

23 Salvendy G. (1997) Ed. Handbook of Human Factors and Ergonomics 2nd Ed. Wiley-Interscience

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26 Woodson W.E. Tillman B. & Tillman P. (1992) Human Factors Design Handbook. 2nd Ed. McGraw-Hill

Task analysis

What is task analysis?

Task analysis is not one specific technique, but rather a methodology for collecting and recording information about tasks in a systematic way. You can use it whenever you need to understand exactly what a task involves in terms of the knowledge, skills and behavioural requirements of people. Task analysis is particularly important in three main areas of organisational activity:

- *Design* – where it can help with the specification of *interfaces* (page 33) and *workplace* arrangements (page 41), as well as *function allocation* (page 37) between users and machines
- *Training* – where it can help determine what needs to be trained, as well as the performance standards against which people must be assessed
- *Staffing* – where it can help inform accurate recruiting needs and selection criteria.

There are several techniques for doing task analysis. The most developed is *Hierarchical Task Analysis* (HTA), which arose out of the need to understand the components of complex, real world tasks in safety-critical industries such as the chemical processing industry. In HTA, system goals and sub-goals – and the activities needed to achieve these goals – are described in more and more detail until it's possible to make design decisions at the lowest level. HTA is a traditional form of task analysis which focuses on what people must do in all circumstances that might arise. An alternative approach focuses instead on specifying the constraints within which people have to work (see Panel, *Challenging the traditional approach*).

Challenging the traditional approach

There are two fundamentally different approaches to task analysis. The traditional approach, eg HTA, is to describe tasks in terms of instructions that state what actions must be carried out in response to stipulated conditions. This *instruction-based* approach works best with what are called closed systems – systems isolated from the environment. Here, analysts are free to focus on influences that are internal to the system itself.

The problem is that many systems are open rather than closed. In other words, they are likely to be affected by unpredictable events outside the system. The more open a system is, the more difficult it is to analyse tasks in terms of instructions that will meet every eventuality. This is because every eventuality cannot be known. The impossibility of predicting every event has led some analysts to switch to *constraint-based* task analyses. Instead of trying to write exhaustive instructions aimed at reducing human error, they try to set out the operational constraints within which operators can work safely and flexibly.

To get a better idea of what this means, consider the difference between navigational directions and maps. Clear directions allow people to navigate their way between two points very efficiently, with minimum mental effort. Maps require people to think more about what they are doing, but offer several different ways of completing a journey. Maps are essential in coping with unexpected events – such as an accident that blocks the route – while directions become useless.

If you are interested in knowing more about constraint-based methods of task analysis, the approach is fully described in Vicente (1999).

How is task analysis done?

Stages of HTA

There are three main stages in conducting HTA.

1 *Data collection stage* – in which information about the system of interest is collated. A variety of data collection methods can be used, including observation (direct or via audio/videotaping), questioning techniques (informal discussion through structured interviews), and workshop-based techniques (involving role-play and walk-throughs). If the system is a new one, then the data will need to come from a functional analysis of the system's goals, supported by data from pre-existing tasks that are similar.

2 *Description stage* – in which the results of the data collection stage are organised into clear statements describing the task requirements and goals.

3 *Analysis stage* – in which the task descriptions are re-expressed in terms of the behaviours that are required from the user. At this analysis stage, there are a number of steps that must be carried out (see Panel, *Key steps for a Hierarchical Task Analysis*).

What can task analysis be used for?

You can use task analysis to support the following activities.

- *System design/evaluation* – in which you can use task analysis after *function allocation* (page 37) to help you understand the human *workload* (page 125), task responsibilities and workflow implications of design decisions. This analysis also shows you where further design solutions, such as job/task aids, are needed.
- *Training design/evaluation* – in which you can use task analysis to generate training scenarios, content, skill and knowledge requirements, and criteria. If the reason for the task analysis is as part of *training needs analysis* (page 55), you will want to focus on tasks that are the most likely to be performed incorrectly and have the highest error cost.
- *Interface/workplace design/ evaluation* – in which you can use task analysis to help you decide what demands (sensing, associating, interpreting, remembering and responding) user-equipment *interfaces* (page 33) and *workplaces* (page 41) impose on your target users. For interface design, the analysis might concentrate

Key steps for a Hierarchical Task Analysis

Hierarchical Task Analysis involves breaking down the task into a hierarchy of goals and plans.

Stage 1: Identify the goal of the task as a whole

After collating relevant task information (eg via interview or your own experience), you specify the overall task goal, eg 'Repair faulty track circuit'.

Stage 2: Identify the sub-goals and plan for the task as a whole

You can now break down the top-level task goal into a sequence of sub-goals (four or five is a convenient number), together with a description (a plan) of how they should be carried out. Sub-goals for the repair task identified above might be:

1 Check track circuit status
2 Diagnose source of problem
3 Contact signaller to agree repair
4 Carry out repair and test
5 Contact signaller to complete repair

Stage 3: Break down sub-goals

You break down the sub-goals into even lower level sub-goals until you reach an appropriate level at which to stop. This level is usually self-evident and is simply the level which yields the most detail needed for the purposes of the analysis. At each level the sub-goal is also a sub-task, which is also the goal for a set of even lower-level tasks.

Step 4: Describe plans

Once you have set out the full structure of the sub-goals, you need to specify plans for how they are to be achieved. At its simplest, a plan might be '*Do each step in order*'. A more complex plan for the example at Stage 2 above, might be *'Do Steps 1 to 5 in sequence. If the test at Step 4 fails, go back to Step 2'.*

on tasks that are mission-critical, difficult to perform, complex or novel.

- *Job design* (page 50) – in which you can use task analysis to help you decide which tasks you can assign to individual jobs without risking *workload* (page 125) that is too high or too low. Task analysis can also support your decisions about team design.
- *Personnel selection* (page 79) – in which you can use task analysis to provide information about the mental and physical demands of tasks. This can then be used to identify appropriate criteria against which you can compare the applicants.
- *Supervision and appraisal* (page 68) – in which you can use task analysis to develop scenarios for assessment of particular skills and knowledge and to provide a rationale for performance audits.
- *Human reliability analysis* – in which you can use task analysis to provide human error data for each task component. This can then be used to help predict the future reliability of the system. For hazardous operations (HAZOPS) and *training needs analysis* (page 55), the tasks associated with the severest health and safety risks to personnel might be selected.

Non-human factors specialists can successfully tackle most parts of a task analysis: it is more about applying a logical thought process than understanding human factors data. However, you may need the help of human factors professionals in working out the implications of the analysis for training methods, selection testing, and workload issues involved in job and interface design. Stammers & Shepherd (1995) say that task analysis creates the following kinds of information:

- Identification of tasks and their sub-task components
- Grouping of components – an organised, often hierarchical, listing of the sub-tasks involved in a task, showing how sub-tasks cluster around goals and over time, and which sub-tasks share common methods
- Importance, priorities and criticality of sub-tasks
- Frequency of sub-tasks – possibly in different conditions, such as degraded working
- Sequencing of sub-tasks – either serially or via conditional branching
- Decisions that must be made – eg for taking one branch rather than another
- Trigger conditions for sub-tasks – a new sequence may need to start as a result of another finishing, or as a result of a new environmental event
- Goals for each task/sub-task – goals are established for each task/sub-task, resulting in a hierarchy of goals in increasing levels of detail
- Performance criteria for each sub-task – criteria need to be specified for each goal so that it is clear when it has been achieved
- Information required by each sub-task – the items of information needed, and their sources, eg displays
- Information generated by each sub-task – the items of information that users must supply and its sources
- Knowledge employed in making decisions – the information that users must use in decision making, both from displayed sources and from memory
- Knowledge of the system employed in performing sub-tasks – the understanding that the users must have of the system and its functions in order to fulfil their role.

Stammers & Shepherd (1995), in Wilson & Corlett (1995), reproduced with permission

'Sometimes, it is not enough to simply observe what people do … this is when you might need Cognitive Task Analysis.'

What is Cognitive Task Analysis?

Hierarchical Task Analysis (HTA) focuses on what people can be seen to do and documents their actions. However, when tasks are complex, it is not enough to simply observe what people do. It is also important to find out how they think and what they know, how they organise and structure information, and what they seek to understand better. This is where what is known as Cognitive Task Analysis (CTA) comes in.

The aim of CTA is to describe both the cognitive – or conscious thought – processes that underlie the performance of tasks and the thinking skills needed to respond adeptly to complex situations. The advantage of this is that designers get a much better insight into the way people think about their tasks and what information they need to carry them out. This can lead to much better interface layout designs and more useful job aids.

One of the more well known methods of CTA is *ACTA* (Applied Cognitive Task Analysis) developed by Klein Associates. ACTA is an interview process that is used with expert users (sometimes known as subject matter experts – SMEs) to find out about the mental demands of tasks in order to inform new designs.

Tools and techniques

See Part 3 for more information on data collection techniques for *focus groups*, *interviews*, *workshops*, *observational analysis* and *questionnaires*. Part 3 contains more information on task analysis techniques including: *Hierarchical Task Analysis (HTA), Applied Cognitive Task Analysis (ACTA), Team Cognitive Analysis* and *Link Analysis*

Further information about task analysis

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2 Kirwan B. & Ainsworth L.K. (1992) A Guide to Task Analysis, Taylor & Francis, London

3 Shepherd A. (2002) Hierarchical Task Analysis. Taylor & Francis, London

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Job design

What is job design?

Job design specifies the tasks and roles that form an individual's job. Its purpose is to ensure that jobs are appropriately structured and achievable.

Job design often follows *function allocation* (page 37) (in which decisions are made about what is to be performed by machines and what by humans) and *task analysis* (page 47) (in which task steps, sequences and criteria are specified). An essential step in function allocation is role definition, in which related tasks are collated into a set of duties that can be assigned to jobs. Role definition is particularly important when existing jobs are radically changed by automation or the introduction of new management structures.

Good job design involving human factors analyses will pay huge organisation dividends in terms of effective and efficient operations (see Panel on page 51, *A new railway job*). Conversely, failing to consider job design can have a serious effect on *morale* (page 117), staff *retention* (page 87) and safety.

What should be taken into account?

The main considerations in creating effective job design involve several of the other aspects of human factors discussed elsewhere in this Guide. These aspects are brought together in the following list of questions.

- How can targets be set and measured? Are they fair and achievable? What *supervision and appraisal* (page 68) procedures will be used to support this?
- Do the tasks that make up each role over-burden any individual in the system? Too much *workload* (page 125) will cause physical and/or mental fatigue, degrade operator performance, and generally reduce workplace system efficiency. You particularly need to be aware of the possibility of overburdening in emergencies – and make sure adequate experienced judgement and simulation are used to avoid it.
- Is the work made harder by the way it is organised? For example, are any required *shift work* patterns (page 128) designed to enable people to perform at their best? Are rest and meal breaks adequate? Are the tasks arranged so as to minimise boredom? People can become just as fatigued by boredom as by overwork.
- Is the work organised to provide reasonable opportunity for the individuals involved to experience some form and degree of self-fulfilment? Job rotation, job enlargement and job enrichment are examples of work organisation strategies. These strategies attempt to ensure that personnel are allocated duties that provide sufficient variety, autonomy, complexity and responsibility to maintain *motivation* (page 117) and performance. Jobs also need to be structured in a way that is compatible with available career development.
- Have all the training needs been identified and properly addressed with adequate training plans and provision? *Training needs analysis* (page 55) should start with the task analysis output and identify the skills and knowledge that will require training, together with recommendations on the training content.

Further information about job design

1 Kroemer K.H.E. & Grandjean E. (1997) Fitting the Task to the Human (5th Ed) Taylor Francis

A new railway job

The basic design of many railway jobs (eg signaller, train driver) has remained fundamentally unchanged for many years. Sometimes, however, a re-organisation can lead to a job with new characteristics. Some years ago, as part of an upgrade to the signalling system, it was proposed to close the old mechanical signal box at Barnes and move the functions performed there to the Wimbledon ASC. The old signal box involved two jobs: the signaller and a crossing keeper. Between them, they were responsible for an unusual sequence of five CCTV controlled level crossings. The crossings were supposed to be operated in sequence, but their closeness meant that at busy times this was impossible to achieve. When the functions of the Barnes box were moved to Wimbledon, it was hoped that these two jobs could be combined into a single job. It was argued that the improvement in the technology to be used by the signaller would mean that this could be achieved without unacceptable risk.

Before this proposal could be acted on, it was necessary to carry out an assessment of the safety implications of this change in job design. This assessment was performed by two human factors specialists. The first phase involved gathering all relevant details of the current and proposed working arrangements. The old working situation at Barnes and the new situation at Wimbledon were analysed and compared. The task at Barnes was analysed using *Hierarchical Task Analysis*. This analysis was based on observation and debriefings of the existing staff, supported by training documentation.

Discussions with the project team identified the critical changes to the work that would result from the move to Wimbledon, such as the move to NX panel working, the provision of more integrated communications facilities and the introduction of 'one-touch' crossing controls.

On the basis of all the information gathered, the second phase – the *human reliability analysis* – was carried out. The implications of each change (two- to one-man operation, shift to NX panel, etc) were assessed for all safety critical tasks in terms of their impact on workload and the risk of error. The error risk assessment was based on a human error checklist identifying all perceptual, control, communication, decision making and event recording errors.

The initial risk analysis identified that the *mental workload* (page 125) placed on the signaller was the primary risk area. To assess this more fully, the Simplifier was analysed to identify the periods of peak traffic to be regulated. This was expressed in terms of both train movements and crossing operations. Discussion with signal box staff had identified factors which occurred fairly regularly and which increased workload. These included such factors as pedestrians and vehicles attempting to 'beat the barriers', bridge strikes, barrier failures, T2 possessions, and additional traffic due to diversions. Problems involving the junction outside Barnes station were judged to impose the heaviest additional workload.

Several scenarios were developed and used as the basis for *walk-through analysis* with a panel of experienced signalling staff, including those from Barnes. To assist in these walk-throughs a simple cardboard mock-up of the facilities that would be used by the signaller at Barnes was developed. The participants were asked to act out the actions required by the signaller as the scenario unfolded and to identify the points at which they thought the signaller would be unable to cope. They were also asked to develop working strategies (eg how and when the crossings were operated relative to train movements) to identify the most efficient methods of operating the panel.

The conclusion of this assessment was that the risk of the signaller being overloaded was within acceptable limits provided a number of conditions were met. The three most important conditions were that (a) the panel was designed so that a second person from the ASC could assist the signaller in their duties when peak traffic times coincided with other problems adding significantly to their workload; (b) the signallers should be trained in the most effective working strategies to adopt; and (c) the timetable should be developed to avoid the particular combinations of train movements that caused the highest levels of workload for the signaller.

understanding
human factors

Training

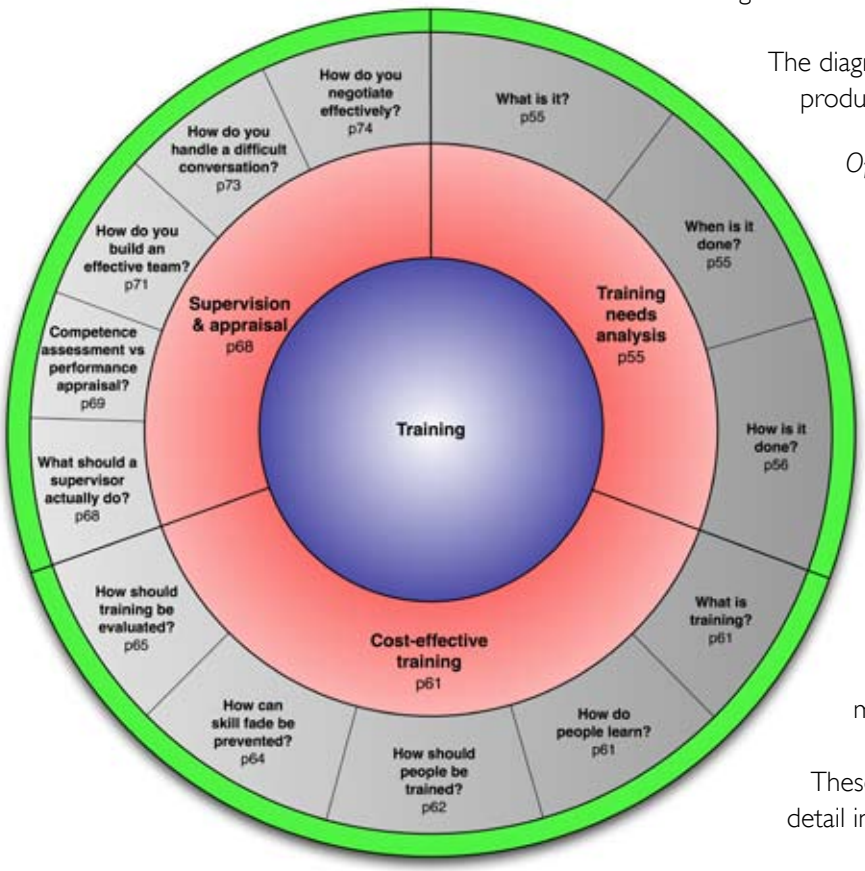
understanding
human factors

Training

Training

The diagram below focuses on Training. It shows three sub-areas (in the middle red ring), and identifies the main human factors questions that this Guide answers (in the outer grey ring). In this Guide we take a broad view of training. In particular, we view supervision and appraisal as an opportunity to facilitate continuous training rather than simply a management activity. At the end of each section, you will find sources of further information.

Focus on training



Training needs analysis

What is training needs analysis?

Training Needs Analysis (TNA) helps you to identify training requirements and their implications for everyone who works in your organisation. It is a flexible procedure, with a choice of supporting tools and techniques (see end of this section). You can use it repeatedly (eg to support different stages of a *user-centred design* (page 25) or *staff appraisal* process (page 69), generating clearly defined products and providing an audit trail for all training decisions.

The diagram shows three key stages and products.

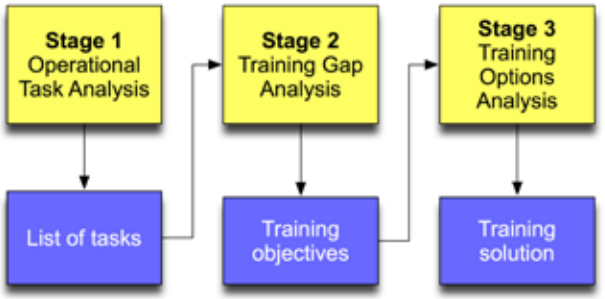
Operational task analysis produces a list of tasks, together with how well they need to be done (ie the required performance standards).

Training gap analysis produces a set of training objectives whose achievement will close any gap between the existing performance and the new required performance.

Training options analysis examines alternative ways of accomplishing the training, and finds the option that is most cost-effective.

These stages are explained in a little more detail in the section on how to do a TNA.

Stages of training needs analysis



Do you need to do it?

Have a look at the checklist in the Panel on page 56, *Do you need to do a TNA?*. If you can answer yes to all of these questions, you almost certainly don't need to dwell on this section of the Guide.

When is training needs analysis done?

TNA may take place for two main reasons:

1 To identify training needs as part of the *staff appraisal* process (page 69). Here the aim is to ensure either that any skills or knowledge gaps in staff performance are addressed, or that staff are developed for future roles in the organisation as part of their career development. In either case, the training needs analysis should proceed in conjunction with the organisation's staff appraisal process.

2 To identify training needs due to the planned acquisition of new equipment or processes. In this case, the training needs analysis should proceed in conjunction with a *user-centred design* process (page 25) for the new system.

Do you need to do a TNA?

TNA is a wide-ranging process that helps you to identify training requirements and their implications for everyone who works in your organisation. If you can answer 'no' to any of these questions, you should consider carrying one out.

- Is there a clear process for analysing the training needs of all staff at every level in your organisation?
- Are training needs analysed at the organisation, team and individual levels? If they are, can you show that they have led to measurably improved workplace performance?
- Does the training needs analysis process have clear links with the Finance and HR departments?
- Are managers at all levels skilled in analysing training needs for those for whom they have responsibility?
- Are training needs prioritised in line with the achievement of organisational objectives?
- Are the training needs that arise from new initiatives, projects and equipment all analysed for all their stakeholders?
- Are appropriate targets set for the length of time taken between the identification of training need and its final delivery?
- Does your organisation have a system whereby all training and development needs are recorded, and updated once the need has been addressed?

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'Here we outline **two methods** for doing TNA ... a standard method and a quick and easy method.'

How is training needs analysis done?

Here we outline two methods for doing TNA. The first method is a standard approach that can be used for either of the purposes above (ie staff appraisal or to support new system design). The second method is a quick and easy TNA process that takes only a few hours (with the right participants) and which you will find useful if you are just interested in reviewing the training needs of existing job holders (ie in support of staff appraisal).

Standard TNA

Standard TNA goes through the three stages shown in the earlier diagram on page 55. For new system design it is normal to carry out Operational Task Analysis several times as more detailed prototypes are developed and more information becomes available, before attempting the other two stages. However, it is important that the required training is developed in conjunction with the plans for any new system roll-out.

Stage 1: Operational Task Analysis

Operational Task Analysis should produce:

1 A list of tasks involved. If more than one job is affected (eg if there is to be a major new system), you should produce a list for each job affected. Each task should carry a description of the operational circumstances under which it is performed, together with the operational standard to which it must be performed. It may be helpful to use one of the methods of *task analysis* (page 47) for this stage. Where appropriate, you may wish to use a panel of subject matter experts (see Panel, *Using subject matter experts*).

2 The interface and workplace assumptions of the new operational requirements in terms of physical, functional and environmental factors (you may need human factors specialists for this). The assumptions will need to be identified in conjunction with the systems engineers as part of a *user-centred design* process (page 25).

Using subject matter experts

To obtain information on required knowledge, skills and abilities, you can interview job supervisors, HR managers or, when appropriate, existing experienced operators. Often the best procedure is to supply a panel of five or six knowledgeable people with a list of the tasks, and ask the following type of questions:

- What does a person need to know in order to do the task?
- What do you expect a person to learn in training that would make them effective at this task?
- What are the characteristics of good and poor operators on this task? A useful way of getting at this kind of information is via the repertory grid technique – see *Further information*).
- Think of someone you know who is better than anyone else at this task. Why are they able to do it better?

3 The training priority for each task based upon its Difficulty, Importance and Frequency (often called a DIF analysis). You will need to work with one or more experienced operators in producing this DIF analysis.

Stage 2: Training Gap Analysis
This produces Training Objectives which should specify the additional training requirements you will need to address, compared with current arrangements. These new training requirements should be described in terms of the knowledge, skills and attitudes that people will need to acquire.

Stage 3: Training Options Analysis
This produces a recommended training solution from a range of possible options. You should initially choose options on the basis of an analysis of the training objectives and the constraints of current organisational training policy. For example, if distance learning is the preferred training policy, then the media will have to be compatible with this method of training. If, however, it could be beneficial to amend policy, then this should be open for discussion. The options analysis should identify the most cost-effective option. It does this by comparing the Training Effectiveness and Cost-Benefits of each option (see below).

The output from the options analysis is a recommended training solution. This should incorporate the following:

- *Option specification* – a description of the media options that will partially or fully meet the training requirements as described by the training objectives (see Panel, *Selecting training media*).

Selecting training media

Selection of training media boils down to a choice between three broad approaches:

- *Telling the trainee what to do* using verbal methods, eg lectures, discussions, notes
- *Showing the trainee what to do* by demonstration or guidance, eg animation, video
- *Having the trainee practise what to do*, eg using role play, simulators, part-task trainers.

The strengths and weaknesses of different technological solutions to these approaches are shown in the Panel on page 58.

- *Training Effectiveness Analysis* – an evaluation predicting the relative training effectiveness of each option based on comparisons against similar proven media systems, and/or research carried out with new technologies. You can use prototyping, experiments, research of literature and comparisons with existing training to predict or assess performance. This is, by its nature, a subjective process, which makes it important to consult appropriate training analysts and subject matter experts for the best advice. You will need to consider all the criteria that contribute to an ideal solution and then rank how well each option meets every criterion. Later sections in this Guide on training methods and training delivery mechanisms will help here.
- *Cost-Benefit Analysis* – a list of the major costs for each option, covering capital, staffing, infrastructure and support costs over the projected life of the training system. Each cost should have a risk factor, ie a level of confidence or tolerance. The costs should then be offset against any benefits, such as the potential for income generation. In the absence of any actual numbers, you can do a Relative Cost-Benefit Analysis that simply compares the options with each other in terms of High, Medium and Low costs and benefits. (You'll find a method for doing this in the Teamworking Journey Guide published by RSSB and available from their website.)
- *Selection of the most cost-effective option* – a clear description of the advantages and disadvantages of each option, with supporting arguments for the recommended solution. You need to examine the trade-off between training effectiveness and cost-benefits, and then decide on the optimum solution in terms of cost-effectiveness. See the section on *cost-effective training* (page 61) for comprehensive guidance on this aspect of training.

Training

Strengths and weakness of different training technology options			
Technology option	**Description**	**Strengths**	**Weaknesses**
(CBT) • Standalone systems • Networked systems	Training delivered via personal computer or (web) server. Materials are presented as a mix of text, graphics, photographs, animation, video and sound tracks, and pre-sequenced for the learner by the author(s). Often includes some form of branching to provide different sequences dependent on what the trainee has learned so far.	• Improved training standards (quality, consistency, trainee attention and retention) • Complex task procedures presented very effectively via video and animation • Efficient use of courseware (eg multiple language commentaries) • Reduced training costs (timeliness, availability, higher throughput, reduction in central facilities and personnel, 30% faster training, reduced failure rates) • Easier training management (trainee monitoring, courseware revision, course validation) • Risk-free learning environments • Learning on a computer in your own time and in comfortable settings can be very effective • Trainees may have more flexibility in using their own learning style and can select learning materials that meet their level of knowledge and interest • Trainees can study anywhere they have access to a computer and Internet connection • Trainees can test out or skim over materials already mastered and concentrate efforts in mastering areas containing new information and/or skills • Learning objective tests can be incorporated in the teaching software • Release of instructor time for effective tasking: debriefing, reviewing, discussing and directing • Portable and flexible	• High up-front development costs (hardware, authoring system, software design, programming, editing, testing). These costs increase in line with the complexity of the media • Costs escalate if materials need frequent revision • Trainees require certain level of computer literacy • Trainees cannot ask questions or brainstorm ideas • Lack of human/trainer contact, which can greatly affect learning for some • Trainees with low motivation or bad study habits may fall behind • Slow Internet connections or older computers may make accessing course materials frustrating • Managing computer files and online learning software can sometimes seem complex for trainees with beginner-level computer skills
Intelligent CBT	Training delivered by personal computer or (web) server. Includes some form of exploration environment for the trainee to explore the material, 'watched' by the computer. Sequence of materials decided by the computer on the basis of observed trainee performance.	• As for CBT • Optimised learning progress (materials customised for individual trainees 'on the fly')	• As for CBT • Less mature than CBT – very restricted choice of system • Training time can increase (although quality of learning is better)
Simulators • Part-task simulators • High fidelity simulators	Dedicated hardware/software that simulates a dynamic task environment with near perfect fidelity. Part-task simulators simulate selected parts or dimensions of the task with near perfect fidelity (ie non-critical parts of the task are represented only symbolically).	• As for CBT • Safety critical/rare procedures can be safely practised • Increases utilisation of operational equipment (ie real equipment not used for training) • Very high transfer of training to real tasks	• High fidelity simulators are very expensive to develop and build and maintain • It may be difficult to ask questions or discuss ideas • Full simulation is intimidating for non-experts
Embedded training • 'Stimulation' • Manual help systems • Automatic and semi-automatic context-sensitive help systems	Software that uses the real task equipment to present help or training materials relating to user tasks. Automatic context-sensitive help systems anticipate user requirements and intervene with suggestions or explanations, triggered by user error or delay.	• As for Simulators (in the case of embedded simulation, sometimes known as 'stimulation' since fake data are used to stimulate real displays) • Saves time and increases productivity (readily accessible, relevant help whenever required) • Reduces or eliminates need for paper reference manuals	• User has to take effective control of own learning • User needs to know what they are trying to achieve for help to make sense (automatic help systems) • User needs to understand enough of system to know what help to ask for (manual help systems)

Strengths and weakness of different training technology options			
Classroom-based courses, seminars and workshops	Classroom-based courses, seminars and workshops are generally held off-site (without normal office distractions and can typically last from a couple of hours to a whole week or more)	• Classrooms can be enjoyable and comfortable settings in which participants can get better acquainted with their company and their fellow employees. This leads to greater readiness for training • Low cost • Can ask questions and brainstorm ideas • Trainees can develop analysis and decision-making skills, learn from mistakes and discover principles and concepts for themselves • Increased retention rates	• Trainees cannot use own pace or sequence • Dedicated sessions can be used for (self) assessment, though this is usually not appropriate in a workshop or seminar • Classroom-based processes may not suit individual learning styles. • Some trainees find classroom environments stressful • Trainee tracking is not very practicable • Classroom-based training cannot prepare trainees for the miscalculations, delays, and other obstacles they inevitably will encounter on the job

Quick and easy TNA

Quick and easy TNA was developed by Via International Ltd and is reproduced here by permission. It takes just a couple of hours or so and is especially useful for reviewing the training needs of existing job holders. This means it is best suited to the staff appraisal process. It is less suited to supporting new system design, although it could be useful for the appraisal of new system prototypes by experienced holders of related jobs (eg drivers appraising a new cab design).

The process avoids asking participants directly what training they want or need. Instead it focuses on issues that may be addressed by training (emphasising that training is but one solution to the issues faced by the organisation). Here's how you do a quick and easy TNA.

Preparation

You will need:

- Prepared flip charts (about 10 pages, 4 columns on each flip chart page: issues, training, non-training, combination)

'Quick and easy TNA takes just a **few hours** and is especially useful for reviewing the training needs of **existing job holders**.'

- Post-it notes for each participant
- Coloured dots (three colours, 48 dots per colour – one sheet – per participant to start with; make sure you have spare sheets to hand)
- Index cards (one per participant) for forced ranking
- Markers (at least three colours) to write on flip charts
- A group of participants sufficiently experienced to generate informed insights about their tasks.

Process

The process comprises four steps:

Step 1: Generate issues (30 minutes)

Ask each participant to list the issues they face in their work. Issues should be written on post-its, one issue per post-it.

Illustrate what type of response you expect, eg lack of understanding about how to perform a particular procedure, lack of information about the network, failure of management to respond quickly to queries, inappropriately targeted marketing (give one training and one non-training related issue as an example).

Confirm that instructions are clear.

Allow 15 minutes (including set-up instructions). In the meantime, you can put flip charts on the walls.

Ask participants to post their notes on flip charts in the first column (allow 5 minutes).

Go through the issues, reading each one out and asking participants to take off their issue if it is similar; maintain physical movement of participants, (allow 10 minutes).

Note 1: Avoid discussion at this stage. Any issue is valid, even if only one participant thinks so!
Note 2: Number the notes in sequence - but don't try to group anything yet.

Step 2: Identify training/non-training solutions (30 minutes)
Explain that the next step is to decide for each issue whether it can be addressed by:

- *Training* – when an issue is caused by a lack of knowledge, skills, ie *I don't know how to...* (red dots)
- *Non-training* – when an issue is caused by inappropriate policies, inadequate communications, inappropriate remuneration, lack of clarity in responsibilities, etc. (blue dots)
- *A combination of training and non-training* (white dots).

Ask participants to assess for each issue whether it can be addressed by training (red), non-training solutions (blue), or a combination of the two (white).

Hand out sheets with coloured dots for each participant.

Note 3: Don't use red and green dots together because colour-blind people will not be able to distinguish between the two.

Ask people to come up to the flip charts and stick the dots on the post-it notes to reflect their assessment for each issue (allow 15 minutes).

Step 3: Clarify results (30 minutes)
Explain that there is no time to discuss each issue and assessment in detail, but that you need high-level agreement on the outcome of the previous steps, ie 'Are there any assessments (or issues) that you absolutely disagree with (and why)?'

Note 4: Look for issues where there is a wide spread of different assessments. Avoid discussion on areas where people already mostly agree that training, or a combination of training and non-training, should be used.
Note 5: Identify issues that should be totally or partly addressed by training (circle the letters identifying these issues), and add any that get resolved as such via this part of the discussion.

Emphasise that the focus for today is to identify potential areas for training, other issues will be documented and fed back, but cannot be discussed in detail within the scope of this workshop. However, recognise the issues as important to the participants!

Step 4: Force-ranking of training needs (15 minutes)
Hand out index cards (one per participant).

Ask each participant to review the issues that have been identified as having full or part training solutions (ie the circled ones) and list the five issues that they feel should be addressed within the next six months. They should prioritise these five issues by allocating a value of 5 for the most important and 1 for the least important.

Collect the cards and explain that you will review the results and combine certain areas where similar training can address multiple issues.

End.

Tools and techniques

- *Relative Cost-Benefits Analysis* - described in the Teamworking reference (later in this Guide)
- *Hierarchical Task Analysis*

Further information on training needs analysis

1 Jankowicz D. (2003) The easy guide to repertory grids, Wiley

2 Gregory D. & Shanahan P. (2004) Teamworking best practice in the railway industry: The Journey Guide, Gregory Harland Ltd, for RSSB, Euston

3 Patrick J. (1992) Training Research & Practice, Academic Press Ltd, London

4 RSSB (2007) Good Practice in Training: a guide to the analysis, design, delivery and management of training, RS/220 Issue 2, June 2007

5 RSSB (2007) Good Practice Guide on simulation as a tool for training and assessment, RS/501 Issue 2, June 2007

6 Via International Ltd (unpublished) developed the 'quick and easy' training needs analysis described in this section. Via International, Building 3, Chiswick Park, 566 Chiswick High Rd, Chiswick, London W4 5YA

Cost-effective training

What is training?

Most definitions agree that training is the development of knowledge, skills and attitudes required to perform a specific task or job to a specific standard.

The goals of training are quite different from those of education. Training is concerned with getting an individual to *home in* on a specific performance in a specific context. Education is concerned with getting an individual to *open up* to new possibilities that are essentially unspecified in both content and context. Training succeeds by eradicating individual differences; education seeks to identify and exploit them (where they are usually referred to as 'talents'). Any confusion between training and education is due to the fact that they both share the requirement that people are able to learn.

How do people learn?

It is tempting – even usual – to imagine that people learn through the transmission of 'knowledge' from some source (eg a book, a computer screen, a teacher) into their brains. In fact, learning depends on people's ability to develop meaning for the patterns of events, activities and relationships all around them. This is a complex, individual process which trainers and teachers can either help or hinder. People learn because they can create meaning and integrate it with what they already know, not because they simply receive information.

Furthermore, it appears that what is learned is fundamentally connected to the conditions in which it is learned. Like a bird with a nest, learning is built out of the materials to hand and constructed to reflect the constraints of local conditions. For humans, these constraints include the organisational rules and working conditions imposed upon them, and the way their colleagues respond to these rules and conditions in working practice. People learn not just what to do and think, but how to do and think those things 'around here' so as to be acceptable to their managers and workmates. (See the sections on *Why do people break rules?* on page 12), and *Culture* on page 91 and *Conditions* on page 117).

> 'Recently, I was asked if I was going to **fire an employee** who made a mistake that cost the company $600,000. 'No,' I replied, I just spent $600,000 training him. Why would I want somebody to hire his experience?' Thomas J. **Watson**, Founder of IBM

A lot of research has revealed which factors are the most important for effective learning (see Panel, *Key factors for effective learning*).

Key factors for effective learning

- *Doing* – to rehearse our developing skills and knowledge
- *Failing* – with feedback to give us insight into the progress and nature of our learning
- *Reasoning* – to allow us to generate explanations for failure
- *Trying again* – to allow us to test and improve our explanations for failure
- *Well-told stories* – to allow us to connect together what we learn and embed it in our everyday knowledge
- *Just-in-time instruction* – to prevent our newly acquired skills and knowledge from fading
- *Progressive fidelity* – to give us the right amount of realism to support our learning progress. Too much realism is a waste of money and overwhelms novice learners; too little realism prevents people fine-tuning their expertise, and may encourage them to depend on responses that do not transfer very well to the operational task environment. They may end up depending on cues that never occur in reality
- *Access to resources* – to provide us with demonstration, explanation or further detail whenever we might benefit from them
- *Emotional predisposition* – to ensure that we are motivated and energised to engage with the learning process
- *Sympathetic context* – to ensure that external conditions and media for learning are suited to us (eg for many, sitting at a VDU or in a busy office is not a sympathetic context for some stages of learning)

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Training

How should people be trained?

How should you design training?

There are three aspects to the design of an effective training programme:

1 Proper understanding of the trainees (see *How do people learn?* on page 61)

2 A relevant and well structured training content (see *Training Needs Analysis* on page 55)

3 The application of an effective training method (ie ways of organising and presenting training materials so that we maintain trainees' attention and maximise their learning progress).

Unfortunately – and despite a great deal of research – there is no agreed best training method. While we can be clear about what components a successful method must

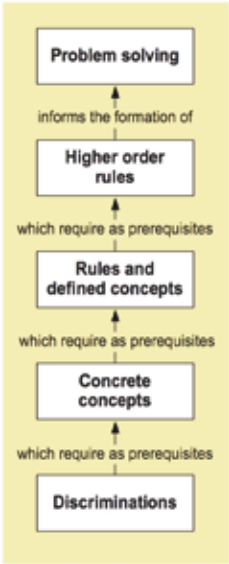
Is part-task better than whole-task training?

On the basis of common sense you would expect part-task training to be better than whole-task training. However, what this overlooks is the subsequent problem of how to help the trainee put together the various parts.

Where there is high interdependence between different parts of the task, it may be better to arrange for the trainee to work with successive approximations of the whole task. You then introduce more nuance and detail across the whole task as performance improves.

Part-task training is a good bet when performance on different parts of a complex task have little effect on each other.

Guidance on training method components

Training components	Design guidance
Define the pre-conditions for training	• Be clear about the capabilities and limitations of the specific trainee audience. • Take steps to understand their interests, motivations, expectancies, hopes and fears about the training. Ensure that training materials are attention-getting and communicate the training objectives and trainee benefits clearly and appropriately. Doing these things will help to ensure that trainees are ready for the training. • Do not limit your attention simply to the entry criteria for the start of the training: make sure that you have defined the criteria for transition to each of the stages of the training. • For knowledge-based training, consider the use of 'advance organisers' before each new stage of training. These are organising concepts that give previews of what is to come and help trainees develop a way of integrating the detail of what they are to learn under training. In developing advance organisers, try to use concepts that the trainees already understand.
Design and present the structure and sequence of the training materials *Gagné's skill acquisition hierarchy*  	The objective here is to structure and sequence a body of knowledge or a skill so that the trainee can progressively grasp it. You will need to use your understanding of the subject matter to decide how to simplify the information to be learned and organise it into chunks that will be manageable for the trainees. For training involving a new software system or software application, you may wish to consider an alternative approach to training design based on the minimalist approach to training (see Panel on page 63, *The minimalist approach to training*). *Skills training* Skills are often acquired via: • *A thinking phase*, where the required performance is discussed. You can support the thinking phase by clear descriptions and explanations of the principles, objectives and techniques of the required performance. • *A doing phase*, where task performance, with feedback, becomes increasingly rapid and error free. For tasks that can be separated into discrete stages, you can support the doing phase via part-task training (see Panel, *Is part-better than whole-task training?*). Here, the skill is broken down into parts that are practised separately before the well-rehearsed parts are then put together. Several variations are possible. In *progressive part-task training*, the first and second parts are practised separately before being combined and practised together. A third part is then practised separately before being added to parts one and two – and so on. *Cumulative part-task training* is the same as progressive except that there is no pure-part training. So part one is practised, then parts one and two, then parts one two and three etc. Finally, *retrospective part-task training* starts with practising the last part to which is then added the penultimate part and so on. Retrospective part-task training can be useful for motivating some people since they are quickly rewarded with successful completion of the task • *A tuning phase*, in which normal performance becomes automatic and less demanding of conscious thought, and thus able to cope with more unusual events. You can support the tuning phase by injecting increasingly subtle interruptions into the task, eg to simulate degraded working. Another good technique is some form of overtraining in which training is continued past the point where the performance criteria are met. It sounds as though 'overtraining' is wasteful, but it is not. This is because it increases resistance to stress, fatigue and other interference during subsequent performance of a task. Using a simulator, you can achieve overtraining by 'above realtime' training in which the task or scenario is run faster than in real life. This can be very effective in producing stress resistance. *Cont./*

Guidance on training method components

/Cont.

Knowledge training

You may find it helpful to structure and sequence training materials according to a hierarchy of knowledge elements, such as that worked out by Gagné (see diagram in this table, also *Further information*).

Essential features to be picked out from their surroundings (discriminated), such as alarm sounds or visual cues, may be isolated or exaggerated to make them more obvious initially. Materials to support the learning of concepts and rules require the use of a variety of examples that emphasise generalisations and exceptions. Rules should be applied to a variety of examples to ensure that the trainee understands each rule and its use.

You should ensure that the structure used can support exploration and navigation by the trainees.

Provide appropriate levels and types of feedback

Feedback (sometimes known as knowledge of results) is an essential part of training. Without it there can be no learning. There are five different types of feedback which you should be concerned with:

Trainee question	Feedback type	Trainer guidance
What is that (for)?	Display	Explain objects and their functions
What should I be looking at?	Event	Explain changing significance of objects
What should I be doing?	Task	Describe rules, give prompts
What should I have done?	Review	Highlight & review decisions & errors
How well did I do?	Results	Encourage, score and grade

Facilitate retention and transfer

Several factors influence how well skills and knowledge are retained after training. Some enhance retention while others make skills resistant to decay (often called skill fade). Unfortunately, it's not clear what the relative importance of these factors is. But enough research has been done to indicate their general influence (see How can skill fade be prevented?).

have, there are almost as many ways of implementing those components as there are training designers.

The Panel on these pages, *Guidance on training method components*, shows what components a training method must have, and gives some practical guidance on how to address these.

Note, however, that you should not interpret the components in the Panel as serial steps, but as areas for attention. For example, you would normally give feedback in the course of presenting the training materials. You would also take opportunities for retention and transfer at every stage of training design and its execution.

How should you design training for different people?

People differ in their capacity to learn new things. This capacity may be natural and related to ability. However, it can also be related to experience – as when, for example, people have bad memories of school – or to age. Older people are often slower in acquiring new skills, and previously learned materials may interfere more with new learning.

In the Panel, *Guidance on training design for trainees with different needs*, you'll find information on how to adapt training design to better suit people who for one reason or another are less able to learn new things.

The minimalist approach to training

During the 1980s, a group at the IBM Watson Research Center developed a 'minimalist' approach to training design. They realised that the natural problem-solving behaviour of people could be used to support the goals and activities of users rather than trying to teach them everything there was to know about the tasks that could be accomplished by the software. They used their analysis of this problem solving to identify five minimalist principles, as follows.

1. *Make sure learners can get started quickly.* Reduce repetition; eliminate non-essential instructions; offer the learner meaningful activities as soon as possible.
2. *Rely on learners to think and improvise.* Encourage learner inference; leave out material that can be inferred; don't give the learner understanding – allow them to create it.
3. *Embed information in real tasks.* Introduce real work immediately; recognise that people will bring real goals to the training situation – so allow them to achieve them.
4. *Take advantage of what learners already know.* Make connections between new concepts and those already understood from previous software systems; ensure that full use is made of concepts already covered in the current training (sometimes known as 'scaffolding').
5. *Support error recognition and recovery.* Mistakes cannot be avoided, but they can confuse and frustrate; if harnessed they can be very useful.

Creating minimalist instruction involves a *task analysis* to understand what learners are trying to achieve, how they are likely to approach their tasks and what mistakes they are likely to make. Minimalist training design entails building a sequence of real world tasks with minimal documentation. This means that it involves users from the beginning in the very tasks they need to accomplish with the software.

Summarised from research by Carroll (1990)

Guidance on training design for trainees with differing needs	
Potential trainee difficulties	**Guidance on training design**
Tasks depend on short-term memory	• Avoid verbal learning and the need for conscious memorising. Use cues which guide the trainee. • Avoid part-task training. If it's essential, use cumulative part-task training. • Ensure enough testing has taken place before moving on to the new material.
Tasks suffer from interference from other training activities or prior learning	• Restrict the range of activities in the training course. • Employ longer learning sessions (ie longer periods without interruption). • Provide variety by changing the teaching method rather than the subject matter. Change in content may lead to confusion.
Information must be translated from one medium to another (eg from the training to the operational environment)	• Ensure visual materials are consistent with operational reality. • If you use simulation, make sure that it is sufficiently realistic to enable the trainee to relate what is learned to the operational task.
Learning is abstract or unrelated to realities	• Present new knowledge only as a solution to a problem that is already appreciated.
Tasks are 'paced'	• Allow trainees to proceed at their own pace. • Allow trainees to structure their own programme if possible. • Encourage trainees to beat their own targets rather than those of others.
Tasks get more complex	• Allow trainees to learn by easy stages of increasing complexity.
Trainees lack confidence	• Use written instructions. • Avoid using operational materials too soon. • Use longer induction periods. • Assign groups of workmates to the same course. • Avoid formal tests. • Don't give formal time limits for course completion.
Learning requires extended attention and concentration *Adapted from Newsham (1969). © Crown copyright material is reproduced with the permission of the Controller of HMSO and Queen's Printer for Scotland.*	• Avoid 'chalk & talk' as far as possible. In earlier years trainees may have had a bad experience of the classroom. • Use a learner-centred, discovery learning style – even in the classroom setting. • Use meaningful material and tasks which are challenging to an adult.

How can skill fade be prevented?

Completing a training course is one thing. But people tend to forget what they have learned. Even experienced operators will perform less well on aspects of the task that do not crop up very often. And some skills and knowledge seem to fade faster than others if not practised. The research on 'skill fade' is by no means complete: you cannot look up any table that lists all the knowledge and skills and tells you how often they must be rehearsed to keep them fresh. However, there is quite a bit of useful guidance.

Factors affecting skill fade	
Skill fade factors	**Training guidance**
Training factors *Related to the way the task is formally taught and to differences in teaching methods*	• The more coherent (ie connected) the content of a learning or training programme, the less likely it is that the knowledge will be forgotten. • Grouping pieces of information into categories increases the amount of information recalled. • Short sessions (1 hour max per day) can induce better skill acquisition than long or multiple sessions. • The more that the training content can be elaborated (ie with additional information) or rehearsed during training, the more durable trainees' recall of it is likely to be. But there is a trade-off between this and using the available training time for new material – it needs an experienced trainer to judge this • For complex tasks, explanations of how things work result in better recall of task procedures after training than simply procedural training on its own. Simple or well-rehearsed procedural tasks do not benefit from functional explanations. • Training on different pieces of similar equipment decreases the rate of acquisition but increases retention. • Feedback about the direction and scale of error (eg 'too much', 'too little', rather than 'right' or 'wrong') improves trainee performance over subsequent trials. • Giving feedback in summary form rather than after every practice trial slows performance but promotes a marked improvement in retention. • Gradually fading out the amount of feedback, instead of providing either a constant or increasing amount of feedback, improves retention.
Skill maintenance factors *Related to activities undertaken by the individual after the task is learned*	• Using skills on the job immediately after training prevents skill fade. • Mental rehearsal throughout training enhances subsequent task performance. It's best to combine it with physical practice and it should not be allowed to exceed five minutes. • Having access to embedded training facilities means that people always have the means to practise aspects of required skills, including rarely occurring events.
/Cont.	

Factors affecting skill fade */cont.*	
Skill fade factors	**Training guidance**
Re-training factors *Related to the way the task is formally re-learned/re-taught and to differences in re-learning/ re-teaching methods*	• The more experienced a re-trainee is, the better their performance after retraining. • Expecting and receiving an evaluation test increases retention. • Retraining on the same task will take much less time than first training (often about half). • Psychomotor tasks (eg driving) are re-learned faster than procedural tasks
Individual factors *Related to characteristics of the individuals learning the tasks and differences between these individuals*	• High aptitude people learn more quickly than low aptitude people. They learn more within the same period of time and retain more for longer. • People with similar levels of knowledge but different levels of aptitude forget the same amount of information within the same period of time. • Adding noise and variation during practice improves retention for people who are impulsive rather than reflective – probably because it forces impulsive people to be more reflective than they otherwise would have been. • Retention is highest when the operational conditions (eg stress, noise etc) under which people must recall information are the same as those employed during training.
Task factors *Related to the task characteristics and differences between tasks*	• Retention is improved if high-quality job aids are provided. • The fewer the number of steps in the task, the better the retention. • The less rigid the sequence of steps in the task, the better the retention. • Retention is improved if each step in the task has built-in feedback. • Retention is improved if the task is not time-limited. • The less the mental processing involved in the task, the better the retention. • The less the difficulty and number of facts and terms to be remembered, the better the retention. • The less the motor control demands of the task, the better the retention.
Context factors *Related to the context in which the task is learned, performed or recalled. This context can be internal (ie mood state), external (ie environmental) or task-related (ie contextual task demands such as time)*	• Training designers need to establish a context that is similar to the operational one in which trainees will be expected to recall the content of the training programme.
Summarised from research by Gregory Harland Ltd (1999), © Gregory Harland Ltd, reproduced with permission	

The table on these pages, *Factors affecting skill fade*, lists the types of factor that affect skill fade, and gives guidance on how to control their influence.

How should training be evaluated?

Evaluation of training plays a critical role in enabling your organisation to spend large sums of money effectively, so helping it to assure its own future. Just as human learning depends on knowledge of results to develop effective individual performance, so your organisation requires feedback on its training investments in order to develop effective organisational performance.

Ideally, the evaluation of training should proceed at four levels (see Panel on page 66, *Four levels of training evaluation*). However, many organisations fall short of carrying out training-related evaluation beyond the first level. Some fail to carry out any evaluation at all, though there can be understandable reasons for this.

Sometimes, organisations fail to carry out proper evaluations of their training investment due to practical difficulties. For example, the training may be administered by a contractor who does not have any access to the trainees once they return to the workplace. Or the time lag may be too long between the training and the post-training assessment to be of any use in deciding how to modify the training. Or there may not be sufficient staff, resources or operational opportunity to carry out the job assessments.

In other cases, there may be organisational difficulties. For example, there may be resistance to the collection of field data due to a fear of liability among management

Four levels of training evaluation		
Evaluation level	**Description**	**Implementation**
Trainee reaction	This measures the degree of satisfaction with the course and its presentation. It is a useful indicator of course popularity and the quality of the presenter and materials used on the course.	Typically measured by a course feedback questionnaire.
Learning objectives	This is sometimes called internal validation. It measures the ability of the training course to achieve the learning objectives set for it. It is possible for a training course to get a very positive trainee reaction (they all had a good time), but very low internal validation (they didn't learn what they were supposed to).	Internal validation uses learning objectives derived from a training needs analysis, possibly itself informed by performance criteria from a task analysis. It can be carried out via three different kinds of test: • A pre-test (or assessment process) establishes the pre-course performance of the trainee • A post-test establishes the difference the course made to the achievement of the learning objectives • A retention test establishes the level of performance against the learning objectives some time later. Note, however, that retention or 'skill fade' factors can be influenced by the design of the training in the first place – see earlier in this section.
Job behaviour	This is sometimes called external validation. It measures the ability of the training course to deliver the required levels of operational performance. It is possible for a training course to have high internal validation (trainees learned exactly what they were supposed to) but low external validation (what they learned is of little benefit in the workplace).	Typically measured via a staff *supervision and appraisal* process (page 68) – which has its own sets of problems.
Organisation function	This is the highest level of training evaluation. The impact of training is measured in terms of organisational criteria such as production time and quality, damage to equipment, absenteeism, staff turnover, safety statistics, and staff attitudes. It is possible for a course to have high internal and external validation (it does what is says and is of measurable value in the workplace) but scores badly at an organisational level (eg operators get overstressed and frequently go sick, or infrequently used equipment gets damaged through skill fade).	Typically measured via corporate statistics and staff surveys. You should compile the data in a way that establishes its relationship with the existence (or absence) of specific training interventions. For example, absentee data should include information that allows managers to deduce any training-related causes.

for what might be discovered. Or there may be financial pressures that prevent management trying to find out if people need retraining. It is sometimes tempting to decide that what you don't know will probably hurt you less than what you might find out.

An obvious alternative to post-training evaluation is to try to do it while the training is still underway – but there are some difficulties with this. For example, a trainee doing well in a performance test on the training course may not be reflected in their operational performance. This is often because the benefits of recent intensive practice are lost with time.

Another difficulty is that training courses are often designed to keep performance levels artificially high, by limiting the type and number of mistakes that trainees can make – for reasons of *motivation* (page 117)and safety. This can lead both trainees and trainers to overestimate the true levels of trainee expertise (see Panel, *The Longford Explosion*). However, with care, the quality of in-training test data can be improved in order to estimate post-training effectiveness. You can do this in two main ways:

- You can give trainees greater insight into their own learning. This will help to prevent them confusing their feelings of familiarity with the ability to recall information. Through feedback from regular in-course testing, it will also help them to understand the need for, and value of, making mistakes, allowing them to get a sense of the impact of the training on their own performance. (Actually, in-course testing that demands *recall* rather than *recognition* – as in multiple choice testing – increases the value of training, because

The Longford explosion

In 1998, the Esso Gas Plant exploded in Longford, Australia. The immediate cause of the explosion was a ruptured heat exchanger which had become very brittle due to intense cold. The cold had been caused by an earlier problem in the oil circulation system.

The results of the inquiry showed that operators did not understand what could happen when metal got cold - even though they had been through what at first appeared to be a proper training course.

Closer inspection by the inquiry revealed that if operators failed the test at the end of the training module they were given further coaching. Importantly, though, operators were re-assessed simply by asking them if they now understood the training. In the event, operators reported they felt under some pressure to say that they did.

The inquiry questioned the operators further and discovered that they had not grasped the fundamental meaning of what they needed to know. For example, operators knew enough to say that they took specific actions to prevent 'thermal damage' but it turned out they could not explain the concept of thermal damage. They were simply remembering what they had been told rather than what it meant.

The basic problem was that the assessment was testing the wrong thing – rote memory, rather than a deep understanding of the job.

recalling material from memory makes such recall more likely in the future.)

- You can also educate trainers about the use of in-training testing. However, particular care is needed for tests of skill (rather than knowledge), since such tests can be very unreliable predictors of long-term performance. Training designs that use closer and closer approximations to the whole operational task, and are practised and tested under variable conditions, offer much better predictions of long-term performance (and therefore post-training evaluation) than part-task training regimes.

Further information about cost-effective training

1 Air Affairs Ltd (2003) Safety critical roles: refresher training and re-assessment frequency, RSSB Research report, Rserv479. Available at www.rssb.co.uk/pdf/reports/research/safety%20critical%20roles%20-%20refresher%20training%20and%20re-assessment%20frequency.pdf (as of May 2008)

2 Buckley R. & Caple J. (1992) The Theory and Practice of Training, Kogan Page

3 Carroll, J.M. (1990) The Nurnberg Funnel. Designing Minimalist Instruction for Practical Computer Skill. Cambridge, MA: The MIT Press

4 Gagné R.M. Briggs L.J. & Wager W.W. (1992) Principles of Instructional Design. Holt, Rinehart & Winston

5 Gregory Harland Ltd, (1999) Development of a skill fade model, GHL/CHS/SkillFade/Deliverables/FinalReport/Volume1/v3.0, Centre for Human Sciences, DERA

6 As of May 2008, http://tip.psychology.org/theories.html Summarises 50 or so different theories of learning developed by a large number of psychologists and researchers in the field of human learning

7 Newsham D.B. (1969) The Challenge of Change to the Adult Trainee. Training Information. Paper 3. HMSO

8 Patrick J. (1992) Training Research & Practice, Academic Press Ltd, London

9 Seely Brown J. & Duguid J. (1991) Organizational Learning and Communities of Practice: Towards a Unified View of Working, Learning, and Innovation, The Institute of Management Sciences (now INFORMS)

Training

Supervision and appraisal

We have placed supervision and appraisal in this section on training to emphasis their crucial role in the continuous development of front line staff in the railway industry. Several key supervisory skills are covered in this section of the Guide. Together, they equip a supervisor to facilitate the training development of all the staff for which they are responsible.

What should a supervisor actually do?

At first sight, supervision seems to be all about monitoring and controlling the work of others. In fact, Morrison (1993) says that to be an effective supervisor you need four distinct skill sets:

- *Management* (see page 99)
- Staff development
- Support
- Mediation.

Management includes:

- managing the time and workload of staff
- assessing their competence by reference to professional, organisational and legal requirements
- ensuring that records are completed.

Staff development includes:

- appraising the performance of staff to identify their training needs
- building effective teams
- fostering a relationship which allows both supervisor and staff to learn from mistakes via constructive feedback.

Support includes:

- creating a safe climate for staff members to reflect on their working practices and their effects on self and others
- conducting 'difficult conversations' and helping them to talk about their feelings, especially fear, anger, sadness or helplessness
- recognising and supporting staff who may suffer from abuse – whether physical or psychological
- monitoring overall health and emotional behaviour of staff, especially with regard to the effects of *stress* (page 120)
- advising when staff might need to seek external counselling.

'**Supervision** is about managing staff, developing them, supporting them, and mediating on their behalf'

Mediation includes:

- briefing more senior management about resource problems
- linking staff with other parts of the organisation, including higher management
- negotiating and developing team purpose and scope
- contributing to the formation of organisational policy
- consulting and briefing staff on wider organisational information and safety issues
- dealing properly with complaints about staff
- assisting staff through the complaints process.

Underpinning all of these four functions is the essential skill of clear and effective *communication* (page 106). You'll find further information and guidance on various topics that need to be understood by supervisors elsewhere in this Guide. As well as communication, these topics include *training needs analysis* (page 55), *teamworking* (page 103), *stress* (page 120), and *workload* (page 125).

This section provides human factors good practice guidance in areas that are particularly relevant to supervision – namely:

- Competence assessment (used in management)
- Performance appraisal and teambuilding (used in staff development)
- Difficult conversations (used in support)
- Negotiating skills (used in mediation).

What's the difference between competence assessment and performance appraisal?

The difference between these two is really all a matter of what the purpose is. Competence assessment is concerned with regulation: it is a management concern with establishing that an employee has the knowledge, skills and attitudes necessary to perform work to the standard expected. In the railway industry a code of practice exists (ORR, 2007) for competence assessment.

'**Performance appraisal** looks at past performance to specify current development needs; **competence assessment** looks at current behaviour to assure future performance.'

Performance appraisal is concerned with staff development. Its purpose is to ensure that people are motivated in their jobs and are developed to their full potential.

Most organisations have well-defined procedures for both competence assessment and performance appraisal. Some of the methods underlying these procedures overlap (eg in the use of rating scales).

However, *competence assessment* relies more on direct observation of the operator at work (either on the job or in a simulation) to assure future performance, while *performance appraisal* relies more on interview and discussion that draws on records of past observation to identify development needs. Both procedures are usually based upon pro-formas and a pre-defined schedule for their use. The procedures often rely on being heavily informed by the supervisor's own experience in the job.

As a supervisor, you may also be guided by the use of validated task descriptions via a *task analysis* (page 47), skill and knowledge inventories, verbal test questions, and guidelines on (for example) the number of times a person needs to correctly perform a task to be deemed competent.

RSSB maintains several good practice documents on assessment and appraisal - see *Further information*.

What should competence assessment cover?

Competence assessment should cover:

- *skills*, such as being able to demonstrate an ability to (say) interpret display readings, diagnose faults, operate controls, enact a procedure
- *underlying knowledge*, such as understanding the relationship between interacting rules
- *safety behaviours and attitudes*, with regard to (for example) communication and teamwork.

How should competence assessment be carried out?

Greenstreet Berman (2003) say that appropriate competence assessment methods depend on whether the focus is on knowledge, skills or attitudes.

- Physical skill competencies can be demonstrated by practical 'show me' assessments, in which people either complete the real task or a piece of it, such as setting a route on an NX panel or troubleshooting a signal.
- The ability to carry out a prescribed procedure of work can, usually, be demonstrated by a 'show me' test, in which people attempt to complete the task.
- Mental skills, such as the ability to assimilate signal control information from an IECC and then interpret it, might be demonstrated by the operator talking through the interpretation of displayed information. However, this may interfere with some mental skills. It may also not be possible to verbalise other mental skills, such as mental arithmetic. In these cases post-task debriefing of operators may be appropriate.
- Completion of a task requiring knowledge, such as fault diagnosis, may be indicative of underpinning knowledge. However, it is possible that the correct action was by luck. Accordingly, knowledge should be assessed through verbal or written questioning.
- Psychometric personality tests may provide a prediction of interpersonal, team management and safety behaviours. However, observing actual behaviour in the real or simulated work setting using behavioural observation tends to provide a more valid measure.

Greenstreet Berman (2003), reproduced with permission. © Crown copyright material is reproduced with the permission of the Controller of HMSO and Queen's Printer for Scotland.

What should performance appraisal cover?

To carry out performance appraisal you should:

- discuss how the individual's job objectives contribute to organisational goals
- discuss the organisation's expectations regarding employee performance
- provide feedback to the individual about their job

performance in light of organisational objectives

- coach the individual on how to achieve their job objectives or meet the requirements of their job
- diagnose the individual's strengths and weaknesses
- determine what kind of development activities might help the individual to make better use of their skills to improve performance on the current job – and in preparation for future jobs.

How should performance appraisal be carried out?

Hansen says you should carry out performance appraisal via the following four inter-related steps:

1 Establish a common understanding with the employee regarding work expectations – mainly, the work to be accomplished and how that work is to be evaluated.

2 Assess performance and the progress against work expectations on an ongoing basis. Provide regular feedback to clarify and modify goals and expectations, correct unacceptable performance before it is too late, and reward superior performance with proper praise and recognition.

3 Produce formal documentation of performance through the completion of a performance and development appraisal pro-forma appropriate to the job.

4 Hold a formal performance and development appraisal discussion, based on the completed appraisal form and ending in the construction of a development plan.

Hansen (undated), reproduced with permission

What problems are there in assessment/appraisal?

Two general problems in carrying out assessment/appraisal procedures arise from:

- insufficient structure
- taking things at face value.

Insufficient structure may be due to an organisation failing to invest in the *task analysis* (page 47) needed to define the critical tasks, together with the criteria for their successful performance. It may also be due to the failure of the supervisor to be sufficiently trained in understanding and using this structure. Structure can be greatly enhanced by the use of rating scales. Best practice here is to ensure that the scales are developed for aspects of performance identified as most important by the task analysis. Even so, organisations will need to be aware of a series of biases and other factors that can make their use less reliable. These are listed later in this section.

Taking things at face value refers to the supervisor failing to marshal the necessary evidence for their judgements about the performance they are assessing. It is never enough to allow people – either trainees or trainers – to make face-value judgements about their competence levels (see Panel on page 67, *The Longford Explosion*). This may be because of time pressures, lack of training, or one or another observational biases to which all human judgements are vulnerable. All appraisal and assessments inherently depend on subjective judgements. This means they are subject to certain problems and biases that you need to guard against if the results are to be considered reliable (see Panel on page 70, *Appraiser biases*).

Appraiser biases

Halo/Horns Effect The halo effect is the tendency to rate someone high against all criteria because they are high on one or two. The resulting appraisal is not helpful to employees, since it does not identify development needs. The opposite effect also happens when consistently low judgements in one or two categories are allowed to affect judgement in other areas. This is sometimes referred to as the 'devil' or 'horns' effect.

Matthew Effect This is related to the Halo Effect and refers to the tendency of people to judge others over time in the same way they have always judged them. This tends to create a self-fulfilling prophecy, with more weight being given to the previous judgement than to any evidence to the contrary. This is called the Matthew Effect after the New Testament statement: 'To him who has shall be given, and he shall have abundance: but from him who does not have, even that which he has shall be taken away.'

Interpretation Bias This refers to the fact that different people use different meanings for terms like fair, good, and excellent. It is best not to use these terms in any case because they do not help managers to know what to do about the results.

Central Tendency Effect This refers to the tendency for raters to assess most people as average. Rating people average can seem safer to many supervisors. It means they don't have to have *difficult conversations* (page 73) with their staff and it may give them some illusion of control over very good people. It also means that they can avoid explaining to their own management why some of their team are poor performers.

Recency Bias This is a tendency to assess people on what they have done most recently and ignoring behaviour that is less recent..

Leniency Bias This is a tendency to rate people higher than they deserve. This may be because the supervisor wishes to avoid confronting people with their limitations, or because they have allowed friendship to become confused with management, or because they are concerned that negative feedback will de-motivate their staff.

False Attribution This is the tendency to attribute success or failure exclusively to what people do and ignore the context and constraints under which they are working. So if someone does well, we give them credit, and when someone poorly we say they are to blame. In both cases it is easy to ignore the circumstances of their performance. In making the mistake of assuming that good and bad performance are both under the complete control of the employee we miss the opportunity of taking a systemic view and of recognising real success or truly helping someone to improve.

Countering the effects of appraisal bias

There is a series of simple steps you can take to limit the effects of appraiser bias.

- *Be aware of the problem.* The first line of defence lies in raising awareness of the problem. All staff – not just supervisors – should be informed of the types of subtle bias that can interfere with performance judgements. If everyone involved understands the existence and influence of biases on human judgement, much can be done to overcome or challenge them.

- *Use better rating scales.* Rating scales that grade people from poor to good should be avoided. Far more preferable are forced choice rating scales that make supervisors select a pre-defined statement that is nearest to the observed performance. Even better are behaviourally-anchored rating scales. These mark points on the scale with actual job behaviour relevant to the job-holder being rated. The job behaviours used on the scales are usually developed from observations of a range of people on the job. The supervisor who uses such a scale can 'anchor' their assessments of each individual in an unambiguous, more objective way that means more to both parties.

- *Get evidence for judgements.* All assessments should be backed up with objective evidence for supervisor judgements. In competence assessments, this evidence needs to be drawn from the behaviour observed on the job (or its simulation) during the assessment session. In performance appraisal, it may be helpful to use the *critical incidents technique*. Here, critical performance categories are identified, and during the evaluation period the supervisor records examples of critical behaviours in each of the categories. This log is then used in an evidence-based discussion to evaluate the employee at the end of the evaluation period.

- *Use multiple sources.* Better assessments and appraisals can be made by combining multiple sources of information. For example, evidence-based peer reviews are usually highly acceptable to all participants and fairly accurate as well as relevant to the task in hand. Evidence-based self-reports using structured forms can work well for people with a clear understanding of their own work. Placing self and supervisor judgements alongside each other can be a very useful basis for discussion.

  '360 degree feedback' is a comprehensive but expensive type of appraisal. It includes ratings by both self, peers, and subordinates, as well as the more traditional, downward assessments from line managers. It gives people a chance to know how they are seen by others and to become aware of their skills and style. It may also improve *communications* (page 106) between people. However, it only works for people with at least three people reporting to them and may be uneconomic for all but senior managers.

- *Incentivise the development of poor performers.* The organisation may offer incentives (financial or non-financial) to encourage supervisors to make special efforts to help poor performers improve.

How do you build an effective team?

Guidance on how an organisation can diagnose and improve *teamworking* is given elsewhere in this Guide (page 103). Of particular relevance in this section on supervision and appraisal is a particular aspect of teamworking – teambuilding. Any search of the Internet will produce a large number of sites offering information in this area. From a human factors point of view, the most useful guidance is on the general process that a team needs to go through, which can be considerably helped by effective supervision.

How do teams develop?

Teams seem to go through a number of stages as their members develop together. The Panel on page 72, *Stages in team development*, describes these stages and how supervisors can best deal with the typical things that go on in their teams at these different stages. What is meant by 'team' here is a group of people who work together over a relatively long period (weeks, months or longer), such as a track gang, station staff, a signal box shift, an administrative team, or staff put together for a special project. The development process described here is especially relevant to those teams for which there is any kind of opportunity for interpretation of the Rule Book or other organisational procedures.

Stages in team development			
Stage	**Description**	**Likely supervisor feelings**	**Effective supervisor behaviour**
Forming	When a new team is first formed, people's own agendas dominate. They may not declare all of their interests. The supervisor's key role here is to get team members oriented – towards one another and their joint responsibility (team task). The key focus should be on this team task, time scales and resources. Progress on the team task may seem slow.	• Anxiety about being liked • Anxiety about the abilities of the team members.	• Clarify and explain task objectives and demands • Make people feel included – identify and use previous experience of new team members • Create 'getting to know you' opportunities • Clarify and explain communication channels – often a problem area for new teams • Be directive but don't be dictatorial: create opportunities for participation • Take the initiative and allow the team to depend on you • Relax – avoid seeming over-anxious
Storming	Where there is room for manoeuvre outside the Rule Book, people will disagree about the best way to carry out the team task. Supervisors can find this frustrating and difficult to manage. But conflict has its benefits – the emotions often result in greater team cohesiveness. The supervisor should focus on ensuring that participants understand the team's terms of reference. Supervisors should also expect their own performance to be challenged.	• Anxiety about where the team is going and how it will get there. • Anxiety about how much control should be exerted. • Anger, frustration – maybe apathy.	• Allow differences of opinion – but do not allow extreme views to develop. • Respond to challenges constructively – harness the expertise of the whole team • Respond to feedback seriously, and insist that it is constructive – distinguish between yourself as a team members and your role as supervisor • Accept responsibility for your role as supervisor
Norming	The clash of personal agendas gives way to a more collective team concern with how they are going to work together. Each team member starts to accept that the needs of the whole group are larger than their personal issues. Team focus turns to the timing, pattern and quality of operational matters. Some storming will continue for remaining issues. Supervisor attention should be focused on the achievement of the required quality standards.	• Relief, sense of getting somewhere at last.	• Allow the team to develop norms rather than rules: don't let behaviour get rigid • Continue to focus attention on assuring a constructive feedback climate for everyone • Use the performance appraisal process to reinforce team roles • Let team members begin to 'have their head' – but check results against standards
Performing	The team has replaced its many personal agendas with a creative focus on team problems via mature procedures. Team members will have developed trust that allows them to review progress frankly. They can effectively deal with setbacks and devise remedial steps. The team will feel at home with each other and enjoy their success. Leadership often becomes a shared function with different members taking the lead for those task elements that best fit their skill sets..	• Contentment, involvement, commitment, relaxation – but some anxiety about taking more of a 'back seat'.	• Challenge existing norms – allow the team to consider degraded/emergency operations • Don't let the team get too focused on itself – develop relationships with others • Allow others to lead and let go as far as possible – but check the results! • Do what you can to create more sense of equality between team members
Deforming	Teams deform for a number of reasons. The project may have finished or a key member leaves. Teams develop their own ways of marking their successes and changes. If publicised, these can make the team attractive to outsiders and a desirable one to join. If someone leaves due to promotion, this can be confirmation that the team is a desirable place to be. Trying to carry on as normal may cause problems, and the supervisor will need to pay attention to these.	• Celebration, success, pride – and anxiety about 'having to start again'.	• Recognise the change as a positive endorsement of the whole team • Involve the team in discussing the implications for the forthcoming change • Monitor team performance during the change and discuss problems as they emerge • Involve the team fully in the discovery and resolution of these problems
Reforming	Reforming is necessary when the team changes in membership or scope. Reforming is similar to the forming phase but is often easier due to familiarity. Supervisors may need to correct a common assumption by team members that the new person is simply filling in for the person who left, when in fact they have their own contribution to make. An older team facing a new task may be over-confident. It may be necessary to take the team back to its previous decisions to allow it to storm its way again to a new set of norms that will pave the way to further success.	• Concern over how the change will affect team performance. • Interest in making other changes that will benefit the team or organisation. • Anxiety and frustration about having to start again – albeit with much more confidence than before.	• Involve the team in full discussion of the change. If a new team task, work with the team in understanding its challenge and impact on existing work patterns and practice. If a new member, make opportunities for personal contact with the rest of the team. • Take the initiative in valuing the new member's ideas, contribution and perspective. • Encourage the team to spot opportunities for using the change to resolve existing problems and make improvements.
Summarised from work by Tuckman (1965) and Morgan et al (1994)			

How do you handle a difficult conversation?

What is a difficult conversation?

Stone et al (1990) say that a difficult conversation is anything you find hard to talk about. The context might be reviewing bad performance with someone, disciplining someone, having to make someone redundant who is also your friend, dealing with the bereaved spouse of an accident victim who was your colleague and so on. But whatever the context, the conversation will be difficult whenever you feel vulnerable or it has implications for the way you feel about yourself, when the issues are important but there is uncertainty about how things will turn out, and when you care about the people with whom you need to have the discussion.

Research has shown, maybe surprisingly, that despite the many variations, all difficult conversations share a common structure. Understanding this structure makes it possible to conduct such conversations more effectively – and with much greater confidence. In fact, in each difficult conversation, Stone et al (1990) say there are really three different conversations going on. In each of these, we all tend to make predictable errors that distort our thoughts and feelings, and make the conversation much more difficult than it need be. This can lead us to far more unsatisfactory outcomes than necessary.

What are these common threads?

1 *The what happened? thread.* Here we spend a lot of time wrestling with each other over who is right, who meant what and who is to blame. The problem is that we tend to make incorrect assumptions which cause a significant amount of the difficulty we experience.

2 *The feelings thread.* Very often we try to suppress the strong feelings we have within a difficult conversation. We tend to think this is better this since expressing them may lead to temper and loss of control, or else things being said which are then regretted. The problem is that feelings are at the very core of difficult conversations. They are not a by-product of engaging in a difficult topic: they are an integral part of the topic – and they need to be recognised as such.

3 *The identity thread.* Our role in the conversation affects our sense of who we are and how we are perceived by others. Something beyond the subject of a difficult conversation is always at stake. And that something is us. For example, our determination to turn down a proposal from a keen young team member is undermined when we are suddenly reminded of ourselves at their age and the way we would have felt. We are overcome by self-doubt and our anxiety level suddenly soars. We lose our balance. In mild cases, our confidence leaves us, we lose concentration and forget what we were going to say. In extreme cases, we may feel paralysed, overcome by panic and 'wish for the earth to open up and swallow us'.

So what can be done? The Panel, *Making difficult conversations easier* gives some good clues.

Making difficult conversations easier

	A battle of messages	**A learning conversation**
The What Happened? Conversation **Challenge**: *The situation is more complex than either person can see*	**Assumption**: I know all I need to know to understand what happened. **Goal**: Persuade them I am right.	**Assumption**: Each of us is bringing different information and perceptions to the table; there are likely to be important things that each of us doesn't know. **Goal**: Explore each other's stories: how we understand the situation and why.
	Asssumption: I know what they intended. **Goal**: Let them know what they did was wrong.	**Assumption**: I know what I intended and the impact their actions had on me. I don't and can't know what'ss in their head. **Goal**: Share the impact on me and find out what they were thinking. Also find out what impact I'm having on them.
	Assumption: It's all your fault. (Or it's all my fault.) **Goal**: Get them to admit blame and take responsibility for making amends.	**Assumption**: We have probably *both* contributed to this mess. **Goal**: Understand the contribution system: how our actions interact to produce this result.
The Feelings Conversation **Challenge**: *The situation is emotionally charged*	**Assumption**: Feelings are irrelevant & wouldn't be helpful to share. (Or my feelings are their fault & they need to hear about them.) **Goal**: Avoid talking about feelings. (Or let them have it!)	**Assumption**: Feelings are the heart of the situation. Feelings are usually complex. I may have to dig a bit to understand my feelings. **Goal**: Address feelings (mine & theirs) without judgements or attributions. Acknowledge feelings before problem solving.
The Identity Conversation **Challenge**: *The situation threatens our identity*	**Assumption**: I'm competent or incompetent, good or bad, lovable or unlovable. There is no in-between. **Goal**: Protect my all-or-nothing self image.	**Assumption**: There may be a lot at stake psychologically for both of us. Each of us is complex, neither is perfect. **Goal**: Understand the identity issues on the line for each of us. Build a more complex self-image to maintain my balance better.

How do you negotiate effectively?

What is negotiation?

Negotiation is a communication between two parties designed to reach an agreement when both parties share some interests, but not others. Fisher et al (1991) say that less obvious than this straightforward idea is the notion that negotiating does not mean giving in. Nor does it mean settling for less than you wanted – or even compromising. However, it does often mean settling for something different – sometimes more – than your original objectives. If this is surprising, it is because it is common to have an incorrect sense of what negotiation is all about. The usual assumption is that the subject of negotiation is like a pie, and the object of negotiation is to get as much of the pie as possible. And, of course, getting more means that the other side gets less. But in fact, it's better to think of negotiation as a creative process in which opportunities are developed and expanded so that the interests of both parties are met. In its ideal form, it's the process of making the pie big enough for everybody.

What's involved in negotiation?

The notion that negotiation is like a pie that must be fought over goes hand in hand with an approach to negotiating called *positional bargaining*. The classic example is the haggle that often takes place when buying a used car or something from a car boot sale. The approach depends on each side successively taking – and then giving up – a series of positions. While this approach tells each side what they want and can eventually lead to an acceptable agreement, it is fraught with serious problems.

The four principles of negotiation

Negotiating principle	How to do it
1. Separate the people from the problem. *It is people who negotiate. Yet people have strong emotions, different perceptions and problems communicating. Emotions often get mixed up with the merits of a problem, and taking positions just makes this worse since personalities get identified with positions.*	• Put yourself in their shoes – it helps to see through the 'merits' of your case and the 'faults' on the other side. • Don't infer their intentions from your fears – it is too easy to think the worst of the other side and this will seriously impede progress. • Don't blame them for your problem – it may be justified, but it is almost always counterproductive. • Discuss each other's perceptions – it may reveal new values and options. • Look for opportunities to not always act in accordance with the other side's perceptions – this will dislodge their tendency to 'pigeonhole' you. • Include the other side in the problem-solving process as early as possible (ie avoid having to face the 'not invented here' syndrome (what's this?) when you present your ideal solution). • Make your proposals consistent with their values – help them to avoid having to save face. • Recognise and understand emotions (yours and theirs) – it will give you valuable insights towards the solution. • Make emotions explicit and acknowledge them as legitimate – it reinforces each side's humanity. • Allow the other side to let off steam, but don't react to emotional outbursts – ensure only one side at a time gets angry. • Use symbolic gestures – an apology can vastly improve a hostile emotional situation. • Listen actively and acknowledge what is being said – it will show that you take them seriously and help them to listen to you. • Speak to be understood – often achieved by severely limiting the number of people in the same room. • Speak about yourself, not about them – it is difficult for them to challenge how you feel and very easy for them to argue that you are wrong about them. • Speak for a purpose – make sure that you have thought through the impact of what you might say beforehand.
2. Focus on interests, not positions. *Positions usually obscure what people want. Finding a compromise between two different positions will often not address the interests that led the two sides to take those positions in the first place. It is far better for people to declare what they want to achieve and where they want to get to.*	• Ask 'why?' and 'why not?' – it will lead you from their position to their interests. • Realise that each side has multiple interests – they are trying to solve problems that are more complex than might at first be apparent. • Realise that the most powerful interests are basic human needs – like recognition, security, a sense of belonging, and control over one's life. • Acknowledge their interests as part of the problem – people will listen better if they think you have their interests at heart. • Put the problem before your solution – if they hear a position first, they will not listen to your problem. • Look forward with a purpose in mind, not back with only causes to dwell on – or you will just end up point scoring off each other. • Be concrete, but flexible – you need to be clear about what will satisfy you, while always being open to new suggestions that may turn out to be better. • Be hard on the problem, soft on the people – commit to your interests, but do not attack people or they will become defensive and closed.

The four principles of negotiation

Negotiating principle	How to do it
3. Invent options for mutual gain. *Rather than spending time under pressure trying to reach an agreement with the other side, it often pays to set aside some time to brainstorm a wide range of options that advance shared interests and reconcile differing ones.*	• Brainstorm options, identify the most promising ideas – then figure out ways to improve on them. • Consider brainstorming with the other side – harder to do, but potentially valuable. But make it clear that the brainstorming session is off the record. • Broaden options – seek variations by thought experiments which try the options out hypothetically – and then critique the implications. • Look for mutual gain – by identifying shared interests and seeing if different interests can be dovetailed (Jack Sprat could eat no fat; his wife could eat no lean …)
4. Insist on using objective criteria. *Negotiations can get stuck if one side simply decides to be stubborn. This can be countered if both sides agree ground rules that allow matters to be deferred to some third-party standard, such as an independent expert, market value or legislation. Discussing such criteria, rather than what sides are (un)willing to do, means that neither needs to give in to the other. Instead, both defer to a fair solution.*	• Decide on fair standards – eg what a court would decide or scientific judgement. • Decide on fair procedures – eg some version of 'one cuts, the other chooses'. • Discuss the standards and procedures with the other side – so that agreed, third-party criteria can be used to determine progress towards an agreed solution.

- *Positional bargaining is not guaranteed to produce a wise agreement.* In adopting a position and then defending it, people tend to get locked into that position. The transaction then takes on a new dimension as people try to save face – reconciling future action with past positions, and less and less attention is paid to the underlying concerns of the parties involved.
- *Positional bargaining is inefficient.* The process often takes a lot of time – due to starting with an extreme position in the expectation that you will need to give it up for something less, but which is still more than your undeclared objective. All sorts of delaying tactics are also employed to apply pressure – dragging feet, threatening to walk out etc.
- *Positional bargaining endangers relationships.* Positional bargaining is a contest of will. As one side bends to the will of the other, there is anger and resentment. A win for one side can lead to long-term or permanent damage to the relationship, which makes further agreements less likely.

There is an alternative to positional bargaining – called *principled negotiation* – that has come to be adopted in many countries and organisations as a much more effective and practical approach to negotiation. The four key points of principled negotiation, and the ways in which they can be addressed, are set out in the Panel, *The four principles of negotiation*. You will find further helpful information in the main source for this table.

Further information about supervision and appraisal

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understanding
human factors

Staffing

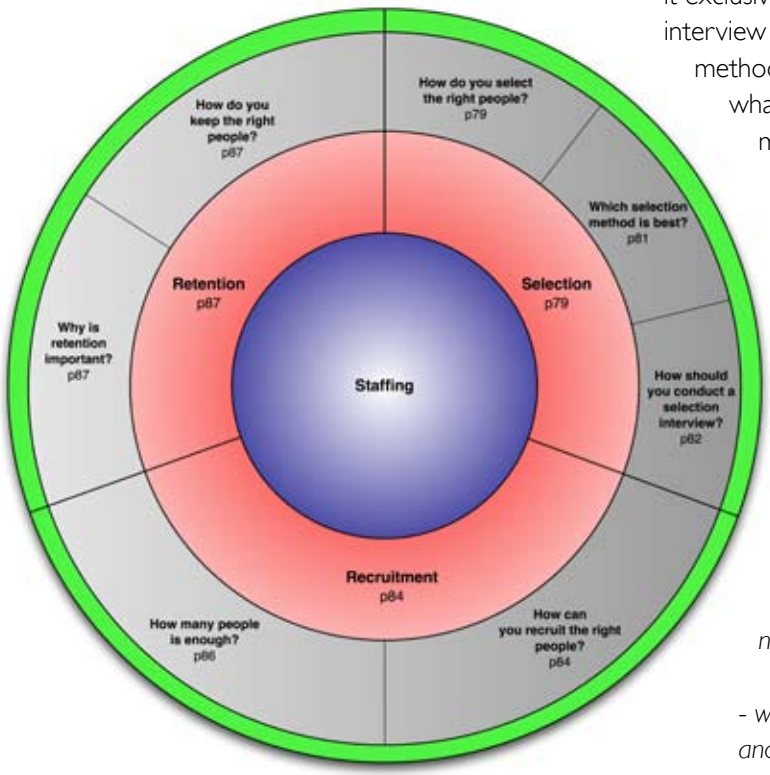
understanding
human factors

Staffing

Staffing

Staffing is concerned with the human factors of recruiting, selecting and retaining the right people in your organisation. The diagram below focuses on Staffing. It shows its three sub-areas (in the middle red ring), and identifies the main human factors questions that this Guide answers (in the outer grey ring). At the end of each section, you will find a list of sources of further information that will provide more detail. In addition, Part 3 gives further detail on key human factors methods that are mentioned throughout the Guide.

Focus on staffing



Selection

How do you select the right people?

The first thing to say is that unless you are already a Human Resources (HR) professional, you will need to work with one – as well as occupational experts – to assure the quality of your selection process.

When most people think of how to select the right people, they most often focus on the selection interview. It is certainly true that the selection interview is by far the most common method used to select people for employment. However, it is not best practice to rely on it exclusively. In fact, in its traditional form, the selection interview is greatly inferior to several other selection methods described in this section. Furthermore, whatever selection method – or combination of methods – is used, it is important to approach selection as a process that takes place over time rather than the means by which an organisation makes a decision about a job applicant on a particular day.

What is the selection process?

The selection process runs as follows:

- Carry out a job analysis to identify:

- the most difficult, frequent and important tasks that make up the job

- the knowledge, skills and aptitudes the person needs to do the job

- which of the knowledge and skills can be trained and which the applicant will need to have.

- You will almost certainly have to provide some induction training – so that the new people can get acquainted with your organisation's culture and procedures. If you expect to hire experienced people (eg COSSs, depot fitters), you may need to provide only minimal job training. In other cases (eg new signallers, drivers), job training will form a significant early phase of employment.
- Decide upon the selection methods that will best assess the knowledge, skills and aptitudes that will be needed to carry out the tasks that make up the job.
- Attract as many applicants as possible – the more there are, the better the choice and the more likely you are to get who you want (see *Recruitment* on page 84).
- Apply the selection methods (sifts, tests, interviews etc) to the job applicants and on the basis of these assessments, select those most likely to do the job well.
- Make job offers to the selected candidates, conditional on references, and follow up on references. While you are waiting for references to be completed, it is a good idea to contact the successful candidate: if you want to employ them, it is highly likely that others do too, so you will need to make sure they remain interested in your job offer until they can start.
- Evaluate the effectiveness of the selection methods by seeing how well they predicted the performance of those selected and by calculating their cost-benefits. (Of course, these calculations are hampered by the fact that you can never know how well the people whom you didn't select would have done.)

What selection methods are available?

A variety of selection methods are available and there is a great deal of reliable evidence about their value. The main methods are:

- interviews
- practical tests
- psychometric tests
- biographical data (biodata) questionnaires
- assessment centres.

Interviews

There are two main kinds of selection interview. Most organisations use a traditional interview approach in which candidates are asked a series of straightforward questions about their previous experience, interests, aims, ambitions and expectations (see *How should you conduct a selection interview?* on page 82). However, some organisations are increasingly using a competency-based interview approach (sometimes known as behavioural interviews). Here, a candidate's previous behaviour is sampled in order to indicate their future performance. They may be asked to describe a real situation from their experience that required for example, problem-solving, leadership or stress management. The interviewer will want to know specifically how the candidate handled these types of situations – in terms of both their behaviour and attitude (see Panel, *More about competency interviews*).

More about competency interviews

It is can be quite effective to combine competency or behavioural questions with more traditional interview questions. Skilled interviewers commonly do this. The questions often overlap and are designed to gather information about the working issues most relevant to your organisation. But make sure that any competency questions you ask do not discriminate unfairly against people who have not had a chance to experience the situations you are asking about eg younger applicants. These are examples of interview questions.

- *Initiative and follow-through*
  Give me an example of a situation where you had to overcome major obstacles to achieve your goals.
- *Thinking and problem solving*
  Tell me about a time when you anticipated potential problems.
  Describe the preventive measures you took to avoid a major problem.
- *Communication*
  Describe for me a situation where you persuaded team members to do things your way. What was the effect?
- *Working effectively with others*
  Tell me about a difficult situation you had with a co-worker, and how you handled it.
- *Leadership*
  Tell me about a time when you were able to step into a situation, take charge, muster support and get good results.
- *Priority setting*
  Tell me about a time when you had to pick out the most important things in some activity and make sure that they got done.
- *Decision making*
  Describe for me a time when you had to make an important decision on the basis of limited facts.
- *Ability to work in varying work conditions* (stress, changing deadlines, etc)
  Tell me about a time when you worked effectively under pressure.
- *Delegation*
  Describe for me a time when you had to delegate to a person with a full workload, and how you went about doing it.

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Practical tests

These are only appropriate for candidates who already claim to have the skills necessary to do the job. Practical tests directly assess the abilities required on the job. For example, a fitter might be asked to undertake a repair task on a piece of equipment (or simulator), a technician might be asked to troubleshoot a faulty signal, or a secretary might be asked to carry out a task using word-processing software.

Psychometric tests

Psychometric tests can be useful when choosing a candidate from a group of people who do not have easily comparable skills or experience. You normally need a specially trained and certified person to administer them, and using them often involves a fee. Psychometric tests are used to measure intelligence, personality or aptitude for specific tasks, such as decision making, and interpersonal skills. A Guidance Note on psychometric testing for train driver selection and management is in an advanced stage of preparation by RSSB, and further general information is available from the British Psychological Society website (see *Further information* at the end of this section).

Biodata (biographical data) questionnaires

This method takes the form of a multiple-choice biographical questionnaire and is more likely to be used by large organisations. Sometimes applicants may seem much the same on paper, but some have greater initiative or 'people skills' than others. Biodata consists of systematic information about hobbies, interests and life history, which is assumed to be more or less indicative of the suitability of people for different kinds of jobs. The main use of

biodata is in the pre-selection of people for basic-level jobs, such as apprentices or graduate trainees. The logic is that if candidates are matched with existing staff, people with similar interests can be found who are likely to be suitable for the job. The greatest value of the technique is its ability to reduce staff turnover.

Assessment centres

This is often a day-long, or even residential, process in which candidates are put through a battery of interviews, psychometric tests, group discussions and other exercises. A well-known example is the in-basket exercise. Here, applicants work through a pile of written notes and problems and must determine how – and in what order – they would handle each. In-basket exercises are useful to determine how applicants work under time pressure and how they plan their time, as well as their ability to distinguish priorities.

Which selection method is best?

There has been a lot of research into the effectiveness of the different methods of selection. By 'effectiveness' we mean how well the results of a selection method predict later performance on the job. This is sometimes known as 'predictive validity'.

The ability of a method to predict later performance depends on the extent to which what it measures turns out to be necessary to the performance of the job. For example, a selection method might include a test of intelligence or verbal ability, both of which are clearly important to all jobs in the railway industry. However, training or job experience may be equally important. If they are not taken into account the utility of the selection method will suffer. It will also suffer if the method turns out to be a bad test of what it is supposed to be measuring. For example, there are good and not so good tests of intelligence.

The Panel, *Which selection method is best?*, summarises the general situation. Note how far down in the list the traditional structured selection interview comes. This is because the selection interview has high *face validity,* but low *predictive validity*. In other words it may seem to be powerful, but it is not a very good measure of how well a person will actually do on the job. The selection interview is important – but should not be used on its own to make reliable selection decisions.

Which selection method is best? *(Listed in order of effectiveness)*

Method	Best for	Cost	Effectiveness
Assessment Centre	Applicants to higher paying and/or higher risk positions, where the consequences of a wrong hire decision may carry higher penalties for an organisation or its customers	High	Good
Psychometric tests of intellectual ability	Applicants with no previous experience in the job for which they are applying. Here, the selection method is used essentially to measure the 'trainability' of the applicants	Moderate	Moderate to Good
Practical tests or trials	Applicants with previous experience of the job they are applying for	Moderate to High	Moderate to Good
Structured competency interviews	Applicants with previous experience of the job they are applying for – although read-across from similar situations is often possible	Moderate	Moderate to Good
Previous job and/or personal references	All applicants	Low	Moderate to Good
Biodata (biographical data) questionnaires	Applicants with little previous experience and who will be new trainees	Low	Low to Moderate
Structured traditional selection interviews	All applicants where it is not appropriate or practical to carry out structured behavioural interviews or practical tests	Low	Low
Psychometric tests of personality	Do not use on their own – may have a helpful role as part of an assessment centre	Low to Moderate	Low
Unvalidated tests, eg graphology (handwriting), astrology etc	Do not use!	Low to Moderate	Nil

In choosing a method (or a combination of methods), you will need to take into account how appropriate they are to your situation and resources. But remember, no selection method on its own – or in combination – provides anything like a certain prediction of job performance. The best psychometric test or practical test only measures a small percentage of the reasons why people do well or poorly at their jobs. When the best methods are combined – as they are in assessment centres – the percentage gets bigger. However, even then it is still the case that most of the reasons for successful job performance cannot be assessed. This is because job performance is affected by a large number of interacting reasons that emerge as job holders develop over time: eg their changing domestic circumstances; their relationships

at work; their hopes, ambitions and fears; and, most of all, their experience of doing the job itself in the context provided by the culture of the organisation. As time goes on, the relationship between selection test results and job performance gets weaker and weaker.

'The traditional interview is not one of the best selection methods…but you can **improve its usefulness** by following a basic few rules.'

The real value of selection methods is that when they are applied appropriately, with care and in combination, they can sufficiently predict performance for the next two to three years to be capable of saving organisations a lot of time and money.

How should you conduct a selection interview?

If you are recruiting to a safety-critical role, the traditional selection interview will form only part of a selection process, in which HR professionals should also be involved. The interview is, however, the most accessible method around, and for this reason alone it is here to stay. You can greatly improve its usefulness by following a few basic rules.

In essence, you need to:

- Plan the interview properly – to make things as easy as possible for you and as fair as possible for the applicant. This will involve properly examining whatever materials the applicant has sent you, and being very clear about what you are looking for
- Conduct the interview fairly and consistently for each applicant – to give yourself a basis for comparison. Remember that there is very often a poor correlation between your first impressions and the end of the interview – let alone performance on the job (see Panel, *Don't discriminate!*).
- Follow-up the interview promptly – to give feedback to the applicants and to ensure that references are followed up before your preferred applicants are snapped up by someone else!

Before interviewing

1 Spend time with the results of the *task analysis* (page 47). Use it to develop a list of questions that will answer 'What relevant knowledge, skills and attitudes do the applicants have?'

2 Sift applications. Do not arrange to see too many people for one job – you will be wasting everybody's time, including your own. And do not plan too many interviews on one day. Four or so is about right.

3 Review each applicant's resumé and application form. Write down questions that will answer 'What more do I need to know about this particular applicant?'

4 Make sure you have a written job description and that you are familiar with it so you can answer the applicant's questions.

5 Be aware of the kind of questions you must avoid asking (see Panel, *Don't discriminate!*)

Don't discriminate!

In using any method of selection, you will need to take great care not to fall foul of the discrimination or data protection laws. The discrimination laws make it unlawful to discriminate on the grounds of someone's sex, sexual orientation, marital status, race, colour, nationality, ethnic origin, religion, beliefs or because of a disability, pregnancy or childbirth, or membership/non-membership of a trade union. It is also unlawful to discriminate against part-time workers. A good rule of thumb is to avoid probing personal or private topics that have no relationship to the candidate's ability to perform the job. With regard to the Data Protection Act (1998) you should remember that candidates have the right to demand all the data that you collect about them – so be careful what you record!

6 Book a quiet place for the interview where you will not be interrupted. Try to arrange for a round table rather than a desk (often perceived as a barrier).

7 If you plan to have other individuals in the meeting, plan your roles in advance, ie who will ask what questions.

The interview

1 Make sure you are there before the applicant and that you are relaxed and prepared – remember that the applicant is judging you and your organisation as well. Make sure reception staff are expecting the applicants.

'Remember – if you think the applicant is good - **someone else will too** … keep in touch with them while you are making sure!'

2 Greeting the applicant in a friendly, welcoming way. Break the ice by (eg) asking where they have travelled from and how their journey was. Do not imagine that you are able to sum up the applicant in the first few minutes of meeting them – you will almost certainly be wrong.

3 Do not get straight into questions. If there is more than one interviewer present, make sure you explain to the applicant who the other people are and why they are there. Explain the purpose of the interview and outline the organisation and how the job fits with the organisation. Ask if the applicant has any questions about the job or the organisation before beginning settling into interview.

4 Start with straightforward factual matters covering things like applicant's full name, address and current employment status, employment history etc. They are useful to check and easy for the nervous interviewee to answer.

5 As the interview proceeds, make sure you give the applicant time to think about your questions and to consider an answer. Do not interrupt – but do intervene if the applicant becomes flustered. Use silence after you've asked a question. You'll get interesting information if you let the applicant fill the gaps you leave. The applicant should be talking 75% of the time. Any less and you are talking too much! Keep control of the interview. If you feel the candidate is going off-track, turn the conversation back to the information you need.

6 While interviewing the applicant, keep eye contact and don't anticipate answers, but do listen attentively. And don't show whether you agree with or approve of what an applicant tells you.

7 Use open-ended questions to get information. They begin with *What*, *Why*, *How*, *Describe* or *Tell me about*. Use behavioural questions where possible (see Panel on page 84, *More about competency interviews*). Use closed questions (that can be answered Yes or No) to confirm information.

8 Ask only job-related questions and make notes during the interview – but be aware of the Data Protection Act implications (see Panel on page 86, *Don't discriminate!*). Make sure you develop a picture of how the interviewee's knowledge, skills and attitudes fit with the job description produced by the *task analysis* (page 47). Try to get an understanding of what they value about their work and their relationships. A good question is to ask *'what were you most proud of in your last job and why?'* or *'what did you find most challenging and why?'*. Make sure you understand how they come to be applying for this job at this time, what explanations there are for any historical gaps, and where they see themselves going in the future.

Following up on references

References are so important because a person's track record is probably the most valuable indicator of future success. You need to be sure that the people you hire can do the job and have nothing to hide that might endanger the workplace – or your organisation. You should ask the applicant to give you at least two work-related references whom you can call to discuss their experience of working with the applicant. Ideally these should be people to whom they reported in previous jobs. If the applicant can't give the name of a previous boss who will act as a reference for them, you need to understand why.

Tips for conducting reference checks

- If possible, get candidates to ask their referees to call you. The referee will be much more willing to share information with you if they were asked by the candidate to do so and the call comes from them.
- Where this is not possible (or you get no response within a few days), send a simple written form for them to fill in. Do not make it arduous or you will decrease your chances of a reply. Give them the option of calling you if they would prefer.
- Keep your questions consistent from reference to reference so you can compare responses.
- Pay more attention to negative or neutral information compared to positive information. Most people find it easier to say good things about an ex-employee than bad things.
- Keep your questions focused on what you need to know about the candidate's performance in previous jobs. Good questions for references include:
- *How long have you known the candidate?*
- *What was your reporting relationship to them?*
- *How would you describe their contributions to your organisation?*
- *How would you describe the candidate's strengths? What skills could they further develop?*
- *How did they get along with others?*
- *What seems to motivate them?*
- *Would you re-hire them?*
- *Is there anything else you'd like to add?*

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After the interview

1 Ask the applicant what remaining questions they have - but don't conclude anything from a nil response.

2 Sincerely thank the applicant for coming and let them know when they are likely to hear the outcome. Do not hint what the outcome will be.

3 Make a written record as soon as possible after the interview. Only record what was said in the interview. Do not record your beliefs or thoughts about the applicant – records may have to be made publicly available later. Only keep personal data after an interview if it is necessary and relevant to the selection process, or in respect of a discrimination challenge. All such data must be securely stored.

4 For promising applicants, take up references from former employees. References are a very important source of information about a prospective employee, (see Panel on page 83, *Following up on references*). Let each applicant know if they are going to be considered. Tell them how long it will take for a decision to be made - and be as accurate as possible.

5 Make a decision by comparing all of the evidence you have gathered for the applicants, including the references information, and setting it against the job description, together with your knowledge of the job requirements and present staff.

6 Inform applicants of the outcome by the date you promised.

Recruitment

How can you recruit the right people?

There are two levels of answer to this question. The first level is at the 'sharp end' and concerns the channels by which your organisation can find potential recruits. The second level is a more strategic one and concerns the whole issue of what can be done to make potential recruits want to work for your organisation.

How can you find new recruits?

Most organisations are familiar with the main recruitment channels, which include the following:

- *Recruiting from within.* Your first action should be to see if you can fill a vacant position from your own staff. Perhaps someone needs promoting, and both the employee and the organisation already know each other well. Recruiting from within is also good for employee *morale* (page 117), as it shows the rest of the workforce that progression is possible. It is also usually easier to fill the lower level position vacated by the move. (See *supervision and appraisal* on page 68 for issues and strategies to cope with this.)

- *Staff networks.* If the post cannot be filled directly by existing staff, it is quite likely that potential recruits are known to those same staff, ie friends and relations. These staff networks should also include all those former employees whom you were reluctant to lose, but whose circumstances may now have made them receptive to re-employment.

'Recruitment is a two-way track … you need to do everything you can to **make it *you* that's wanted** by your potential applicants!'

- *Bounty rewards.* It might be possible for your organisation to operate a bounty reward scheme for staff who recruit people to the organisation. Bounties can vary depending on how difficult it is to find people to fill the position. Even though the bounty involves spending money, the amount will be a lot less than an agency fee and represents high value: it not only fills a vacancy, but spreads good will since someone from your own staff will benefit.

- *Temporary personnel agencies.* Temporary employment agencies are a flexible source for a wide range of employee types. It might seem an efficient way of finding suitable new recruits – but there are pros and cons. The advantage is that you certainly can evaluate people for the possibility of permanent hire without committing yourself. The disadvantage is that the agency will probably charge if you do hire them.

- *Employment agencies.* These agencies will find you permanent employees – for a fee. They will usually have a suitable portfolio of potential recruits – and should have already checked their references, which is a crucial step in your hiring decision.

- *Executive search firms.* Also known as headhunters, are more appropriate for senior appointments. You can expect to pay a substantial fee for a successful hire.

- *Your organisation's website.* Your website is an obvious – even expected – recruitment channel. You should ensure all your open positions are posted on it. This

Make sure people want to work for you!

Whatever the medium for your recruitment communication, you should never assume that your organisation is in the driving seat because it's you that has the job(s). There is always keen competition for the better recruits. Recruitment will be a lot easier if it you can project an image that makes people come to you. Your organisation can do this strategically. But you, too, can help to create an attractive target for your potential recruits by following some basic ground rules when you publish recruiting notices. In particular, you should consider the following:

- Include something unique about your organisation
- Present an appealing and accurate representation of your organisation
- Use current employee endorsements
- Declare what education and training will be given, if applicable
- Be clear any required education and training
- Include required previous job experience, if applicable
- Don't over-specify – if a skill is not essential, don't ask for it
- Don't run foul of the law (see Panel on page 82, *Don't discriminate!*)

channel has the added advantage that people who use it is likely to be both well-informed and realistically-motivated. In effect, they will have pre-screened themselves, as long as you have published an appropriate amount of detail about your organisation and the jobs available.

- *Want ads.* Want ads are a traditional way of getting your message to a great number of potential recruits. The obvious channels for want ads are the various trade, industry and railway publications printed both weekly and monthly.
- *Employment websites.* The Internet now contains a great number of third-party sites that carry job postings, want ads and resumés of prospective recruits. A good way to find these sites is through Internet search engines, such as Google™.

How can you encourage recruits to find you?

One of the rail freight companies currently franchised to operate in the UK hardly ever needs to recruit drivers. The drivers find the company. They hear about the modern, innovative working practices the company offers through word of mouth. They check things out by visiting the company's website and they call.

There are several ways in which organisations can do a lot strategically for their recruitment prospects. The important thing is to promote a positive image for the organisation that has high visibility – both inside and outside the organisation – with initiatives such as the following (see Panel, *Make sure people want to work for you!*):

- *Provide a working environment that employees value highly* – the word will spread. This may include implementing modern working practices, schedules and management structures (like the rail freight company), participation in best practice staff development and training programmes such as the Government's Investors in People programme, or operating a caféteria-style benefits programme (so that employees can select the package of benefits that best suits them).
- *Get involved in community events and programmes.* Local communities – and sometimes, not so local ones – respond well to organisations that spend resources on helping them to address some of the problems they face. This can represent a good investment – especially if it is combined with an open-door recruitment policy in which people are welcomed to find out more about employment prospects.
- *Sponsor work-study programmes* and create good relationships with schools careers officers. These sorts of initiative spread the word very effectively, leading to natural employment opportunities for school leavers – leading in turn to positive attitudes amongst the parents of those school leavers, and so on.
- *Open up your gates* for classroom visits and possibly Public Open Days for a 'behind the scenes' look. This will be more appropriate for some companies than others (eg those with engine yards, control rooms and signal boxes etc). While there are always health,

'An organisation's ability to recruit the right people in the right numbers at the right time is **intimately connected** to its strategic and economic decision making.'

safety and security matters to consider, it is the case that the railways hold a fascination for many people. Using this fascination to build rapport with a large community can produce significant visibility.

How many people is enough?

This is not just an economic question, but one of safety as well. An organisation needs to be sure that it can meet the demands of its customers in a way that keeps it profitable. But it also needs to be confident that it can meet the demands of severely degraded or emergency conditions and so fulfil its safety responsibilities.

The question of how many is enough is easier to answer in some areas of the railway industry than others. Where there is a clear staffing requirement (eg a train timetable, a signal box with a specific number of panels or a depot with a specific number of service bays) and an agreed *shift work* pattern (page 128), it is relatively straightforward to work out how many people are needed to make the system work. On the face of it, the impact on recruiting of complicating factors, such as sickness rates, holiday entitlements, train failure rates and servicing schedules are also relatively easy to calculate.

Difficulty for recruiters can, however, start to occur when some of these 'fixed' assumptions turn out to be not so fixed. For example, it is tempting for a TOC's accountants to re-think the maintenance regime for its train fleet, and cut out one of the major services by increasing the amount of maintenance work done during minor services. While this will save significant amounts of rolling stock downtime during the major service, it means that the number, level – and therefore cost – of fitter

How can you tell if your organisation is the wrong size?

There are several things you can do to establish whether your organisation is the wrong size:

- *Benchmark staffing levels*. On paper divide all your staff into two groups – those who actually earn the revenue for your organisation and those who are employed to support the revenue earners. For both groups, add up all the weekly hours, including their typical overtime, and divide by 40 to calculate the number of full-time staff members in each group. Divide the support group number by the revenue group number to calculate the number of support staff you employ per revenue earner. Now compare that number with other organisations like yours, including those considered to be 'best performers. You may find that the best-performing organisations have higher support staff-to-revenue ratios and typically spend more on support staff. But support staff costs may be a smaller percentage of total revenue, because the best performing organisations bring in more income.
- *Track productivity*. Keep tabs on a few staff for a few days to see how many tasks they perform, then compare those figures to the norms elsewhere. But don't use this information as the basis of hiring/firing decisions – it would be very premature. Instead, use the data to build organisational snapshots that help you spot problems. If your organisation's productivity seems low, try to find out why. Perhaps existing or new staff members need more or different training. Or maybe your computer system is not working properly. Or perhaps a working practice has not kept up with recent changes. You might find that staff members are being pulled away to do other tasks, as in the case of a station despatcher who is needed elsewhere on the station.
- *Look for signs of 'wrongsizing'*. If you have too few staff members, you are probably paying a lot of overtime, which affects profits and burns out staff. Another classic sign of trouble is that staff can't stay ahead of train movements or maintenance schedules. Even organisations that have enough staff can often do a better job with staff scheduling. Do you never have enough station staff or fitters during peak times, but find staff standing around at other times of the day? In that case, adjust staff schedules and shift patterns to better match demand, or hire part-timers to get the coverage you need.
- *Simplify your workflow*. Staffing needs are influenced by how complex you make your organisational rules and procedures. While care must be taken to ensure that safety is not compromised, it is sometimes the case that rules are put in place more to cover the organisation than to facilitate its work – see *Why do people break rules?* (page 12) Create a flow chart for each staff position or department, which shows the steps needed to accomplish daily tasks. Identify steps that create barriers or do not add value, and look for simplifications.
- *Audit staff activities*. If your most experienced staff spend their time doing things below their skill levels, you're not taking advantage of their expertise – and they are getting de-motivated.

Adapted from McGuire (2002), reproduced with permission from ACP Online.

skills must be greater for minor services. Simultaneously, work will be taken away from the TOC's maintenance contractor, who has arranged their business so that they can perform a certain frequency of major services. If this demand is removed, the contractor capability will probably vanish with it. In a case such as this, changing an assumption will mean that the recruiters in both the TOC and the contractor will have provided the wrong numbers of people with the wrong type of skills at the wrong times. And this will have major consequences for both organisations – in terms of staff *morale* (page 117), economics and future possibilities.

It is important to understand how numbers and quality of staff affect, and are affected by, decisions elsewhere in the organisation. A general technique for doing this is the influence diagram (see *cognitive mapping* in *Part 3, Techniques*). Based on the premise that things are in the end connected to everything else, the influence diagram is a simple but powerful means to track the knock-on effects of decisions as they ripple through an organisation.

Research has also revealed indicators that allow an organisation to detect when its recruiters are getting it wrong – or perhaps not being allowed to get it right (eg by their finance department or company strategists). As it turns out, 'rightsizing' an organisation may lead to *more* staff (and therefore more operating costs) but ultimately more profit and more safety – through less staff turnover, less disruption and better capacity to deal with degraded or abnormal working (see Panel on page 86, *How can you tell if your organisation is the wrong size?*)

'The **average cost** of replacing an employee is between 1 and 2.5 times the employee's annual salary plus benefits.'
The **Gartner** Group

Retention

Why is retention important?

Losing people is expensive. That said, retention is actually something of a bidirectional line. It is an essentially desirable goal – since the *recruitment* (page 84) and *selection* (page 79) processes are expensive and divert organisational resources from earning revenue. In addition, the hiatus that can be caused while the organisation and new staff adapt to each other can be very disruptive to overall productivity (see *supervision and appraisal* on page 68). However, staff turnover is also an essential part of the process by which organisations renew themselves with different thinking and 'new blood'.

The ideal situation is one in which staff only ever leave an organisation for positive reasons – and the organisation's strategic recruitment plans allow for this. Such plans may even deliberately allow for personnel swaps with other organisations or industries, and for sabbaticals, in recognition that key staff will need to be developed in ways that single organisations cannot provide. Arrangements like these are mutually beneficial and help to assure the recruitment of valuable people in the first place.

'**Listening** is the most cost-effective way to acknowledge people. Being heard **builds self-esteem**, and employees with high self-esteem feel trusted and valued.'
Mike **Flaherty**

How do you keep the right people?

For most situations, the keys to employee satisfaction and retention hinge on:

- how valued they feel
- how challenged they are
- what opportunities they have for growth and advancement.

Many of the strategies aimed at attracting prospective employees to an organisation in the first place will, of course, be effective in helping to retain them. This means that many of the strategies that are good for *recruitment* (page 84) will also support retention. These strategies will be complemented by an effective selection process that can pick the right people for the organisation's jobs and culture. Much of the best practice that you'll find in the section on *morale and motivation* (page 117) applies here.

The following best practice is particularly relevant to retention

- *Listen to your staff.* Flaherty (2002) says that "listening is the most cost-effective way to acknowledge people. Being heard builds self-esteem, and employees with high self-esteem feel trusted and valued". The main means by which you should listen is through your *supervision and appraisal* process (page 68). Best

practice here will result in an honest assessment of the 'fit' and potential of staff – as well as the identification of a development path that makes the most sense for both the individuals and the organisation. If individuals see that they have a long-term future, they are likely to stay around. And if they choose to go anyway, then it's a good idea to listen to them as they go out of the door – so, make sure you conduct an exit interview.

- *Train your staff*. Conducting regular *training needs analysis* (page 55) – usually as part of the *supervision and appraisal* process (page 68) and leading to organisational investment in staff *training* (page 55) – sends a powerful message to everyone about how much you value your staff. Investment in training is also a vital tool at other times. Organisations sometimes go through difficult times, which can lead to redundancies and re-organisation. It is likely that the employees you most care about and who escape a layoff won't sit around very long wondering if their jobs are safe. Scheduling training for them can provide much-needed reassurance at times like this.

  You should also consider how you can use the knowledge that your staff has already acquired for the benefit of others. People who have worked in your organisation for a number of years are experts. Make sure they are involved in the induction programme for new recruits. There may be other opportunities, too - eg on public open days (see *Recruitment* on page 84). Their knowledge will be useful and you will make them feel valued.

- *Offer incentives*. Employees are more committed when there is a financial reward at stake. Paying attention to this aspect of retention is an additional reason for a recruitment bounty reward (see *Recruitment* on page 84). If 'employee of the month' seems a little too brash for your organisational culture, it shouldn't take you too long to think of more appropriate staff loyalty schemes. For instance, you could arrange an incentive that adds up to an additional 10% of their base pay as a bonus. Of that 10%, 60% might be linked to individual performance; 30% to their team goals; and 10% to the entire organisation's performance.

  More informal, non-financial reward systems can also be very effective. Here, recognition is linked to personal desires such as time off, job sharing, flexitime, office space, special tasks, public acknowledgment, news releases, etc. The most important part of any informal reward/recognition system is that it is linked to organisational values and that it is seen to come directly from management.

- *Don't reward the wrong people*. Don't reward poor performance by giving overtime to someone who works too slowly. And don't penalise good performers. It may seem easier to make allowances for less efficient staff – while failing to extend the same flexibility to people whom you depend on to get things done. It's also tempting to keep piling projects onto high achievers, making them work much more than less productive colleagues. These are mistakes that will lead to you losing your best people and retaining your worst.

Further information on staffing

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understanding
human factors

Culture

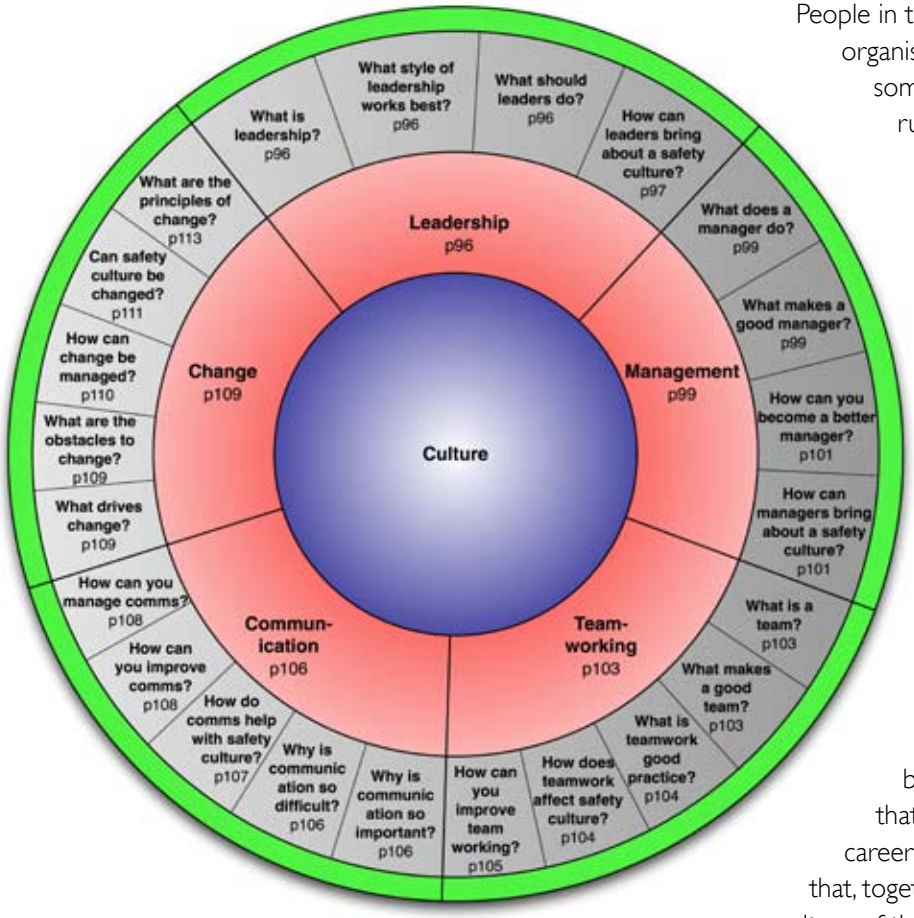
understanding
human factors

Culture

Culture

An organisation's culture is a complex, subtle phenomenon that influences every aspect of organisational life. This means that staff at every level have to be sensitive to their organisation's culture if they are to achieve today's goals and bring about change in readiness for tomorrow's challenges.

Focus on culture



The diagram on this page focuses on culture. It shows five sub-areas (in the middle red ring), and identifies the main human factors questions that this Guide answers (in the outer grey ring). At the end of each section, you will find a list of sources of further information. But first, we provide a concrete introduction to what can be a rather vague notion.

What is organisational culture?

People in the railway industry – as in all organisations – sometimes make mistakes and break rules (see *Why do people make mistakes?* on page 9) and *Why do people break rules?* on page 12), but most of the time they do what is expected of them. This is partly, of course, because they want to get paid and because, in safety critical areas of work, the Rule Book defines in considerable detail what must be done. However, for much of the time, people do not work with either their pay or the Rule Book consciously in mind. Instead, they work in response to a set of shared goals, values, beliefs, expectations and so on, that they have acquired during their career in the railway industry. It is these that, together, comprise the organisational culture of the railway industry as a whole.

Of course, the situation is complicated by the fact that different companies and different occupational groups also have their own unique culture.

Usually people do not talk about the values, beliefs, and so on that they share with other people working on the railways. But the fact that they are shared means that staff can usually work together without major difficulties, even when they don't really know each other. It is only when somebody starts acting in accordance with, say, different values or beliefs, that you may become aware of what you normally take for granted.

How do you recognise what the culture is?

In order to 'read' your organisation's culture, you need to be able to decipher what messages are being sent at each of a number of levels – namely:

- how things and people appear
- what people say they think and believe
- what people really think and believe.

Based on: Schein (1999)

How things and people appear. These include not only all the physical things – such as architecture, room layout and decoration, computers, car parks, reception areas and messrooms – but also things to do with the people, such as dress code, uniforms and general tidiness of appearance. – as well as the way they behave. They also include certain jobs that say something about the kind of organisation it is – such as receptionists, security guards and car park attendants – and working practices. These cover what people do and how they do what they do. Are they, for example, brisk and business-like? Do they

appear bored and slow or even reluctant about their jobs? Are they quiet or chatty? Do they talk about the weekend's football or only about work?

What people say they think and believe. There is often a mismatch between an organisation's stated values and the values reflected in what it does. For example, an organisation may state that it values good working conditions for its staff. But in reality it may have dingy messrooms, dirty washrooms, old and poorly maintained company vehicles, and so on.

'Culture is the meaning people share for the things they can see, the values they have and the goals they pursue. Culture is a **two-way track**: it emerges from the things people share ... and it allows people to make sense of what is shared.'

What people really think and believe. These are basic assumptions which are rarely, if ever, spoken, about the way the world really is. They are held about questions concerning the nature of reality, business and work, people and much else. For example, is the world of work a harsh, cut-throat competitive environment in which only the strong will survive? Or is work best seen as a cooperative enterprise in which everyone must work together? Are people basically lazy and can they only be made to work in a regime of close monitoring coupled with tightly defined systems of incentives and punishments? Or do most people actually want to do a good job, and just need the right resources, direction and encouragement?

The assumptions widely held within an organisation about the answers to these and many other questions will ultimately determine how decisions are made, who gets recruited and promoted, how resources are allocated, how staff are treated, and how customers, suppliers and competitors are viewed and dealt with. In short, they will determine how the whole organisation functions.

Because organisational culture is all-pervasive, we could consider any of the topics covered in this Guide in relation to it. Here, however, we concentrate on five areas where culture is more of a foreground issue.

Leadership
Leaders have an important role in forming the organisational culture. While most organisations in the railway industry have formally designated leaders, in practice every member of staff is probably called upon to exercise leadership at some time or another. This means that everyone, regardless of their formal position, needs to have some understanding of how to be a leader.

Management
Being a manager is not the same thing as being a leader. But managers are obviously responsible for ensuring that the necessary things get done in the organisation, and that they get done properly. In this section we will look at some key cultural aspects of management.

Teamworking
A central part of any organisation's culture is how people relate to, and work with, each other. How an organisation uses teams and how these teams work are key cultural issues.

Communication
People in almost every organisation report communication as being a major problem. What is communicated, by whom, to whom, how and when, are important aspects of the culture. But communication is not only a manifestation of the culture; it is also the main mechanism for spreading and institutionalising the culture.

Change
Any organisational change is only true change if it lasts and transforms the nature of the organisation in some way – or, in other words, involves a change in culture. This is immensely difficult and takes a very long time.

We also pay particular attention to *safety culture*. It is important to know how this manifests itself in your organisation, how it can be managed and, where necessary, changed.

Why do you need to be concerned with your organisation's culture?

A good culture plays an important role in organisational success. When there is a good culture, people have little uncertainty: they know what is expected of them, what they should do, and what they can expect of others. Avoiding uncertainty means avoiding confusion and delay, two of the key ingredients in poor performance and poor safety.

Having awareness and knowledge of your organisation's culture means that you can work with it rather than against it. The values and beliefs that form the bedrock of culture have evolved because they work – at least most of the time. They can be an important guide to action when there are no rules or procedures to direct you, or in novel situations when the existing rules and procedures no longer apply. Those around you are more likely to act on any decisions you make if these decisions are consistent with their expectations.

Having knowledge of your organisation's culture – both its strengths and limits – will also play an essential role in helping you to bring about change. It's important to bear in mind that true organisational change almost always entails some change in culture.

What is safety culture?

In this Guide we pay particular attention to safety culture. Safety culture is the set of values and priorities placed on all aspects of safety by everyone at every level of an organisation. Although the concept of safety culture was widely used in other industrial sectors and was already known within the rail industry, this idea has been given much greater prominence since Lord Cullen addressed safety culture on the railways so forcefully in his inquiry into the Ladbroke Grove accident. Since then, RSSB has produced a number of reports addressing various aspects of safety culture and the closely related concept of safety climate (see Panel, *Definitions*).

The interest in safety culture comes from the realisation that no matter how good the engineering or technological measures to ensure safety on the railways, these will not be effective if safety is not a key value that exists at all levels of railway companies.

Each of the five areas of culture that we consider in the following pages – leadership, management, teamworking, communication and change – has something important to say about safety culture.

Definitions

Safety culture

A combination of values, beliefs, vision, purpose, policies, objectives and leadership styles that impact on an organisation's safety. A positive safety culture is characterised by awareness, assessment and action on safety matters in all these areas, and is supported by an open communications style throughout the whole organisation.

Safety climate

A snapshot of the surface features of the safety culture resulting from the workforce's attitudes and perceptions at a given point in time. Sustainable change is achieved through continually looking beneath the surface and questioning assumptions.

It is helpful to think of *culture* and *climate* as the invisible and visible portions of an iceberg. Safety climate, the visible part of safety culture, only represents the tip of the iceberg. The actual problems of culture might lie hidden deep beneath the surface. Rather than just treating the visible symptoms, real improvements can only be made by changing the underlying culture.

Best practice is to develop excellent communications and teamworking, and early warning systems, eg near miss reporting within your organisation.

Adapted from: Rail Safety, Safety Culture Bulletin 1, Jan 2002

> '**Safety culture** is the set of values and priorities placed on all aspects of safety by everyone at every level of an organisation.'

A wide range of tools and methods are available for assessing safety culture. RSSB has developed a web-based Safety Culture Toolkit that will allow rail companies to measure their own safety culture, and determine what actions they could take without the need for extensive external support. The Toolkit facilitates the data management, making it easier to establish a single industry view. It also enables the benchmarking of individual companies' cultures. See *Further information*.

The Panel on page 94, *How should you assess safety culture?*, explains how you should approach the assessment of safety culture in your organisation. (Note that all safety assessment processes should be designed in accordance with HS(G)65 – see *Further information*.)

But what should you be assessing?

HMRI have recently published the safety culture inspection toolkit. Although designed for use by HMRI inspectors, the approach taken is of much wider value. The toolkit is based around the assessment of five safety culture indicators (see Panel, *What should you assess?*).

How should you assess safety culture?

Plan the assessment
Planning is everything, and communicating the plan and providing feedback are equally important.

Recognise the importance of involvement
Involve staff throughout the whole assessment process. This will help them to buy-in to the outcomes from the assessment.

Ensure effective communications
Communicate management's commitment to the process so that the staff have confidence in the importance of the process and that something will be done with the results. Provide plenty of information on the reasons for doing the assessment and how the results will be used.

Provide feedback
Do this as soon as possible after completion of the assessment so that staff see the momentum is being maintained. If you are providing feedback following introduction of improvement actions or other changes, make clear what the changes have been at the beginning of the feedback.

Analyse results
Use a form of analysis that will produce meaningful results to enable tracking of future changes and further feedback to staff.
Review and discuss the issues raised and request clarifications from each group that has taken part in the assessment.

Create an effective action plan
The action plan should start by addressing the most significant or critical development needs. Plan re-assessments as part of the action plan, but do not be tempted to reassess for between 18 and 24 months to allow changes to take effect.
Source: RSSB (2005)

What should you assess?

Leadership
Management must take explicit and continuous steps to ensure that goals, targets and issues are made clear, and are known to all personnel. An indicator of good safety leadership is that safety is always prioritised over performance.

Two-way communication
There are multiple channels for the discussion of safety matters, concerns and goals between and within all levels of the organisation. The flow of information should be in an upwards as well as a downwards direction.

Employee involvement
Personnel from all levels within the organisation should be involved in decision making, safety planning, and providing ideas for improvement. Employee participation and feedback should be actively sought.

Learning culture
Steps should be taken to monitor known problems, identify new ones, detect trends over time and develop effective preventative measures. Efforts must be made to ensure that lessons are learned from incidents, including the wider application to other situations. Intervention measures must be introduced for all situations.

Attitude towards blame
Developing a just culture is the acceptance that the ultimate responsibility for incidents lies with the organisation, and investigations must therefore take full account of multi-causality. The purpose of investigations is not to take retribution or assign blame, but to learn from incidents.
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The content of this panel is highly consistent with the requirements for High Reliability Organisations (HROs).

Research has discovered that HROs have a safety culture that is different from other organisations in a number of important ways. The result is that they have far fewer incidents than might be expected, given the dangerous nature of their operations (see Panel on page 95, *How does a high reliability organisation differ from other organisations?)*

Further information

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How does a high reliability organisation differ from other organisations?

1. Preoccupation with failures

High reliability organisations (HROs) treat any failure, whether large or (as is usually the case) small, as a symptom that something is wrong with the system – something that could have severe consequences if it were to coincide with others at one awful moment. HROs encourage the reporting of errors and near-misses and set out to learn from them. They are wary of what success can bring – things like complacency, the temptation to reduce safety margins, and the drift into automatic processing where people stop thinking about what they are doing.

2. Reluctance to accept simplification

HROs take deliberate steps to avoid the process of simplification that happens when managers focus on a handful of key issues and performance indicators. HROs know that the world they face is complex, unstable, unknowable and unpredictable. As a result, they have learned to value people who operate in several different areas and can develop a wider perspective. They have also learned to be sceptical of received wisdom and they pay attention to differences of opinion. It is in these differences that new organisational problems can be detected – but only if the organisation is listening.

3. Sensitivity to operations

HROs are very sensitive to operations – because they expect the unexpected – and are aware of 'latent failures'. These are loopholes in the system's defences, barriers and safeguards, such as imperfections in supervision and the reporting of defects, and the probable incompleteness of safety procedures, safety training, briefings, certification, and hazard identification. Many latent failures are discovered only after an accident has occurred, but this need not be the case. We can spot the deficiencies in normal operations that may lead to unexpected events by frequently assessing the overall safety health of an organisation.

'HROs push decision making down – and around. People with the **most expertise**, regardless of their seniority, make the decisions on the front line.'

4. Commitment to resilience

No system is perfect. HROs know this as well as anyone, and so develop the ability to detect, contain and bounce back from the inevitable errors. Resilience is a combination of keeping errors small and improvising ways of keeping the system functioning. Both require deep knowledge of the technology, the system, one's co-workers, one's self, and the raw materials. HROs put a premium on experts: well-trained personnel with deep experience and recovery skills. Such experts imagine worst-case conditions and mentally practise their own equivalent of fire drills.

5. Deference to expertise

HROs value not just expertise, but a diversity of expertise. This helps them not only to notice more in complex environments, but also to do more with the complexities they spot. Rigid hierarchies are particularly vulnerable to error. Errors at higher levels tend to pick up and combine with errors at lower levels, making the resulting problem bigger, harder to understand, and more likely to escalate. To prevent this deadly scenario, HROs push decision making down – and around. People with the most expertise, regardless of their rank, make the decisions on the front line. This is not simply a case of deferring to the person with the 'most experience'. Experience by itself is no guarantee of expertise, since all too often people have the same experience over and over again and do little to broaden it.

'HROs expect the unexpected – they have far **fewer accidents** than you might expect in complex and dangerous environments.'

One of the best examples of an effective HRO is an aircraft carrier, where there are far fewer accidents than you might expect in such a complex and dangerous environment. During flight operations, when there is a need for accurate decisions, they tend to be made by the nearest expert – whatever their rank.

Adapted from Weick & Sutcliffe (2001), reproduced with permission.

Leadership

What is leadership?

Leadership has probably received more attention from writers on management and organisations than any other topic. Over its long history the concept of 'leadership' has changed dramatically. Originally leaders were seen as 'born, not made'. Leadership was something that you had (probably as a result of being born into a particular strata of society) or you did not. Nowadays there is much greater emphasis on leadership as a set of skills that most people can learn. It is also now a common expectation that leadership can be exercised not just at the top of the organisation but at every level. What is important is whether the right person takes on the leadership function to meet the demands of the particular situation that has arisen.

There are many hundreds of different definitions of leadership. Taken literally the term 'leadership' implies 'getting others to follow'. You can think of leadership as a relationship through which one person influences the behaviour or actions of other people. This leads to the question of why some people are better able to influence others. Some leaders rely on their formal position in the organisation, their ability to reward and punish others. Other leaders gain authority through their expertise. They are recognised as having knowledge that particularly fits them to take on the leadership role in that situation. Still other leaders rely on the force of their personality, their ability to impose their views on others. Leaders need to display initiative and self-confidence. A key quality is the 'helicopter factor': the ability to rise above the details of a particular situation and see it in relation to the bigger picture.

Managers and leaders: what's the difference?

In their book *Leaders* Warren Bennis and Burt Nanus note that many organisations are 'over-managed and under-led'. They stress that management and leadership are both important – but different.

The manager is concerned with accomplishment, taking charge and having responsibility.

The leader is trying to influence and guide to bring about some desired future state.

Bennis and Nanus say managers do things right, leaders do the right thing..

Summarised from: Bennis & Nanus (1985)

Leadership entails a contract between the leader and followers. Followers are willing to let a leader have power as long as the leader continues to deliver. If the leader fails to deliver, sooner or later the followers will withdraw their support. This could seriously affect the organisation in terms of productivity, turnover and even safety.

'You can be appointed a manager but you are **not a leader** until your appointment is ratified in the hearts and minds of those who work for you.' John **Adair**,, leadership development expert

What style of leadership works best?

Leaders display a great variety of styles. For example, in decision making some leaders are entirely dictatorial, simply telling others what to do. Some consult the wider team before making the decision themselves. Some delegate decisions to trusted subordinates. Others seek the participation of all the team or staff.

Leaders also vary in terms of where they focus their efforts. Some concentrate single-mindedly on the task to be done, expecting staff to do what is necessary to achieve the task goals. Other leaders devote most of their efforts to getting the best out of the other people, trusting that they will get the job done given the right *motivation* (page 117) and direction.

As a result of extensive research, the most widely accepted current view is that there is no one best style. It all depends on a number of factors, including:

- the position and nature of the leader
- the nature and diversity of the subordinates
- the task to be done
- the organisational norms
- the wider situation.

What should leaders do?

Leaders are oriented towards the future. Perhaps the key thing that they do is formulate a vision, a picture of how things could be. This vision needs to be capable of exciting and motivating others to bring it into reality. Closely connected with this, leaders communicate, tirelessly articulating the vision in ways that can be understood and generate enthusiasm. Communication is not only a matter of what the leader says but also what they do. The successful leader should act as a role model, exemplifying the values of the organisation. Leaders must

be able to build trust – and not only trust in themselves as leaders (largely through ensuring their words and deeds are consistent). They also need to build the necessary trust and confidence that the workforce will need to do what is necessary to make the vision come about.

Leaders must also strive after self-knowledge. They know their strengths and how to exploit them, and also know their weaknesses and how to compensate for them. Closely connected with self-knowledge is something called *emotional intelligence*, which means being able to recognise their own feelings and those of others, and being able to manage their emotions well.

How can leaders bring about a safety culture?

Nowhere is the role of leadership more important than in developing an organisation's safety culture. Developing and maintaining a safety culture require leadership to be exercised at all levels throughout the organisation. However, senior management have a key role here as they can formulate the vision (eg what kind of organisation do we want to be?). They can also send critical messages both through the way they allocate resources and the example they set. Particularly important is how much of their own time they are seen to devote to safety matters.

The HMRI safety culture inspection toolkit includes two assessment criteria specifically relating to leadership. These are the first two items in the list below. They are followed by two criteria relating to attitude to blame, since this attitude can largely be seen as a leadership issue.

- *Performance vs safety priority.* Safety should always be prioritised as more important than operational performance
- *Safety management leadership*. All management should be committed to safety and should demonstrate this by conducting regular safety tours in all operational areas. Safety tours should provide the opportunity for all staff to discuss safety issues with management.
- *Awareness and adherence to personal accountabilities.* Personnel should be aware of, understand and adhere to personal accountabilities.
- *Presence of a just culture*. Retribution and blame should not be seen as the purpose of investigations when things go wrong. Investigation procedures should clearly distinguish between different degrees of culpability (eg blameless, system-induced or negligence induced errors).

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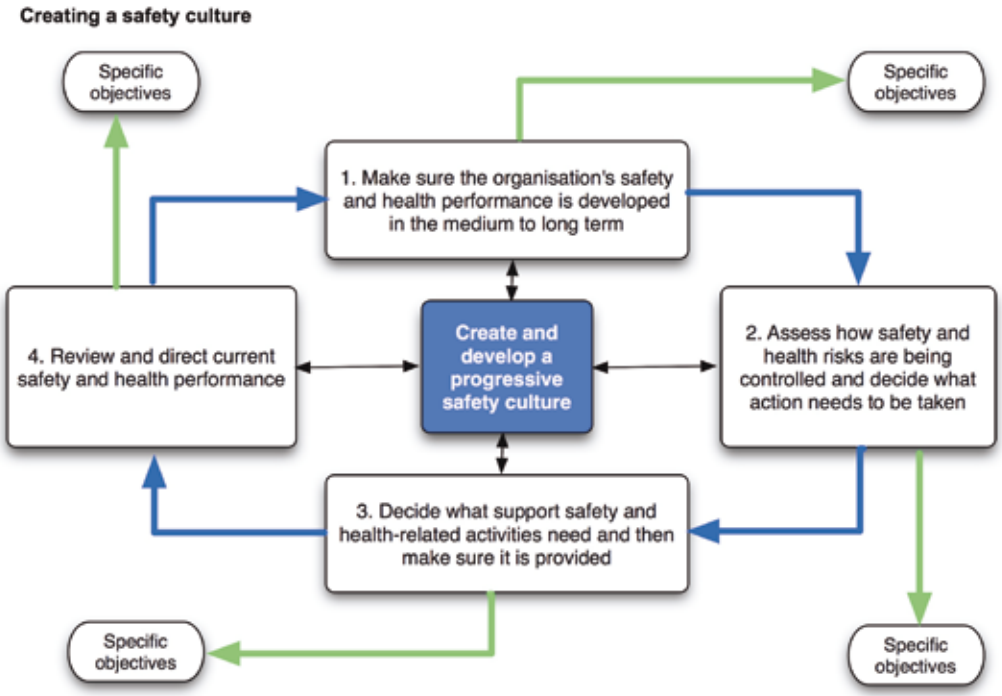
All of these criteria concern the spoken and unspoken messages transmitted by organisational leaders to the wider workforce. It is important here that leaders are seen to 'walk the talk' – to do what they say. There will be times when hard decisions have to be made between actions that are revenue earning but potentially risky, and actions that will cost money but lead to improved safety. One such decision commonly facing railway leaders is whether to take a train out of service because of a defect that may compromise safety. Another example is whether to ask drivers to work longer than the recommended 12-hour shift when there is a shortage of drivers. And having made their decision, are they willing to accept responsibility for their actions when things do go wrong?



Source: Railway Safety (2003)

Good and poor practice in safety leadership		
Leadership area	**Good practice**	**Poor practice**
Business case	Awareness that good H & S management can generate business benefits	H & S seen as a source of 'cost'
Accountability	Senior managers directly accountable to Board for poor H & S performance	H & S seen as a functional responsibility
	Senior managers have bonus-dependent personal H & S objectives	No H & S objectives set for managers
	Director with nominated responsibility for H & S	No responsible Director
	Senior managers involved in all accident investigations	No involvement of senior managers
Behaviour	Senior managers lead safety briefings and regularly include H & S matters in other briefings and presentations	H & S briefings entirely separate and led by functional specialists
	Senior managers all commit to receiving regularly-updated H & S training	No senior manager H & S training
	Senior managers participate in safety audits and raise H & S questions during routine site visits	H & S matters not raised by senior managers and they do not participate in audits
	Senior managers follow H & S procedures and practices at all times	Senior managers ignore H & S rules
Integration	H & S is a key factor in contractor selection and monitoring	Contractor H & S performance not considered a business responsibility
	Spending time within H & S functional role is a key part of career development	H & S function seen as a backwater (eg for those nearing retirement)
	H & S policy fully integrated into business processes (eg product, plant design)	H & S matters not part of business process
Monitoring and measurement	Key H & S indicators set, monitored and reported regularly to Board	No regular monitoring or reporting
	Processes in place to measure the full costs of H & S failures (eg production losses, down time)	No data available on costs of failures
	H & S matters are a regular item for discussion at Board meetings	No discussion of H & S at Board level
	Senior management actively seek staff feedback on H & S issues	Management processes do not exist for obtaining feedback from staff
Prioritisation	Required rate of return for H & S investments is lower than for other investments	H & S investments must meet standard rate of return
	H & S performance and investment maintained at times of commercial uncertainty (eg closure, disposals)	H & S performance falls and investment is suspended during commercial uncertainty
Learning	Commitment to ongoing training of staff and contractors at all levels with mechanisms for sharing learning	Training is limited to legal requirements. No formal mechanism for sharing learning
Adapted from: Ernst & Young's work for HSE (2000), © Crown copyright material is reproduced with the permission of the Controller of HMSO and Queen's Printer for Scotland.		

The choices that leaders make are soon widely known throughout the organisation and will indicate whether safety is an issue taken very seriously or whether leaders just pay 'lip service' to the importance of safety.
The diagram on page 97, *Creating a safety culture*, shows how creating and developing a safety culture involves a range of safety management activities. This diagram, from the Railway Safety Good Practice Guide (2003), illustrates that although leadership is not the same as management, in reality the two areas are closely inter-connected. You can find more about these safety management activities in the section on *Management* on page 99. Central to the role of leadership in developing safety management is the attention senior managers pay to safety. The Panel, *Good and poor practice in safety leadership*, defines a range

of good and poor practices that will all be seen by the workforce as indicating the value that senior management places on safety.

Further information on leadership in safety culture

1 Adair J. (2002) Effective Leadership, Pan

2 Bennis W. & Nanus B. (1985) Leaders: Strategies for Taking Charge, Harper Collins

3 Ernst & Young (2000) Development of a leadership resource pack, Offshore Technology Report 2000/098

4 Goleman D. (1998) Working with Emotional Intelligence, Bloomsbury

5 HSE (2005) Development and validation of the HMRI safety culture inspection toolkit, RR365 www.hse.gov.uk/research/rrhtm/rr365.htm (as of May 2008)

6 Schein E. (1992) Organizational culture and leadership, 2nd Edition, Jossey Bass

7 Roughton J. & Mercurio J. (2002) Developing an Effective Safety Culture: A Leadership Approach, Butterworth-Heinemann

Management

What does a manager do?

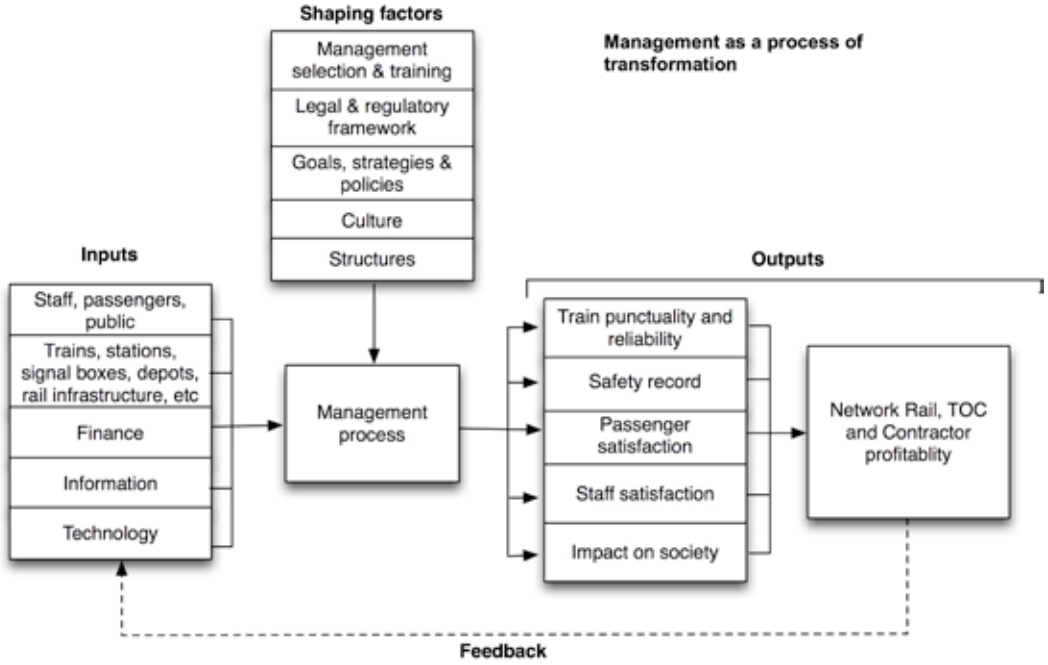
Running a railway involves:

- thousands of staff carrying out many different occupations
- countless physical and material assets in the form of trains, rolling stock, infrastructure, stations, signal boxes, and so forth
- very large financial resources
- vast amounts of information.

The task of a manager on the railways is to plan, allocate, coordinate, integrate and monitor the use of all these resources to provide a safe and reliable train service to many thousands of passengers. Although there are exceptions, most managers achieve their results through other people. The manager does not (as a general rule) drive the train, sell the tickets, set the routes, repair the track, and so on. But they ensure that all these activities happen when they should, in the way that they should, and at an economic cost. Management can be seen as the process of transforming a variety of inputs into a range of outputs under the influence of a number of shaping factors (see diagram, *Management as a process of transformation*).

What makes a good manager?

Managers take on many roles. They allocate resources, deal with conflicts and disturbances, provide liaison with the rest of the organisation, represent the organisation in the wider world, and much else besides. A manager may sometimes have demonstrate *leadership* (page 96).



Culture

To carry out all the varied tasks of a manager and to fill all the diverse managerial roles, the successful manager must possess many qualities.

First, they must have the right situational knowledge. This means knowledge of what has happened, is happening and is going to happen. This knowledge of the situation must be underpinned by the right professional knowledge (eg rules, procedures, working practices). Second, they must have the right management skills. This means being able to analyse the situation, to solve messy problems, to make sound judgements, and to take timely and correct decisions. It also means being able to manage and influence other people. Lastly the manager needs the right personal qualities. They must be mentally and emotionally resilient, must be able to think on their feet and come up with creative ideas when necessary. Importantly the manager must be able to reflect on their own performance and to learn from experience.

The central tasks in which nearly all managers have to be competent are defined in a management standards framework. These standards are the basis for many management qualifications, notably the NVQ qualifications in management at three levels:

- Level 3 – Supervisory or First Line Management
- Level 4 – Middle Management
- Level 5 – Senior Management.

The standards have recently been overhauled for the Government by the Management Standards Centre. Since Sep 05, new courses have been available based on the results – Panel, *What must a good manager be able to do?*

What must a good manager be able to do?
The new management standards

Training units	Elements
A Manage self and personal skills	• A1 Manage your own resources • A2 Manage your own resources and professional development • A3 Develop your personal networks
B Provide direction	• B1 Develop and implement operational plans for your area of responsibility • B2 Map the environment in which your organisation operates • B3 Develop a strategic business plan for your organisation • B4 Put the strategic plan into operation • B5 Provide leadership for your team • B6 Provide leadership in your area of responsibility • B7 Provide leadership for your organisation • B8 Ensure compliance with legal, regulatory, ethical and social requirements • B9 Develop the culture of your organisation • B10 Manage risk • B11 Promote equality of opportunity and diversity in your area of responsibility • B12 Promote equality of opportunity and diversity in your organisation
C Facilitate change	• C1 Encourage innovation in your team • C2 Encourage innovation in your area of responsibility • C3 Encourage innovation in your organisation • C4 Lead change • C5 Plan change • C6 Implement change

What must a good manager be able to do?
The new management standards

Training units	Elements
D Work with people	• D1 Develop productive working relationships with colleagues • D2 Develop productive working relationships with colleagues and stakeholders • D3 Recruit, select and keep colleagues • D4 Plan the workforce • D5 Allocate and check work in your team • D6 Allocate and monitor the progress and quality of work in your area of responsibility • D7 Provide learning opportunities for colleagues
E Use resources	E1 Manage a budget E2 Manage finance for your area of responsibility E3 Obtain additional finance for the organisation E4 Promote the use of technology within your organisation E5 Ensure your own action reduces risks to health and safety E6 Ensure health and safety requirements are met in your areas of responsibility E7 Ensure an effective organisational approach to health and safety
F Achieve results	F1 Manage a project F2 Manage programme of complementary projects F3 Manage business processes F4 Develop and review a framework for marketing F5 Resolve customer service problems F6 Monitor customer service problems F7 Support customer service problems F8 Work with others to improve customer service F9 Build your organisation's understanding of its market and customers F10 Develop a customer focused organisation F11 Manage the achievement of customer satisfaction F12 Improve organisational performance

Source: Management Standards Centre (2005) reproduced with permission

Good practice for railway safety management	
Key objective	**Good practice**
Make sure that safety performance in your area of responsibility is developed and improved.	• Put strategies and policies for dealing with safety issues into practice. • Contribute to a positive safety climate. • Make sure that your team's performance is consistent with safety strategies and policies. • Make sure that your team learns from its experiences
Assess and manage safety risks under your control.	• Assess how safety risks will affect the team. • Assess people's behaviour and attitudes to see how they affect safety risks. • Make sure the actions you chose to control risks are suitable.
Make sure the necessary resources and support are provided to carry out work safely.	• Manage working groups effectively. • Make sure staff and contractors receive the training and development they need. • Motivate staff and contractors to work safely. • Make sure any necessary resources are available.
Manage safety in day-to-day activities.	• Make sure that day-to-day activities are carried out safely. • Put safety measures into practice. • Make sure that your team meets current safety targets. • Make sure there is a quick and effective response to problems related to safety.
Source: Railway Safety (2003)	

How can you become a better manager?

Management is a huge topic and it is beyond the scope of this Guide to define best practice for all areas of management. However, it's important to note that underpinning all aspects of good management practice is management development. For the organisation this means formulating a policy and strategy for continuing management development and making available the resources necessary for them to be properly implemented. At the level of the individual manager, good practice entails regular review of performance, the setting of development objectives, and the pursuit of these objectives through both formal and informal means – see *supervision and appraisal* (page 68).

'Dealing with **small things** that go wrong is the best way to stop large things going wrong'

Good practice in safety management

On the railways, good practice in safety management begins with adherence to the general safety legislation, the Railway Group Standards and specific company standards. RSSB has defined both objectives and statements of good practice for reviewing and developing the safety performance of managers on the railways. They are listed in the Panel, *Good practice for railway safety management*. These objectives aid the development of the organisation's safety culture, as discussed in the section on *leadership* (page 96). RSSB also provides a companion publication covering the safety performance of senior management, as well as software tools to assist in the performance review process.

How can managers bring about a safety culture?

While it is the task of leaders to set the 'destination' and to lead the organisation to that point, it is the task of managers to use resources to achieve more specific organisational goals. While leaders spell out the grand vision of the organisation's safety culture, managers play a key part in reinforcing the message about safety culture through the plans they draw up, the ways they allocate resources, and the manner in which they respond to safety issues and incidents.

One of the less obvious ways that a manager can help develop a strong safety culture is through developing a learning culture (one of the HMRI safety culture inspection criteria – see Panel on page 94, *What should you assess?*). A learning culture is a necessary accompaniment to a safety culture. Without the ability to learn, especially to learn from things that go wrong, no organisation can achieve a high level of safety. Lord Cullen pointed out the need to learn from:

- previous accidents
- near misses
- the analysis of information regarding non-compliance
- analysis of behaviour leading to unsafe acts
- incidents in other related industries

Going back to our earlier discussion of High Reliability Organisations (HROs) (see Panel on page 95, *How does a high reliability organisation differ from other organisations?*), remember that the first characteristic of an HRO is a pre-occupation with failure. No incident where something

goes wrong is too insignificant to be observed, recorded, thought about and learned from. This may seem a very negative way to look at working life, but experience has shown that detecting and dealing with the small things that go wrong is the best way to stop large things going wrong.

This approach not only prevents problems escalating, but it also cuts down on the number of organisational 'holes' that might otherwise line up as part of an accident causality chain (see *Why do accidents happen?* page 18).

One of the tasks of a manager on the railways is to ensure that there are proper mechanisms set up and in use that support this learning process. Such a process must be founded on a system for gathering information on what goes wrong, as well as what goes right. The rail industry does have a national confidential incident reporting scheme (CIRAS), but there is likely to be a need for more local reporting initiatives too. In the event that these schemes are not designed to maintain confidentiality, remember that they will only work if there is a no-blame culture, as discussed in the section on *leadership*, page 96.

Similarly, the rail industry has well-established methods for conducting formal inquiries into incidents. However, these are designed for when something has gone sufficiently wrong for there to have been damage or injury, or at least a serious breach of the rules. An organisation with strong safety and learning cultures will also learn a great deal from much more minor events that were not in themselves serious but may point to potential areas of vulnerability.

But simply collecting information is not enough. It needs to be analysed in the right way, so that the right action can be taken. Plotting trends may be a good way of seeing that a situation is deteriorating, thus enabling timely action to be taken before a major incident arises. A good example here is provided by the RSSB's use of the methods of statistical significance testing to analyse monthly SPAD data. This is a powerful technique not only for obtaining an early warning of potential problems, but also for identifying conditions under which risks are especially high, and for assessing the impact of any remedial actions that may have been taken.

By encouraging staff participation in gathering and discussing information on incidents and concerns, even the most minor, and in showing that the analysis of this information leads to positive actions, you can foster a climate in which everyone takes safety seriously and acts accordingly.

Further information on management

Any bookshop can provide a huge range of books on various aspects of management. Many of these are rather gimmicky, offering instant solutions to all the problems of management. The first three of the following books are views of management by well-respected writers and the second three are good general accounts of management. The last item in the list is a short book that is an easy to read introduction to the methods of Statistical Process Control. Only the most basic knowledge of arithmetic is required.

1 Adair J. (2004) The John Adair Handbook of Management and Leadership, Thorogood

2 Armstrong M. & Stephens T. (2005) A Handbook of Management and Leadership, Kogan Page

3 Crainer S. & Dearlove D. (Eds), (2004) Financial Times Handbook of Management, Financial Times Prentice Hall

4 Drucker P. (1999) Practice of Management, Butterworth Heinemann

5 Handy C. (1999) Inside Organisations – 21 Ideas for Managers, Penguin

6 Management Standards Centre (2005) www.management-standards.org (as of May 2008)

7 Mullins L. (1999) Management and Organisational Behaviour, 5th Edition, Financial Times/Pitman Publishing

8 Railway Safety (2003) Good Practice Guides (2): Reviewing and developing the safety performance of managers

9 Schermerhorn J.R. Jr. (2005) Management, 8th Edition, John Wiley

10 Wheeler D.J. (1993) Understanding variation – The key to managing chaos. SPC Press, Knoxville, Tennessee

Teamworking

What is a team?

Performance and safety on the railways depend on many kinds of teamwork. Usually when we think of a team we think of something like a football team. Here, team members spend extended periods together, practising and working until their efforts can be smoothly coordinated to achieve the desired results. They know each other as individuals and ideally learn to trust each other. At the very least they know each other's strengths and weaknesses, and can take these into account when working together. Signallers working together in a large signal box or signalling centre, the staff of a major station, the crew on a long-distance express train, or an experienced gang of track workers are all examples of this kind of team.

'Teams on the railways may form for only a **few minutes** and its members may never meet each other…'

But there are other kinds of team that play a vital role in the safe and effective running of the railways and which do not have the conventional attributes of a team.

Consider two examples. The first is a signaller in their signal box and the driver of a train passing through this signaller's section. The second is the COSS (Controller of Site Safety) and the ECO (Electrical Control Office) when the COSS requires the electricity to be disconnected from the lines so that engineering work can take place. In both cases, the two interacting workers are not located in the same place. Indeed, they may never ever actually meet each other. All their work is via some form of communication channel (for example, Signal Post Telephone (SPT), Cab Secure Radio (CSR) or mobile phone). Furthermore, their working together does not last over an extended period of time. Its duration is probably measured in minutes. So unlike some of the other examples of teams on the railways, these are highly transient, two-person teams. They probably do not have any personal knowledge of each other. Nor can they practise their teamwork skills. Team building, which is discussed in the section on *supervision and appraisal* (page 68), cannot be used for these kinds of team. Nonetheless, you can think of these driver/signaller and COSS/ECO pairs as teams according to the definition given in the Panel, *Definitions*. These definitions do not assume that the team is either co-located or long-lasting.

Definitions

Team

A group of at least two people, in which each person depends on the work of the other(s) to achieve their own objectives.

Teamwork

How members of a team work responsively with each other to ensure that all the team's objectives are achieved.

What makes a good team?

Teamwork skills

What a good team needs first and foremost is for all its members to possess high-quality teamwork skills. Teamwork skills are different from 'taskwork' skills, which are those that enable a train driver, say, to drive their train, or a signaller to regulate train movements. These are usually well taught as part of a person's occupational training. But in addition, staff on the railways need to be able to work effectively with others. Research has identified what these key skills are. They include anticipation, cooperation, and challenging and backing up each other. However, it has also shown that these sorts of skills often do not form a significant part of formal training but are left to be picked up on the job.

Good organisational practice ensures that any members of staff on the railways, especially those involved in safety critical tasks, acquire these skills as part of their initial training. They should also have ample opportunities to practise and develop these skills throughout their career. Individuals whose job requires them to work briefly, but critically, with a range of other individuals over the working day need to be equipped with the fundamental skills that enable them to work effectively and immediately within teams that form and disband in a few minutes.

An organisational context for teamwork

As well as having reasonable expectations that other staff will possess a satisfactory level of the necessary teamwork skills, a good team needs a sound organisational context for teamwork. Having teamwork skills means that a person knows how to behave as a team member, but does not mean that they know what to do. Good teamwork is only possible when team members believe they

'Effective teamwork requires **both** team skills and a cooperative organisational context'

can rely – within limits – on what other members of staff will do in any given situation. Excessive uncertainty about what the other person may do is highly damaging to effective teamwork.

An important function of the Rule Book is to provide an industry-wide framework which dictates in many situations – but by no means all – what people should do. The Rule Book reduces much of the uncertainty when people are working together, but more is needed. This is where the organisation's culture comes in, for it determines many of the 'softer' aspects of how people work with each other (see *change* on page 109). The values, norms, customs and social practices that characterise the railway industry as a whole are key here. But there is a particular issue nowadays, for within the overall railway culture there are many company-specific sub-cultures. The existence of these sub-cultures can pose a risk to effective teamwork. It is the responsibility of leaders at both the industry and company levels to ensure that these sub-cultures all promote rather than impede teamwork.

What is teamwork good practice?

Good practice for teamwork exists at two levels. At one level, good practice defines what individual team members should do to be effective members of successful teams. But at a more fundamental level, good practice defines what companies or organisations should do to ensure that their staff are able to behave in accordance with individual good practice. Organisations need to create an environment in which teamwork can flourish. If they do, they can have a profound effect on the ability of team members to work with each other.

Good practice in teamworking

Good organisational practice	**Good team member practice**
Personnel in safety critical roles should be trained in how to carry out safety critical communications	Personnel should always communicate safety critical information to those who need to know and confirm the message has been received and correctly understood
All initial training for safety critical occupations should cover basic teamwork knowledge and skills	Personnel in safety critical roles should communicate at a time and in a manner that will be most helpful to the others and minimises the risks of misunderstandings
All safety critical personnel should have regular opportunities to practise teamwork skills, especially in abnormal or emergency situations	All personnel in safety critical roles should seek clarification of communications from others in the event of ambiguity or uncertainty
All personnel should have regular opportunities to spend time with other personnel with whom they perform safety critical functions, including time observing them at work	Personnel in safety critical roles should monitor others' situations and the demands they are facing
Competence in teamwork should form an element in all recruitment and assessment for personnel in safety critical roles	Personnel in safety critical roles should allow for the effect of one's actions on others in the choice and timing of the action
Personnel performing safety critical functions should be provided with an infrastructure that enables them to build and maintain shared awareness of each other and their working situations	Personnel in safety critical roles should challenge the decisions or actions of others that may be unsafe
Supervisors, shift managers, and others responsible for the work of teams performing safety critical functions should be selected for and trained in leadership	Personnel in safety critical roles should anticipate the needs or problems of others and take timely action
Representatives of all groups engaged in safety critical functions should meet regularly to review teamworking practices, identify improvements and introduce these improvements to their colleagues	Personnel in safety critical roles should provide help or support to others who need assistance
Any proposed changes to rules, procedures, working practices, systems and workplaces should be evaluated for their potential impact on teamwork - throughout the company	Personnel in safety critical roles should provide feedback about others' performance and accept feedback about their own performance
All companies employing personnel involved in safety critical teams should have a policy, supported by systems and practices, for how they promote teamwork – especially with other companies	Personnel in safety critical roles should strive to develop an open and positive team climate amongst all those with whom they interact

Source: Gregory & Shanahan for RSSB (2004)

Unfortunately, the opposite is also true. See Panel, *Good practice in teamworking.*

How does teamwork affect safety culture?

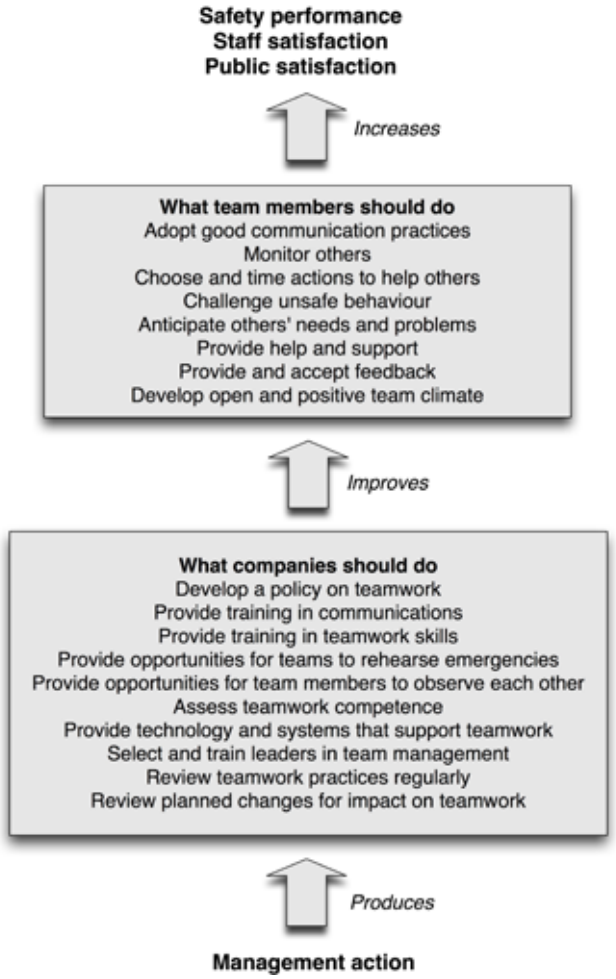
It is clear that good quality teamwork is a necessary ingredient in safety. In particular, it is the ability of members of effective teams to monitor and support each other that enables many human errors to be avoided, or at least detected and dealt with. More generally, teamwork has a two-way relationship with safety culture. On the one hand, a strong safety culture will naturally express itself in terms of high quality teamwork – members of teams will be motivated to support each other and will know how to do so. On the other hand,

teams are important vehicles for transmitting the values of the organisation's safety culture. How team members behave towards each other, and the expectations they have, are ways in which safety values are demonstrated and upheld. Furthermore, a strong safety culture demands the ability to respond flexibly to difficulties and threats. Teams contribute significantly to that ability. Good teamwork depends on good team *leadership* (page 96) and good *communications* (page 106).

How can you improve teamworking?

In 2004 the RSSB published guidance aimed specifically at showing railway organisations how they can use the best practice outlined in this Guide to improve teamworking (see *Teamworking Improvement Process*). This teamworking guidance (see *Further information*) describes a process that can be run in-house and takes your organisation through three stages. In the first stage, you put together a small steering group and use a simple questionnaire to diagnose the nature of any teamworking difficulties at a workshop. In the second stage the process helps you to identify and prioritise the interventions that will be most cost-effective for your organisation to undertake, given the nature of the team working diagnosed. This second stage can take place at a second workshop soon after the first – and often on the same day. The final stage takes place some months later and aims at measuring the new state of teamworking that has been created by your teamworking improvement interventions.

The diagram illustrates the overall direction of the team improvement process.



Source: Gregory & Shanahan, for RSSB (2004)

Further information on teamworking

1 Gregory D. & Shanahan P. (2004) Teamworking best practice in the railway industry: The Journey Guide, Gregory Harland Ltd, for RSSB, Euston (available via the RSSB website)

2 Katzenbach J.R. & Smith D.K. (1993) The Wisdom of Teams McGraw Hill

3 Robbins H. & Finley M. (2000) Why Teams don't Work, Tenere

4 West M. (1994) Effective Teamwork, British Psychological Society

Communication

Why is communication so important?

Good communications are vital to organisational effectiveness, and yet nearly every organisation reports communications as a problem area. For an industry such as the railways, where much communication is safety critical, this is an area that has to be got right. Recent research by RSSB indicates that around a third of incidents sufficiently serious to require a formal investigation are at least partly caused by communication failures of some kind. For this reason we focus here upon safety critical communications.

The railway industry has long recognised the importance of good communications to safety. Much effort has been devoted to researching communications issues and to developing rules and codes of practice for safety critical communication. In terms of the formal requirements the three key documents are:

- Railway Group Standard, GE/RT8046, Safety Communications, dated October 2002
- Railway Safety Approved Code of Practice, Safety Communications, GE/RC8456 dated October 2002
- Rule Book, GE/RT8000, Module G1, General Safety Responsibilities, Section 11, Issue 1, June 2003

In addition, a new Rule Book module on Communications was due in Dec 2005.

In recognition of the importance of safety critical communications, the railway industry has set up the SCCFG (Safety Critical Communications Focus Group). This group has as its first objective *'to raise the profile of safety critical communications within the industry and to encourage cross-industry efforts to improve its quality'*. Its principal aim is *'to encourage a culture of professionalism in safety critical communications – a culture where everyone – managers, supervisors and front line staff - appreciates the role communication plays in reducing safety risks and improving performance, and behaves accordingly'*.

Source: Rail Safety Critical Communications website

Why is communication so difficult?

Communication is often problematic because so many things can go wrong. When, for example, two people in different places try to communicate over some communication channel, such as a mobile phone or radio:

- *People forget*. Especially when under pressure from a high *workload* (page 125) or even *stress* (page 120), people forget to tell other people things they should know. They may not think to call them at all. Even when talking to the other person they may forget to say things they should, or they may forget exactly what it was they wanted to say.
- *People cannot get into contact*. The other person may be engaged in some other conversation. One person may not have the other's phone number. One person may be in a position where their mobile phone cannot receive a signal. Their mobile phone battery may be out of charge.
- *People mishear*. The communication channel may be noisy. One of the people may be in a noisy place. Accents or dialects may make it difficult for one person to understand the other. One or both may fail to use the phonetic alphabet. The person listening is distracted and does not attend carefully to what the other is saying.

'A third of all railway incidents sufficiently serious to require a formal investigation are at least partly caused by **communication failures** of some kind'

Even when two people manage to make contact and can hear each other properly, many things can still go wrong:

- *Slips of the tongue*. One person inadvertently says something different from what they intended.
- *Use of jargon*. One person uses words or terminology that the other person is unfamiliar with so that they either do not understand at all or interpret wrongly.
- *Wrong assumptions*. One person may not realise that they are talking to somebody other than the person they intended to talk to. Or the person may actually be somewhere different from where the other thinks they are. One person may assume the other is talking about X when they are actually talking about Y – and neither of them pick this up.

'Even when two people manage to make contact and can hear each other properly, many things can **still go wrong**'

- *The power of expectations*. People have a strong tendency to hear what they expect to hear.
- *Lack of clarity*. One person may describe a problem, a situation or an intended action in a way that the other misunderstands what they are being told (see Panel, *… know what I mean?*)
- *Failure to do a 'sanity check'*. One person listens uncritically ('brain in neutral') and does not consider whether what they are being told makes sense.

Given all the things that can go wrong, the wonder is not that communications go wrong so often, but that they actually succeed most of the time. The railway rules and procedures for safety critical communications are designed to minimise the risk of many of the problems above. However, it is worth noting that having to speak in a highly formalised way is itself more difficult than talking in plain language. Having to think about rules and procedures is itself an additional mental load that can contribute to communication errors – unless they become 'automatic' through extensive practice.

How do communications help with safety culture?

So far we have considered the immediate contribution that good communications make to safety in the context of safety critical communications. And of course good-quality communications are the foundation of effective teamwork. But when we consider an organisation's safety culture we need to look more widely at communications.

The case for good communication in developing a safety culture can be traced back to the Ladbroke Grove inquiry. Two-way communication is also one of the five key indicators of safety culture examined by HSE's HMRI toolkit (see *Further information*). This toolkit for inspectors picks out three aspects of communication:

- *Promotion and awareness of safety culture*. All personnel should be aware of and understand safety goals, targets and issues. There should also be visible efforts by senior management to communicate their commitment to developing a positive safety culture.
- *Safety concern reporting*. There should be clear and easy to follow procedures to report safety concerns. The reporting system or process should be accessible to all.
- *Discussion and awareness of safety issues*. There should be multiple channels for communication about safety.

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The HMRI toolkit stresses communications should be two way, from staff in the front line, through supervisors and middle managers to those at the very top of the organisation. And of course back down the organisation in the other direction. It is also worth remembering that communications is two-way in the sense that communication only happens if there is both speaking and listening:

Good communications to support a safety culture will use many different channels, formal and informal, and a variety of communication media, such as briefings, notices, videos, etc. There is a common tendency for safety concerns to be expressed verbally by front line staff to their immediate managers. These concerns also need

… know what I mean?

'The protection has been placed on the station side of one six six seven points.'

On the face of it, this might seem like a pretty reasonable statement for one railway professional to communicate to another. It comes from an actual recorded conversation between a COSS and a signaller. But, during a lengthy discussion about the 'station side' of a set of points, it became clear that they were in fact talking about different stations on either side of the points. With personnel working on one side of the set of points while the signaller thought they were on the other side, a major train accident or fatalities could have occurred.

The solution to a situation like this is to be as precise as possible. That doesn't mean you should regurgitate a section of the Rule Book, just in case the person has forgotten their training. But do:

- give names of locations and people.
- give the status of an event: is it going to happen (if so is there a specified time), has it happened or is it happening now?
- use the specific specialist terms when appropriate (eg 'this is an emergency call', 'there has been a train accident')
- be aware that not everybody thinks and speaks the same way as you. Your reference to 'inter' might be understood as 'into' by another person, rather than 'Birmingham International Station' as you intended.

Source: Rail Safety Critical Communications website

to be put in writing, and if necessary the organisation should establish a central database for gathering all these reports. It is vital to identify problems in order to take pre-emptive action. (See also the discussion of learning culture in the section on *Management* on page 99.)

How can you improve communications?

The SCCFG website (www.rail-scc.co.uk, as of May 2008) has an excellent summary of good practice for safety critical communications by front-line staff (see Panel, *Good practice in communications for safety-critical staff*). The website also gives you *The Safety Communications Good Practice Handbook* produced for RSSB in 2004 by Risk Solutions. This handbook covers all aspects of safety communications from the perspective of senior managers and directors, safety and line managers, and briefers.

How can you manage communications?

In addition to rules and guidance on actually communicating safety critical information, the rail industry has formulated good practice on what Railway Group members must do in order to ensure that safety critical communications are maintained at the highest standard possible. GE/RT8046 and GE/RC8456 specify what the management of organisations in the railway industry must do in terms of:

- defining safety critical communication requirements
- recruiting and selecting staff to undertake safety critical communications
- establishing a safety critical communications competence management system

Good practice in communications for safety critical staff	
Start on the right note	You have probably experienced in everyday life that when a conversation starts on the right note, it usually carries on that way, too. The same applies in safety critical communications. Research from the railway shows that when conversations start well, as per the protocols, they tend to continue that way. When you are the first to use the protocols, you help to set the professional tone. When beginning a communication, you must: • identify yourself, your job title and your location • ensure you identify the other person • be clear about the purpose of the call.
The ABC principle: Accurate Brief Clear	The principles of safety critical communications are simple: keep the conversation accurate, brief, and clear. • Speak slower than normal. • Use clear sentences and make sure you use the standard phrases. • Avoid technical and regional jargon – not everyone is familiar with it. • Spell words that are unfamiliar or difficult to pronounce. Use the phonetic alphabet. • Read back to confirm understanding. • Say numbers individually. Read back to confirm understanding. Remember how easy it is to get numbers and codes wrong by a slip of the tongue. • Take time to reach understanding. • If the caller speaks in a dialect or accent which is not familiar to you, what they say may take some repeating.
Lead responsibility	Lead responsibility is an important element in safety critical communications. It means that one person guides the conversation and takes charge of the outcome. That person has the authority and duty to show the way forward and direct the action. Because it is so important, lead responsibility is specifically assigned to different work roles, and varies according to who you are communicating with.
Listening skills	It may be obvious that listening carefully is as critical as speaking clearly. But how do you know if someone is listening? Asking them to repeat the message is a simple way to check it. The protocols give you several ways of doing so. Asking for a read back and repeating messages is always a good practice, but even more important in situations when there is a risk of inattention and lack of focus. On the railway these include: • long-term degraded working conditions – when exception becomes normal • monotony of work • tiredness • stress • intense activity • adverse conditions – wanting to work quickly rather than safely.
Confirm understanding	The ultimate purpose of the protocols is to ensure that clear understanding is reached about all critical details in safety critical operations. No action should be taken without confirming understanding. *Source: Rail Safety Critical Communications website*

- training for safety critical communications
- monitoring safety critical communications performance
- gathering safety critical communication data

If you are responsible in any way for safety critical communications performed by railway staff, you should ensure you are familiar with these management requirements and make the appropriate arrangements.

Further information about communications

1 Clark H. (1996) Using Language, Cambridge Uni Press

2 Cushing S. (1994) Fatal Words: Communication Clashes and Aircraft Crashes, Univ. of Chicago Press

3 Dietrich R. (Ed) (2003) Communication in High Risk Environments, Helmut Buske Verlag

4 HSE (2005) Development and validation of the HMRI safety culture inspection toolkit, RR365 www.hse.gov.uk/research/rrhtm/rr365.htm (as of May 2008)

5 Safety Critical Communication Focus Group www.rail-scc.co.uk (as of May 2008): several publications including The Safety Communications Good Practice Handbook produced for the Rail Safety and Standards Board by Risk Solutions (2004)

Change

What drives change?

It has become a truism that the only constant in working life nowadays is change. But it is certainly the case that the railway industry has seen its full share of change over the last decade or so. Probably the major driver of change over this time has been a series of Government decisions, notably the decision to privatise the railways in the early 1990s. These changes in the structure of the railways have been accompanied by increased exposure to new financial and business pressures. Other drivers of change have been the influence of initiatives at the European level (eg the EU Working Time Directive) and the growth in the number of train passengers.

As it has throughout its history, the railway industry has to remain responsive to changes in the available technology. For example, the availability of cheap, reliable mobile phones has had a strong impact on many areas of railway working. This impact will only increase as new programmes such as GSM-R and ERTMS change fundamentally many aspects of how the railways work. Specific changes in working practices have also been driven by inquiries into major accidents, such as the Hidden Inquiry into the 1988 Clapham accident and the Cullen Inquiry into the 1999 Ladbroke Grove accident.

There have also been changes that have affected the workforce in less obvious ways. Over the years skills have varied as education and training practices have developed. The composition of the workforce has changed under the impact of factors such as immigration and the increasing acceptance of women in many occupations that were traditionally 'male'. Social attitudes have also changed. For example, few people these days expect to have a career for life in the way that earlier generations did. All of these changes are reflected in change in the way that the railways are staffed and operated.

'Nothing is permanent except change.'
Heraclitus 6th Century BC, Greek philosopher

What are the obstacles to change?

In any organisation there is a continual process of evolutionary change. This involves numerous small changes triggered by any of a multitude of factors. Normally the organisation will adapt to these changes without major disruption. But usually when people talk about the problems of organisational change they have in mind larger programmes of planned, intentional change. Such programmes are notoriously difficult. Many of these problems are practical in nature, but here we focus on what most writers on organisational change single out as the greatest issue, namely the *human factor* in change.

The human factor in change normally takes the form of resistance to change. Fear of the unknown is a leading problem. Staff fear that they may lose out financially or in terms of loss of power or influence. They may have fears that they may lose their jobs. Where the change involves new technology or working practices people may have concerns about safety. Even when fear is not a large concern, change always involves disruption and inconvenience. A lot of working life is about habits. Having to give up old habits and learn new ones is usually unwelcome.

More generally, organisational culture can play a major role in holding back the process of change. Many will view attempts to change the culture as putting at risk the very things that have made the organisation successful in the past – the shared values, beliefs and assumptions that have evolved over the years. Yet it may be essential to change the organisation and culture if the organisation is to remain viable. This is likely to be a challenging process since much of culture is deeply embedded in people at a subconscious level, and it is remarkably difficult even to identify what needs to change, let alone to actually change it.

How can change be managed?

Change is driven by many different factors, which means that change management programmes can take many different forms. In keeping with the themes of this Guide, we look here at three highly inter-connected aspects of managing change: technological change, change with safety implications and cultural change.

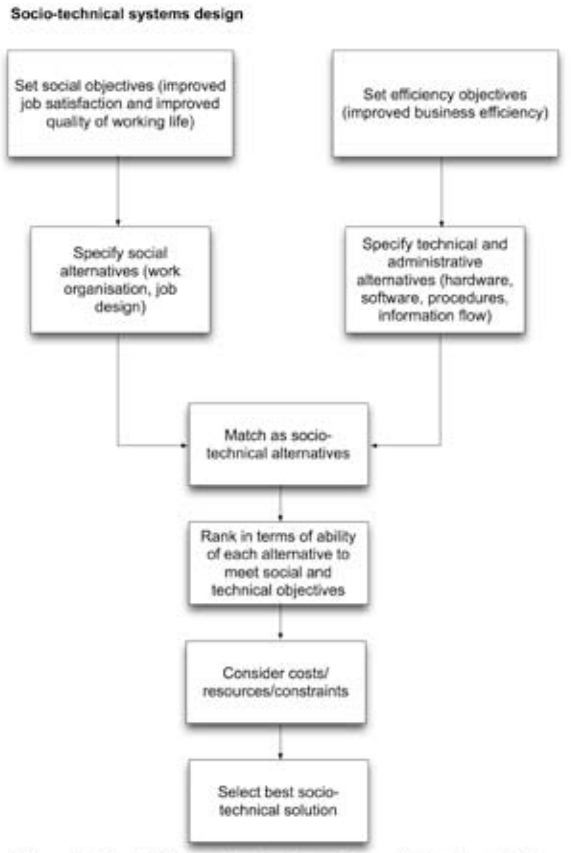
Introducing new technology

The railway industry is of course technology-intensive. There is a continuous process of replacing older technologies with new ones. This has always been the case with the technologies connected with trains, track and infrastructure, but more recently the rapid advance of information and communication technologies has resulted in radical changes in management and administration.

The introduction of new technology into organisations has not always been a story of success. New technology has often triggered periods of disruption and even conflict, especially where people have felt threatened by the technology. Projects to introduce new technology have often been abandoned or the new technologies have soon fallen into disuse. The financial and other costs have been enormous.

Studies of why so many attempts at introducing new technology have failed have consistently pointed to a major cause: the failure to properly consider the human and social working context into which the technology is introduced. Managers have often focused on the operational or business benefits expected of the new technology, and designers have been totally absorbed by the technical challenges it poses. The fact that the technology may disrupt or make obsolete well-established working practices, relationships and senses of professional identity is frequently ignored.

To avoid these difficulties, an approach to the introduction and development of systems, called socio-technical design, has been developed over the last 50 years. The essence of this approach is the recognition that the vast majority of working situations involve teams or groups of people working with each other (the social system) and with complex combinations and arrangements of technology (the technical system). Both the social and technical systems have to develop in step with each other. The aim is to find a solution in which business-oriented and human objectives can be met to the reasonable satisfaction of both types of system. A process for achieving this is outlined in the diagram on this page, *Socio-technical systems design*. You can view this process as providing a wider context for the user-centred design process (see section on *user-centred design* on page 25).



Source: Mumford (1983), reproduced with permission of the Manchester Business School

Change with safety implications

'Organisational change is often an opportunity to improve health and safety, for example though reappraisal of safeguards or clarification of personal accountabilities. However, HSE's experience is that in many instances organisational changes are ***not analysed and controlled*** *as thoroughly as plant changes, resulting in reduced defences against major accidents, sometimes with fatal consequences. This is because, unlike management of plant change, impacts of organisational change are less well understood, and there is a lack of robust, generally accepted approaches to ensuring safety.'*
HSE (2003)

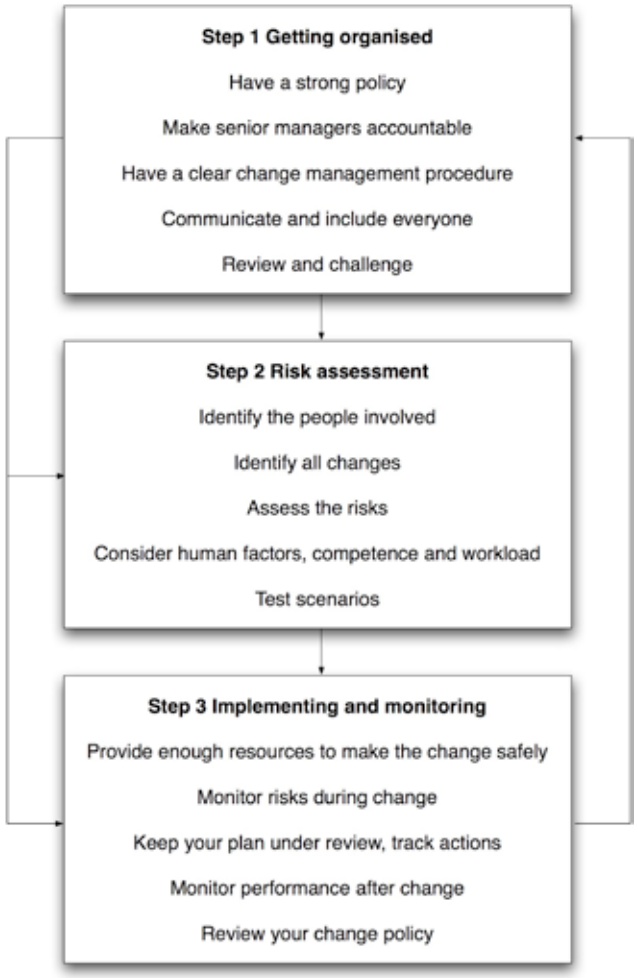
Organisational change can, of course, include the introduction of new technology. It can also include outsourcing, mergers, introduction of 'self managed' teams, and so on. To help overcome the problem of not assessing organisational changes sufficiently for their safety implications, the HSE has developed the change process shown in the diagram, *Managing organisational change*. There are three major steps, each of which involves a number of tasks.

The HSE information sheet (CHIS7) not only gives a detailed description of the process but also a number of valuable checklists. The HSE overview checklist is reproduced in the Panel, *Getting organised checklist*.

Can safety culture be changed?

Within the context of this Guide, the organisational change that is of most relevance is changing the safety culture. We have already considered safety culture in relation to leadership, management, teamwork and communications. Introducing any of the good practice discussed in these sections will begin to bring about changes in your organisation's safety culture. However, there will be occasions when you seek to bring about more comprehensive changes in your organisation's safety culture.

Managing organisational change



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Getting organised checklist

Don't make too many simultaneous changes, resulting in inadequate attention to some or all.

Don't delay or defer safety issues compared to other aspects considered more pressing, because:

- they are seen as a side issue
- they are delegated to people with inadequate influence
- they are not considered early enough in the change process
- inadequate time or resource is allocated to their assessment
- teams making decisions are too inward looking
- there is lack of objectivity
- objectives are passive, maintaining rather than improving standards
- appropriate management controls are missing

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Culture

You can see changing safety culture as a specific example of changing organisational culture in general. An important point here is that culture cannot be changed directly. It can only be changed indirectly, and this will probably take a long time. Culture can slowly change through the operation of a range of organisational 'levers', such as leader behaviour, changing rules and rewards, and visible things such as buildings, names, and so on. What is clear is that because an organisation's culture is deeply embedded in the minds and identities of the members of an organisation, any change in organisational culture usually only happens when a crisis confronts the organisation and its staff, (see Panel, *The key ingredients of culture change*).

'Culture can only be changed **indirectly** – and always takes a long time'

The diagram, *The levers of culture change*, illustrates the mechanisms involved in bringing about culture change.

Change management research in the off-shore industry has shown that an organisation's safety culture typically goes through three stages of development as it changes and matures.

The key ingredients of culture change

- Typically triggered by a perception of crisis
- Initiated and shaped by strong leaders
- Consolidated by perceived success
- Requires extensive re-learning and re-education

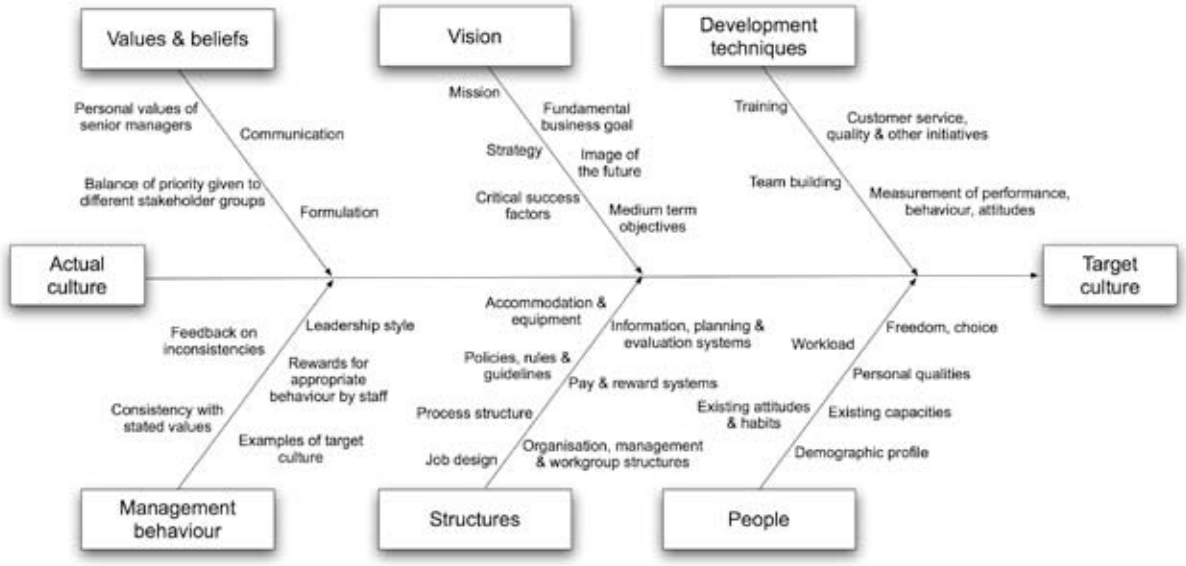
Adapted from Scott et al (2003), reproduced with permission

Stage 1 is a *dependent* safety culture. Here the emphasis is on management and supervisory control, with extensive use of discipline to enforce safety measures. There is a heavy reliance on written safety rules and procedures. Safety performance is dependent on the level of management commitment to enforcing rules and procedures. Safety performance improvement will reach an upper limit with this type of culture – because no matter how committed management are, it is not possible to be everywhere and observe all operations.

Stage 2 is an *independent* safety culture. Here, the focus is on personal commitment to, and responsibility for, safety. This involves all employees in developing their own personal safety standards and demonstrating their commitment by adhering to these standards. While there are still safety rules and procedures, employees look after their own safety and make active choices to keep themselves safe. In an independent safety culture, the focus on individual responsibility for safety may be indicated by statements such as 'everybody is their own safety officer'.

Stage 3 is an *interdependent* safety culture. Here, team commitment to safety is the dominant factor. This type of culture is manifested by workers having a sense of responsibility for safety

The levers of culture change



Adapted from Briault (1994), reproduced with permission

'Culture is always influenced by **management actions** – for better or worse'

beyond their own work and by caring for the safety of others. Employees share a common belief in the importance of safety. The movement towards an 'interdependent' culture is difficult, as it relies on more than personal commitment; it requires shared perceptions, attitudes and beliefs. Employees need to be willing to help others to adopt this belief system – not by sanction but by persuasion.

Adapted from: Fleming & Lardner (1999), reproduced with permission from The Chemical Engineer

What are the principles of change management?

We have looked at ways of introducing new technology, improving safety or changing culture. These each have their different demands and requirements. But research from many areas has indicated that there is a common set of principles that you can regard as good practice in managing change (see Panel, *The principles of change management*).

The principles of change management

- An important priority is to create an environment of trust and shared commitment, and to involve staff in decisions and actions which affect them.
- There should be full and genuine participation of all staff concerned as early as possible, preferably well before the introduction of any change.
- Team management, a cooperative spirit among staff and unions and a genuine feeling of shared involvement will help create a greater willingness to accept change.
- As part of the pre-planning for any change, there should be a 'personnel management action programme' that is carefully designed to prepare staff for the change and to minimise any negative consequences of the change.
- The introduction of incentive payment schemes – based on an equitable allocation of the savings that may result from the changes and more efficient methods of working – may help in motivating staff.
- Changes to the work organisation must maintain the balance of the socio-technical system.
- Careful attention should be given to *job design*, methods of work organisation, the development of cohesive groups, and relationships between the nature and content of jobs and their task functions.

Adapted from Mullins (1999), reproduced with permission

Further information on organisational change

The first of these references is a short publication highly relevant to the theme of this guide. The others are all books that present important views on the process of organisational change in general.

1 Briault S. (1994) What is integrated learning? Training Officer, May, Vol. 30, No. 4

2 HSE (2003) Organizational change and major accident hazards, Chemical Information Sheet CHIS7

3 Kanter R.M. (1983) The Change Masters, Unwin Paperbacks

4 Mumford E. & Beekman G.J. (1994) Tools for change and progress, CSG Publications

5 Scott, T, Mannion, R, Davies, & H, Marshall, M. (2003) Healthcare performance and organisational culture, Radcliffe Medical Press

6 Senge P., Kleiner A., Roberts C., Ross R., Roth G., & Smith B. (1999) The Dance of Change, Nicholas Brealey

understanding
human factors

Conditions

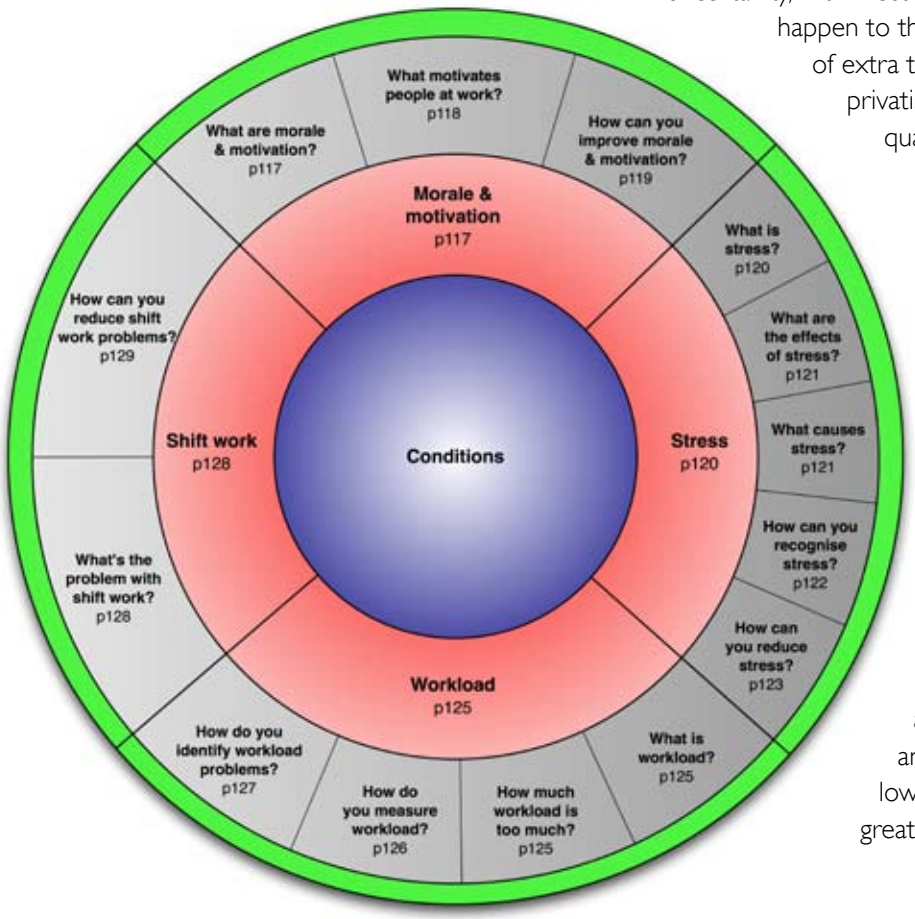
understanding
human factors

Conditions

Conditions

This section is concerned with an important set of human factors which influence the conditions in which people work. The diagram, *Focus on conditions,* shows the four sub-areas that this section focuses on (in the middle red ring), and identifies the main human factors questions that this Guide answers (in the outer grey ring). At the end of each section, you will find a list of sources of further information that will provide more detail.

Focus on conditions



Morale and motivation

In the early 1990s, during the run-up to privatisation, one of the authors of this Guide worked with a group of British Rail S&T supervisors and team leaders on a management training course. It was a time of great uncertainty, with most of the group unsure what would happen to their jobs. They also had a lot of extra tasks to do to prepare for the privatisation, such as documenting the quality system, even though they did not know if they would benefit personally from this work. Not surprisingly, morale was at rock bottom. The group's motivation to learn about management when they did not know whether they would have a job in a year's time was non-existent. They learned little from the course.

A study of drivers of track maintenance trains in Japan found a close relationship between measures of morale and motivation on the one hand and accident rates on the other: the lower their morale and motivation, the greater the risks of an accident.

In this section we look at morale and motivation, how they are related, and what can be done to improve them.

What are morale and motivation?

Morale and motivation are two concepts in managing people that are closely related and important, but hard to define (see Panel, *Definitions*). Both concepts can be used in relation to individuals and groups. If you work with a group of people, you can tell whether their morale is high and whether they are motivated, but it can be difficult to say exactly what it is you sense. Morale is to do with confidence, trust, optimism, self-belief in oneself and the others around you. It is a feeling about a general situation. Motivation is a state of will. It is about a person's commitment to actually doing something to achieve a particular goal.

Definitions

Motivation

'Motivation derives from the Latin verb 'movere', meaning 'to move'. Movement implies action and, in order to act, energy and effort are required from the individual. The level of individual motivation is determined by the amount of energy and effort people put into their work.'

Kakabadse et al (1988)

Morale

'Morale is a state of mind. It is that intangible force which will move a whole group of men to give their last ounce to achieve something without counting the cost to themselves; that makes them feel they are part of something greater than themselves.'

Field Marshal Slim, Defeat into Victory (1956)

Conditions

Morale and motivation are not the same thing, then, but they do tend to go hand-in-hand. It is hard to imagine a person whose morale is low being highly motivated to do a particular task – except, perhaps for reasons of safety and self-preservation. Most of the research and theory in this area has focused on motivation, so we are mainly going to deal with motivation here. You can assume that the factors at work that influence motivation (including your own decisions and actions) will probably also influence morale as well.

> 'The **beatings** will continue until morale improves.'
> **Commander** of the Japanese Submarine Fleet, WW II

What motivates people at work?

Mullins (1999) says that people seem to work for three main reasons:

1 *Economic rewards* – most people need to be paid, to have a pension, to feel secure, and so on

2 *Intrinsic satisfaction* – most people want to do a job that they find interesting and gives them the opportunity to learn, to develop new skills, and to progress

3 *Social relationships* – work is one of the main places where many people make friends, feel part of a group, have status, earn respect, exercise power, etc

Source: Mullins (1999), reproduced with permission

Most people are motivated to work because of some mix of all three reasons, although the precise make-up of the mix will vary. For example, somebody with a strong family and social life outside work may not need the social opportunities that work often provides. This could be important for a signaller working in a single-person signal box or a train driver driving trains on long routes. Or a person who is just doing a job on a temporary basis, while they save up money to do something else, may have little interest in the work itself, only being motivated by the financial rewards.

How to motivate staff has long been a central concern for managers, and many theorists have put forward ideas about how to motivate people. We begin with a class of theories about motivation that starts from the common-sense assumption that people work to get their needs met.

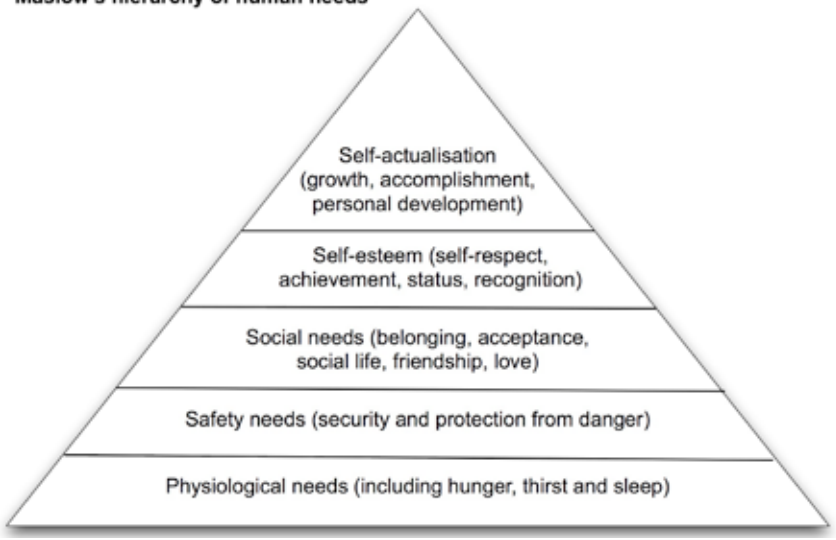
Theories about needs

One well-known theory of this type is Maslow's hierarchy of needs, shown in the diagram, *Maslow's hierarchy of human needs*. Maslow argued that people will only experience a particular level of needs if the levels below it are satisfied. For example, if you are feeling hungry, tired or unsafe, you probably will not be much concerned about your needs for friendship and belonging, and even less so about your needs for personal growth. But in practice, people do not always seem to experience needs in this order and will often sacrifice lower level needs to achieve higher ones. For example, you may be willing to miss meals or sleep in pursuit of some social goal. But as a general classification of the kinds of needs that can motivate people, Maslow's list has proved useful.

Another useful view of motivation is provided by Herzberg. He identified a number of factors that motivated people at work. He called these 'motivators' or 'growth factors'. But it is not simply the absence of motivators that causes dissatisfaction. Dissatisfaction is caused by a separate group of factors he called 'hygiene or maintenance factors'. These two classes of factors are shown in the Panel on page 119, *Herzberg's work motivation factors*.

There are numerous other theories of needs. (You can find out about them in some of the sources listed in *Further information* at the end of this section.) But the

Maslow's hierarchy of human needs



Based on original research by Maslow (1943)

Herzberg's work motivation factors

Frederick Herzberg originally published his influential two-factor theory of motivation in 1959. He distinguished two classes of factor, one of which he called **motivation** factors and the other **hygiene** factors. Motivation factors include receiving recognition, being given responsibility, having opportunities for personal growth, and the like. The presence of these factors is motivating, but if they are absent, then the result is not usually a lack of motivation. Hygiene factors include level of pay, job security, good working conditions, and so on. The effect of these factors is the opposite to that of the motivation factors. If hygiene factors are lacking (poor pay, bad conditions, etc), then staff are de-motivated. But if they are present, this does not result in high motivation.

Summarised from: Herzberg (1959)

general conclusion from all the theories is that what motivates people is a complex set of factors. Individuals will differ from each other in what motivates them. The same person may be motivated by different things at different times. To motivate people means keeping in close contact with them, constantly asking them questions and listening to what they tell you.

Theories about expectations

A number of writers on motivation have focused less on needs and more on the relationships between how much effort people are prepared to put into their work, the expectations that people have about being rewarded for their efforts, and to what extent they see the reward system as fair. People at work tend to observe carefully what happens to them and to others around them. They observe how much effort or what level of performance leads to what kinds of reward. If they see that extra effort or high levels of performance go unrewarded, this will generally reduce motivation. Also if they perceive any injustices in how rewards are allocated, this too will be de-motivating.

It may be that the system of reward is truly unfair or it may be that staff are unclear about what is expected of them in terms of satisfactory performance. It may also be that the person does not have a realistic perception of their own level of performance. Managers and supervisors must be careful in making clear what they expect from staff, and must also give them objective feedback about how well they are doing.

An important idea here is the *psychological contract*. In most employment situations there is an actual contract between the employer and the employee. This sets out in black and white what the rights and responsibilities each has – pay, duties, periods of notice, and so on. But there will also be a contract that is not written down but is equally real. This psychological contract includes the many and various expectations that the employee has of the employer and vice versa. Such expectations might include the opportunities for promotion, a generally pleasant working atmosphere, minimum standards of politeness, a freedom from unreasonable demands, and so forth.

Managers must be aware of the psychological contract whenever they introduce any changes. Violations of this contract will be seen as a breach of trust, and staff motivation will be damaged. Details on where to find out about these theories are given in *Further information*.

How can you improve morale and motivation?

Motivation is ultimately about the question: why do people do what they do? You will find as many answers to this question as there are people you work with. Drawing on the various motivation theories, the following are guidelines on how to motivate staff.

- *Your staff*. Spend time talking with your staff, especially listening to them. Find out what interests them and what they want from their jobs.
- *The jobs you are responsible for*. Make sure you know the rewards that tend to be associated with the jobs of your staff. Some jobs, for example, offer few opportunities for social contact. Or a job may in truth be boring. For some people such things may not matter much, but for others they will be highly off-putting.
- *Working conditions*. Make the physical and organisational conditions as attractive as possible. At the very least ensure that they do not become sources of dissatisfaction.
- *Performance*. Make sure everyone knows what is expected of them. Give them plenty of fair and objective feedback so that they know how they are doing.
- *Job enrichment*. For those who indicate they want extra variety or responsibilities, find ways to make their job more varied. But do not assume everyone wants this; some people might think you are just giving them extra work.

- *Development and career opportunities*. Help those staff who want to move ahead to find opportunities to progress their careers.
- *Psychological contract*. Understand the implicit expectations your staff have of the organisation, and what the organisation expects of them. Many of these expectations may not be directly related to the work. For example, staff may expect working for a certain organisation to give them a status in their local community. Assess any changes you plan to introduce for their impact on these usually unspoken assumptions.
- *Rewards*. Ensure rewards are fairly allocated and that staff fully understand the basis on which rewards are given. Remember rewards are not only financial. Recognition, praise, a good working location, favourable working hours, even being given an interesting extra job, and much else can be highly motivating.
- *The big picture*. Keep staff up-to-date with how the whole department, region, organisation, industry is doing. Especially report areas of progress. Being able to place their work in a bigger context helps individuals feel their jobs are worthwhile and meaningful.
- *Yourself*. Look at the messages your attitudes, behaviour and general demeanour send to your staff. If you are confident, optimistic and enthusiastic, this will be infectious and motivating to those around you.

Further information on morale and motivation

1 Adair J. (2004) Adair on Teambuilding and Motivation, Thorogood

2 Fournies F. (1999) Coaching for Improved Work Performance, McGraw-Hill Education

3 Handy C. (1993) Understanding Organisations, 4th Edition, Penguin

4 Harvard Business Review (2003) on Motivating People, Harvard Business School Press

5 Heil G. & McGregor D. (2000) Revisited - Managing the Human Side of the Enterprise, John Wiley

6 Herzberg F. Mausner B. & Snyderman B.B. (1959) The Motivation to Work (2nd ed.) John Wiley, NY

7 Herzberg F. (1993) Motivation to Work, Transaction Publishers

8 Kakabadse A. et al (1988) Working in Organizations, (especially Chapter 5), Penguin

9 Maslow A. (1943) A Theory of Human Motivation, Psychological Review, 50, 370-396

10 Maslow A. (1998) Maslow on Management, John Wiley

Stress

What is stress?

There are many definitions of stress. The definition and description used by the HSE is:

> *'Stress is the adverse reaction people have to excessive pressure. It isn't a disease. But if stress is intense and goes on for some time, it can lead to mental and physical ill health.'*

The HSE says that stress is widespread in the British workplace:

- About 1 in 5 people say that they find their work either very, or extremely, stressful.
- Over half a million people report experiencing work-related stress at a level they believe has actually made them ill.
- Each case of stress-related ill health leads to an average of 29 working days lost.
- A total of 13.4 million working days were lost to stress, depression and anxiety in 2001.
- Stress has overtaken back problems as the leading complaint in disability claims.

In a safety critical industry such as the railways, stress is a particular issue because stress makes people less safe in their work. Many people being absent from work because of stress only adds to the problem by increasing the *workload* (page 125) and associated stress of those people still at work.

What are the effects of stress?

Stress happens when the safe limits of our natural arousal levels are exceeded. In fact, there is a well-established relationship between performance at work and stressful demand. When the demands placed on us are very low, we tend to perform badly out of boredom or frustration. As the demand increases, our level of arousal rises and we become more alert and decisive. At some medium level of arousal – which varies from person to person – we perform at our best. We feel in total command of our work, able to cope with all the challenges it can throw at us. However, if the demands continue to increase and are not balanced by periods of lower demand, when we can recover and rebuild our reserves of energy, we begin to be stressed. We start to rush tasks, we don't check properly, we don't consider alternatives and we make more and more mistakes. (Stress is often cited as a cause of SPADs.) If the level of stress continues to increase, we may eventually reach a stage called burnout (see *supervision and appraisal* on page 68 for how to recognise and deal with this), where we are ill and unable to work.

It is important to note that while people need to be aroused to some extent in order to act, stressors are always bad (see Panel on page 122, *What causes stress at work*). For example, even a little anxiety (eg caused by fear of bullying at work) affects performance by producing changes in people's ability to pay attention, learn and recall information.

Stress is usually first experienced psychologically, typically with difficulties in sleeping, increasing anxiety and feelings of tension and loss of control. Problems can then start to appear at work, with difficulties in concentrating, inability to make decisions, becoming increasingly short-tempered with colleagues.

But when levels of stress are maintained for any length of time, physical symptoms will begin to emerge. Headaches and backaches are common signs of stress for many people. Stress tends to seek out a person's particular areas of weakness. For one person, this may mean digestive problems. For another person stress may show up in skin rashes.

'Too much stress and we **burn out** … but there are many symptoms that can let us know it's happening.'

While one should avoid the trap of blaming any physical ailment on stress, whenever these kinds of problem appear consideration should always be given to the possible role of work-related stress.

Clearly, stress has a bad effect on the individual. In addition, stress is also a problem for the workgroup as conflicts increase, and cooperation and relationships suffer. All of these effects reduce the quality and safety of the work being carried out. At the organisational level, stress results in a fall in performance and productivity. Staff turnover increases, and experience and expertise disappears with each person who leaves. More resources have to be devoted to *recruitment* (page 84) and *training* (page 55) to replace the staff who leave. But replacing staff who leave because of stress is only a temporary fix. Something needs to be done about the underlying causes of stress.

What causes stress?

Stress has many possible causes (see Panel on page 122, *What causes stress at work?*). A recent survey by the TUC identified *workload* (page 125) as far and away the major cause of stress. Other leading causes were cuts in staff, change, long hours, bullying and *shift work* (page 128). On the railways the factors that cause stress include pressure to achieve targets, threats from aggressive or violent passengers, and risks posed by vandals or trespassers. Suicides are a particularly severe cause of stress for a significant minority of train drivers. RSSB has recently conducted research aimed at minimising the impact of railway suicides on railway staff (see *Further information*).

The HSE has carried out extensive work in the area of stress at work in recent years. One key output of this work is the set of Management Standards relating to stress (see *Further information* at the end of this section). The standards classify the principle causes of work-related stress into six key areas:

- *Demands* – includes such issues as workload, work patterns and the work environment
- *Control* – how much say the person has in the way they do their work
- *Support* – includes the encouragement, sponsorship

Conditions

What causes stress at work?

The causes of stress are very personal. We all vary in what we find stressful. What is enlivening music for one person may be unbearable noise for another. Our age, gender, experience, home life, and many other factors will influence our vulnerability to different types of stressor. Somebody who is having a difficult time in their home life is likely to be more susceptible to stressors at work. But we can identify certain classes of stressor that are likely to be behind most cases of stress.

First and most obviously, physical conditions can give rise to stress. Loud noise, poor lighting, vibration from passing trains or road traffic, too much or too little heat can all contribute to stress. Poorly designed workspaces which are cramped or where equipment and furniture is placed so that it is easy to bump into or trip over, can be psychologically stressful as well as dangerous. Equipment that is difficult to access, or difficult and frustrating to use are common contributors to stress levels of staff.

Perhaps most commonly, stress is associated with levels of work, especially pressure of too much work and too little time, although too little to do can also contribute to stress. Uncertainty is a major element in many cases of stress at work. This may be uncertainty about what to do or what is expected of you, how well you are doing, what your promotion prospects are, and so on. Lack of job security is a serious cause of stress.

For many people stress is associated with their relationships with colleagues, managers and even subordinates. Bullying, conflicts and harassment are all acute causes of stress.

and resources provided by the organisation, line management and colleagues

- *Relationships* – includes promoting positive working to avoid conflict and dealing with unacceptable behaviour

'Stress at work is a major cause of poor performance … and the **major cause of stress** at work is workload.'

- *Role* – whether people understand their role within the organisation and whether the organisation ensures that the person does not have conflicting roles
- *Change* – how organisational change (large or small) is managed and communicated in the organisation.

Source: HSE (2005), reproduced with permission

Stress is also, of course, caused by many life events outside of work. The events most strongly associated with high levels of stress are:

- death of partner, spouse or other close relative
- divorce
- marital separation
- imprisonment
- personal injury or illness
- getting married
- dismissal from work
- marital reconciliation.

Source: Holmes & Rahe (1967), reproduced with permission from Elsevier

Note that not all these events are 'negative'. Some of them are events that are usually considered as 'positive' (eg getting married). Even the 'good things' in life can impose demands that may be experienced as stressful.

Stress within work and stress outside of work tend to add together. This means that moderate levels of stress at work and at home may mean that the overall experience of stress is high. But equally a happy, settled home life may mean that the impact of high levels of stress at work is minimised.

How can you recognise stress?

Good practice in stress management begins with recognising stress in yourself or in others around you at work. Things to look for particularly in your own behaviour include:

- eating on the run, or in a disorganised manner
- smoking, or drinking excessively
- rushing, hurrying, being available to everyone
- doing several jobs at once
- missing breaks, taking work home with you
- having no time for exercise and relaxation.

Source: HSE (2005), reproduced with permission

Aspects of behaviour that you may notice about your colleagues include:

- changes in a person's mood or behaviour
- deteriorating relationships with colleagues
- irritability
- indecisiveness
- absenteeism
- reduced performance
- smoking or drinking alcohol more than usual
- indications of drug abuse
- complaints about their health.

Source: HSE (2004), reproduced with permission

See *supervision and appraisal* (page 68) for more on how to recognise and manage stressed colleagues.

How can you reduce stress?

Helping yourself

Stress arises when you experience a mismatch between the demands placed on you, and your capacity (in terms of time, energy, skills and so on) to cope with them. To manage your stress you need better control over the demands you face and improved capacity to cope.

Gaining control over the demands you face at work may mean re-assessing what you can and cannot do. This in turn may lead you into re-negotiating with managers and colleagues what responsibilities you take on. Remember your employer has a legal responsibility for your health at work and this includes stress arising from work. Maybe some of your stress arises from fears that you do not have all the knowledge and skills for your work. Perhaps there are training courses you could attend to help you develop new knowledge and skills. On a wider scale you may need to re-appraise all of the commitments you have within work and outside work. Are you just taking on more than is sensible?

However effective you become at managing your external demands, the chances are that there will still be times when demands will be uncomfortably high. This is why you need to improve your own inner resources as well. When you look at your own ability to cope with stress, you may realise that you need to develop skills that are not directly work-related and are of a more personal nature. Time management is one area you might want to improve. Or learning how to say 'no' when asked to take on just one more responsibility. It may be that you want better control over how your body reacts to stress. Learning how to relax, to take more exercise, to eat more healthily, to take more time off, may all be things you want to consider. You might also want to find out if your company offers training in stress management or counselling. The sources listed in *Further information* at the end of this section will help you find out what you can do to improve your 'stress proofing'.

Helping others

If you are responsible for the work or well-being of others in your organisation, you will often be in the best position to recognise and help someone suffering from stress. You may well be aware that the person has a stress problem before they are fully aware of it themselves. The Panel on page 124, *Looking after others*, gives good practice for stress prevention and initial stress management if stress does become a problem. The suggestions given in the section on Helping yourself (this page) may also give you ideas that you can pass on to others who ask for your assistance.

Helping your organisation

> *'Stress is often a symptom of poor employment relations and can seriously affect productivity. Organisations who talk regularly with their employees and have sound systems and procedures in place for dealing with issues like absence and discipline are much more likely to avoid work-related stress and to be able to deal with potentially stressful situations when they arise.'* ***ACAS***

If you are responsible for the work and well-being of others in your organisation, you need to do more than respond to particular causes of stress and adopt a more formal and comprehensive approach to stress management. HSE requires every employer to conduct risk assessments for health and safety hazards, including work-related stress. It recommends a five-step approach to risk assessment.

- Identify the hazards
- Decide who might be harmed and how
- Evaluate the risk and take action
- Record your findings
- Monitor and review

Source: HSE (2005), reproduced with permission

Looking after others

What can you do to prevent stress from becoming a problem?

- Show that you take stress seriously, and be understanding towards people who admit to being under too much pressure.
- If you are a manager, have an open and understanding attitude to what people say to you about the pressures of their work, and look for signs of stress in your staff.
- Ensure that staff have the skills, training and resources they need, so that they know what to do, are confident that they can do it and receive credit for it.
- If possible, provide some scope for varying working conditions and flexibility, and for people to influence the way their jobs are done. This will increase their interest and sense of ownership.
- Ensure that people are treated fairly and consistently and that bullying and harassment aren't tolerated.
- Ensure good two-way communication, especially at times of change.
- Don't be afraid to listen.

What should you do if an employee complains about being stressed?

- First, listen to them! If the stress is work-related:
  - try to address the source(s)
  - involve the employee in decisions
  - if necessary, encourage them to seek further help through their doctor
  - if not their manager, ensure that they are treated with understanding and in confidence.
- Where you can't control the work-related sources of stress, it may be appropriate to move the employee if you can. If a period of sick leave is recommended, keep in touch with the employee and their doctor. Remember that before they are ready to return to their old job, they may be able to return to work to do part of their job, work reduced hours or do a different job.
- Try to be flexible!
- Don't be tempted to think that firing someone provides an easy way out! If you don't act reasonably in dismissing an employee, they could claim unfair dismissal.
- Finally, bear in mind that if one of your employees is suffering from work-related stress, they may represent the tip of an iceberg. Find out whether others are also experiencing stress at work.

Adapted from HSE (2004), reproduced with permission

This approach is also based on the new Management Standards for work-related stress that we mentioned earlier. The HSE website is the best place to get full information about both the standards and the assessment process.

Further information on stress

1 The HSE provides many resources dealing with stress at work. The web page URL is www.hse.gov.uk/stress/index.htm (as of May 2008)

2 www.hse.gov.uk/stress/standards/index.htm HSE Stress Standards (as of May 2008)

3 HSE (2004) Work-related stress: A short guide

4 HSE (2005) Tackling stress: The management standards approach

5 International Stress Management Association, ACAS, HSE, Working together to reduce stress at work: A guide for employees, 2004

6 The TUC has a useful account of stress and a description of the management standards from a union perspective: www.tuc.org.uk/h_and_s/tuc-10147-f0.cfm (as of May 2008). Most unions involved in the railways also provide guidance on stress, usually referring to the HSE and TUC websites

There are also many self-help books on stress, eg

7 Davis M. et al (2003) The Relaxation and Stress Reduction Workbook, New Harbinger Publications

8 Greener M. (2003) The Which? Guide to Managing Stress, Which? Books

9 RSSB (2005) Minimising the Impact of Railway Suicides on Railway Staff, Research Project T317.

10 Richards M. (1998) The Stress Pocketbook, Management Pocketbooks

11 Sutherland V. & Cooper C. (2000) Strategic Stress Management: An Organizational Approach, Palgrave MacMillan

12 Williams A. & Cooper L. (2002) Managing Workplace Stress: A Best Practice Blueprint, John Wiley

Two other useful books are:

13 Covey S.R. (1999) The Seven Habits of Highly Effective People, Simon & Schuster

14 Pedler M. Burgoyne J. & Boydell T. (2001) A Manager's Guide to Self-development, McGraw-Hill Education

Workload

What is workload?

Workload refers to the effort demanded from people by the tasks they have to do. It can be the effort demanded at a single point in time, or over a whole shift. It can be the physical demands created by working in a particular posture (eg sitting, standing or reaching at a workstation); manual labour (such as walking, using hand tools, carrying loads); or working in particular environmental conditions (eg extremes of temperature and humidity, and poor lighting). Workload can also be the mental demands created by the need to attend to sources of information and then process the information, often against time pressure. Mental workload can be considerably increased by the operator's knowledge that they are responsible for processing information correctly – and what the consequences of error might be.

Workload is a crucial human factors consideration for both designers and managers. If people have too little to do, they can become bored and inattentive. On the other hand, too much workload is a primary cause of high stress, which seriously degrades human performance. In either case, there is a major implication for safety-critical operations.

> 'Workload is a problem for **safety-critical operations** if it's too low – and an even bigger one if it's too high.'

How much workload is too much?

Physical workload

Excessive physical workload arises from the following typical problems:

- a load is too heavy and/or bulky, placing unreasonable demands on the person
- a load has to be lifted from the floor and/or above the shoulders
- a task involves frequent repetitive lifting
- a task requires awkward postures, such as bending or twisting
- a load cannot be gripped properly
- a task is performed on uneven, wet, or sloping floor surfaces
- a task is performed under time pressure
- a task incorporates too few rest breaks.

These problems may result in physical injuries (eg to the lower back, arms, hands or fingers) and increase the risk of slips, trips and falls.

Much is known about the measurement and limits of physical workload. You can find specific guidance in the *Further information* at the end of this section.

Mental workload

Excessive mental workload arises most typically in tasks that demand more attention than operators have available. People continually change their working methods to keep their mental workload within limits. They may, for example, vary the level of detail they attend to in an attempt to keep the whole picture in their heads. Problems arise, however, when they pitch their attention at too high a level and so completely miss important events or trends in the workflow. Alternatively, sometimes people get tunnel vision as they focus on one particular task element in detail – and so fail to address the rest of their responsibilities. It is possible to see this happening. For example, you may see an air traffic controller who is becoming overloaded in this way move their face closer and closer to the display screen as they slowly 'lose the picture'.

When mental workload gets too much, people become stressed (see *Stress,* page 120) and their accuracy suffers. They give more attention to tasks or information that they consider to be important (which may or may not be the case). They focus on information sources that are easiest to see. They use strategies that require the least mental effort – these are usually the best learned, but may not be the most appropriate. They may also get locked into a single strategy.

Low workload can also be a major problem. Over time it can reduce a person's ability to notice new events and result in slower response times. Sometimes people just go to sleep on the job. People are more likely to become sleepy through boredom if they have suffered sleep loss or disruption to sleep rhythms through *shift work* (page 128).

Conditions

People vary a great deal in their capacity for, and vulnerability to, high workload. Organisations can minimise the negative effects of workload through the following strategies:

- *Design* (page 25) (Interfaces, Workplaces, and Jobs) – to minimise the occurrence of work over/underload.
- *Training* (page 55) – including the use of 'overtraining'; and creating an appropriate team culture that means people anticipate workloads and arrange appropriate backup – see *teamworking* on page 103.

  Note: 'Overtraining' simply refers to giving people more training than they apparently need to pass the test at the end of training. It works because it gives people a chance to practise what they have learned so that their skills become more automatic. Such a strategy is especially useful when training people to respond very rapidly to emergencies.
- *Selection* (page 79) – to assure the correct mix of operator ability and design solution to prevent operators becoming over/underloaded.
- *Recruitment* (page 84) – to assure the supply of the right numbers of human resources to perform the required tasks.

Design is the most important of these strategies. But if a *user-centred design* (page 25) strategy has not been used, you will usually have to fall back on one or more of the other human factors areas to find a solution. This is by no means ideal as well as being expensive. It is important to use workload prediction techniques at an early stage of design to identify likely problem areas, determine the use of automation and define user roles. Workload measurement should be used during prototyping to help identify design deficiencies and/or the need for user role re-definition.

'**Mental workload** problems arise most often when tasks exceed the amount of attention that operators have available.'

A natural approach to reducing workload at the design stage is to find ways to automate some tasks. However, you need to take great care here, since this approach often transfers the problem elsewhere (see *function allocation* on page 37).

How do you measure workload?

Physical workload

Kroemer & Grandjean (1997) say the best indicator of physical workload is heart rate, which rises with increasing workload. This rate of rise is steeper:

- the higher the ambient temperature
- the greater the proportion of static to dynamic effort
- the smaller the number of muscles involved.

Kroemer & Grandjean (1997) reproduced with permission

The least intrusive way of measuring this in a person is for them to wear a continuously recording heart monitor.

'Design is the **single best way** to avoid problems of high workload – if it's not too late.'

A toolset for calculating safe limits for manual handling operations is the HSE Manual Handling Assessment Chart (MAC) (see *Further information*).

Mental workload

There are a number of workload prediction and measurement techniques – ranging from rating scales to performance monitoring. You need to select the most appropriate of these for use in the design process. Primary inputs for workload analysis are:

- *task analysis* (page 47)
- role definition
- *design scenario analysis*
- *team design* (page 103).

These inputs together define the nature of the workload (frequency of scenario events and user tasks to be performed with the equipment) and the resources available (user roles, numbers and team organisation).

You can measure or estimate workload using:

- timelines – which can also be used as the basis for measuring real-time workload during prototyping
- human performance models via task simulation software such as SAMMIECAD or *IPME*
- performance measurement (eg throughput time, number of work units processed, error rate, task conflicts observed etc.)
- subjective rating scales.

You will find summaries of some of the more useful mental workload analysis tools in Part 3 of this Guide. They include:

- *ISA* – Instantaneous Self-Assessment of workload technique, a very simple subjective technique that was developed for use in the assessment of mental workload during the design of future systems
- *SWAT* – Subjective Workload Assessment Technique, one of the most widely used and well known assessment techniques available
- *Team Workload Assessment* – in which team members provide a subjective assessment of their own workload, as well as an estimation of the team's overall workload.
- *IPME* – The Integrated Performance Modelling Environment – software in which a task simulation network is set up. When the software is run, the simulated behaviour is influenced by software models of factors that affect human performance (such as noise and vibration). The results show how task timings and accuracy alter with different levels of workload.

In addition, RSSB has recently developed a suite of tools to measure train driver mental workload (see *Further information)* and Network Rail is developing similar tools to measure signaller workload.

'It is easiest to estimate mental workload via self-report – and there are some **simple and effective tools** to do so.'

You can use the results of workload analysis to identify achievable levels of workload and as the basis for many decisions about *function allocation* (page 37), task and role design, team design and user-equipment interface design. The results will also be used in workspace and workstation design and the health and safety analysis. See the section on *Design* (page 25) where many of these issues are considered.

How do you identify workload problems?

The most powerful way of stopping workload problems from developing in the first place is to ensure there is good design. This may entail using workload assessment techniques and/or structured interviews with users on prototype interfaces, workstations, work schedules and workflows. User trials are particularly important. Mental demands, in particular, are often overlooked during the *workplace design* (page 41) process because they are invisible and not an obvious part of the *equipment design* (page 31).

After the design stage, the best methods for identifying workload problems are:

- talking to employees and getting their views – they are very well informed about the problems they have!
- assessing employees' work by considering the following questions:

  Do they work in a comfortable position?

  Do they complain of any discomfort, including (aches, pain, fatigue, or stress?

  Are they satisfied with their working arrangements?

  Is the equipment appropriate, easy to use and well maintained?

  Are there frequent errors?

  Are there signs of poor or inadequate equipment design, (page 31) such as plasters on employees' fingers or 'home-made' protective pads made of tissue or foam?

  Do the accident report book, the absence record or staff turnover give any clues about any systematic problems?

- deciding if any on-job problems require deeper investigation via the use of a workload assessment technique.

During the process of identifying workload problems you will often immediately see ways of eliminating them. A minor alteration in the workplace may be all that is needed. But you will need to make sure that any alterations are properly evaluated by the people who do the job. Be careful that a change introduced to solve one problem does not create difficulties elsewhere.

'Sometimes a **minor alteration** in the workplace may be all that's needed to reduce workload to safe levels.'

Further information on workload
Physical workload

1 HSE (2000) Management of Health & Safety at Work Regulations 1999 Approved Code of Practice and Guidance (L21) (Second Edition) HSE Books

2 HSE Musculo-Skeletal Disorders www.hse.gov.uk/msd/faq.htm (as of May 2008)

3 HSE Manual Handling Assessment Charts (MAC), www.hse.gov.uk/pubns/indg383.pdf (as of May 2008)

4 HSE (1994) Manual handling: Solutions you can handle. HSG115

5 HSE (2000) Getting to grips with manual handling: A short guide for employersLeaflet INDG143(rev1)

6 HSE (2003) Aching arms (or RSI) in small businesses - Is ill health and sickness absence due to upper limb disorders a problem in your workplace? Leaflet INDG171(rev1)

7 HSE (1997) Seating at work HSG57 (Second edition)

8 HSE (1997) Lighting at work. HSG38 (Second edition)

9 HSE (2003) Work with display screen equipment. Health and Safety (Display Screen Equipment) Regulations 1992. Guidance on Regulations (Second edition) L26

10 HSE (1998) Working with VDUs Leaflet INDG36(r1) www.hse.gov.uk/pubns/indg36.pdf (as of May 2008)

11 Kroemer K.H.E. & Grandjean E. (1997) Fitting the task to the human: A textbook of occupational ergonomics (Fifth edition) Taylor & Francis

12 HSE (1998) Manual handling. Manual Handling Operations Regulations 1992. Guidance on Regulations L23 (Second edition) HSE Books

13 Pheasant S. (1991) Ergonomics, work and health, Macmillan

Mental workload

1 ISO 10075-1:2000. Ergonomic principles related to mental workload: General terms and definitions

2 RSSB Mental Workload Assessment in the Rail Industry, Research Project T147 www.rssb.co.uk/pdf/reports/research/T147%20Train%20driver%20mental%20workload%20-%20the%20train%20driver%20workload%20principles%20guidance%20note.pdf (as of May 2008)

3 Wilson J.R. & Corlett E.N. (1995) Evaluation of human work: A practical ergonomics methodology (Second edition) Taylor & Francis

Shift work

Shift work is inevitable in many parts of the railway industry. A lot of attention has been paid in recent years to its effect on train drivers. But, of course, many other railway employees have to work shifts and possibly suffer from the effects of doing so. Since 2003, the Hidden Recommendations have set maximum limits for railway shift working following the Clapham rail crash. These limits are based on what appeared to be common sense at the time, but are not based on scientific research. Since then, further direction has been given by the EU Working Time Directive. Poorly managed shift patterns can have wide-ranging effects on the staff concerned. They can also affect the efficiency and, most critically, the safety of the industry as a whole. It is therefore important to understand the risks and problems associated with different shift work patterns.

What's the problem with shift work?

Working shifts can have many side-effects. The main ones are listed here.

- *Fatigue*. One of the most inevitable and damaging consequences of shift work is fatigue. This has been explicitly recognised on the railways since the time of the Hidden inquiry into the 1988 Clapham Junction accident. Fatigue is the subject of Regulation 25 in the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (known as ROGS) which came into force on 10 April 2006:

  "Every controller of safety critical work shall have in place arrangements to ensure, so far as is reasonably practicable, that a safety critical worker under his

management, supervision or control does not carry out safety critical work in circumstances where he is so fatigued or where he would be liable to become so fatigued that his health or safety or the health or safety of other persons on a transport system could be significantly affected.

The arrangements in paragraph (1) shall be reviewed by the controller of safety critical work where he has reason to doubt the effectiveness of those arrangements."

'Shift work creates several problems for people, but the biggest by far is **fatigue** – leading to increased risk of mistakes and accidents'

The HSE says fatigue from shift work and overtime is in the Top Ten topics for onshore HID (Hazardous Installations Directorate) industries. Fatigue levels clearly need to be monitored very carefully in shift workers, particularly those playing a safety critical role. It is generally recognised that on average adults need 7–8 hours sleep per night. Less sleep than required will incur a 'sleep debt'. A sleep debt can lead to impaired alertness, which will adversely affect fatigue and reaction times, concentration and judgement and decision making. Sleep debt is accumulative and over several days the effects can be compounded.

- *Health problems*. Gastro-intestinal problems can be common among shift workers. Peptic ulcers and other stomach disorders are five times higher among shift workers with night-shifts, compared to day workers or shift workers without night-shifts. The most likely reasons for this are that shift workers tend to take meals at irregular times and these meals are often rushed or interrupted. Shift workers tend to rely more on snack foods with a high fat content, and to drink more coffee to stay alert.

  Cardiovascular problems tend also to be more prevalent amongst shift workers. Again, the type of meals consumed and the lack of exercise is likely to contribute to this. Furthermore, it has been reported that some women workers can experience adverse effects on hormonal and reproductive functions.

- *Stress*. Shift work can undoubtedly increase work-related stress. This will particularly be the case when the employee has little control over the shifts worked, when shifts are unpredictable, where hours are long and unsociable, and where inadequate provision is made for rests and breaks.

- *Family problems*. Family life is often centred around the shared rhythms of sleep, mealtimes, work and recreation. Shift work can bring a separation from these shared rhythms of general life and can isolate the shift worker from family and friends.

- *Anxiety, irritability and depression*. These are more commonly reported amongst shift workers. In many cases they will clearly be inevitable consequences of the side-effects of shift work already discussed. However, they will also occur when a person feels they have no choice but to accept shift work.

How can you reduce shift work problems?

The main problem with shift work is that of fatigue. In March 2005 a major research study of shift work and fatigue in train drivers was completed for RSSB. The study identified a number of primary influences of shift work on fatigue and recommended a series of guidelines for reducing these influences.

Other key studies have also identified strategies for dealing with fatigue induced by shift work, as well as a number of its other side effects.

In the Panel on page 130, *How to manage shift work problems – a research perspective,* we have used these various sources to summarise the key shift work problems and strategies for their management. These guidelines are highly consistent with the advice published by ASLEF (see *Further information*).

There are a number of tools and techniques for assessing the fatigue risks associated with shift working patterns. The guidance for managing fatigue in safety critical work with reference to Regulation 25 of the ROGS (available from the ORR) is a key document for anyone on the railways who manages, supervises or controls workers doing safety critical work. It is required that effective arrangements are established for managing the risks of fatigue in safety critical workers. This management process should include the nine steps shown in the Panel on page 131, *Managing the risks arising from fatigue in safety critical workers*. You can find detailed descriptions of what to do at each of the steps in the ROGS Guidance. In working through this process you will probably find it helpful to make use of the Fatigue Risk Index tool from the HSE.

Conditions

How to manage shift work problems – a research perspective	
Shift work problem	**Management**
Long shift duration is a primary cause of fatigue. Its effect is most significant on night and early morning shifts.	• Operate a maximum shift length of 8–10 hrs for nights and early shifts.
Long periods of continuous duty without a break are particularly fatiguing. This can be especially so for drivers.	• Ensure breaks are taken of at least 15 minute duration, free from any work-related activities and that continuous driving time is restricted to 4 hours to reduce accident risk.
High percentage of hours worked per week is very fatiguing due to long shifts and short breaks between shifts – or both.	• Ensure a maximum of 55-60 hours per week for train drivers. This is consistent with a 55-hour rolling week limit for aircrew and a 56-hours per week limit for HGV drivers.
Consecutive shifts increase accident risk due to fatigue. The risk is greatest on consecutive night and early shifts due to cumulative sleep loss. Long consecutive shifts can result from workers volunteering to work rest days and Sundays.	• Ensure a maximum of 7 consecutive shifts before a rest day, with this reduced to 3 consecutive shifts for nights. • Review policy on napping. Napping during the duty period is permitted in a number of safety-critical industries. For example, airlines permit aircrew to take a 40-minute nap followed by a 20-minute recovery period during the cruise phase of the flight. Canadian and American railway companies have also introduced schemes allowing napping on duty. Nappers must be made aware of the recovery period required to overcome grogginess. In general, grogginess tends not to be a major problem with naps of less than 30 minutes.
Shift variability is often inevitable but can be fatiguing. The fatigue risk is greatest when there is a rapid switch from a late finish or night shift to an early shift. Shift variability is often increased by shift swapping between staff.	• Eliminate the requirement for shift variability and the opportunity for fatigue-inducing shift swapping. • However, be aware that allowing employees to select/swap shifts to tailor work to their needs can help reduce fatigue and can improve satisfaction with the shift work system.
Lack of rest between shifts is an obvious and common cause of shift work-related fatigue.	• Ensure a minimum rest period of 14 hours between night shifts and 12 hours between other shifts.
Lack of rest days is another common cause of shift work-related fatigue.	• Ensure a minimum of 2 rest days at the change from night to early shifts, and one rest day at the change from late to early shifts. Ensure one rest day after seven consecutive shifts.
Health problems associated with shift work can build up over prolonged periods of time (eg due to poor diet, weight gain, heart problems and disrupted sleep patterns)	• Ensure a continuing programme of education is in operation eg on the use of exercise and how to manage sleep at home eg exercise is often beneficial before the start of a late or night shift. • Ensure a continuing programme of health monitoring for the specific risks associated with shift work is in operation.
Lack of social interaction in late and night shifts exacerbates shift work-related fatigue.	• Social interaction is not always easy to address (eg one-man signal boxes), but it does provide stimulation and help counter fatigue.
Lack of work variety exacerbates shift work-related fatigue – especially on late and night duties.	• Providing variation in the work across a shift can help combat fatigue, but is not always easy. Where possible, make sure that employees are deterred from leaving tedious or routine tasks to the end of a shift when they are likely to be most drowsy.
Inadequate temperature, ventilation and lighting promote fatigue – especially shift work-related fatigue.	• Adequate lighting, proper ventilation and a comfortable working temperature will help control fatigue. A well-lit workplace signals to the body that it is time to be alert and awake.
Poor diet can arise from difficulties with eating at the right times or the right foods.	• Ensure there are facilities that enable – and a culture which encourages – regular, nutritious meals to be taken. • Caffeine can be a useful stimulant before and early on in a shift but should be avoided late in a shift if the employee is due to sleep shortly. • Ensure an education programme that teaches and reinforces good dietary practice, eg meals taken at the end of a shift should be easily digestible so that sleep is not disturbed due to an active digestive system.
Sources: RSSB research and general human factors literature	

This tool uses the five main factors that affect fatigue:

1 Shift start time

2 Shift duration

3 Length of time between shifts

4 Breaks within duties

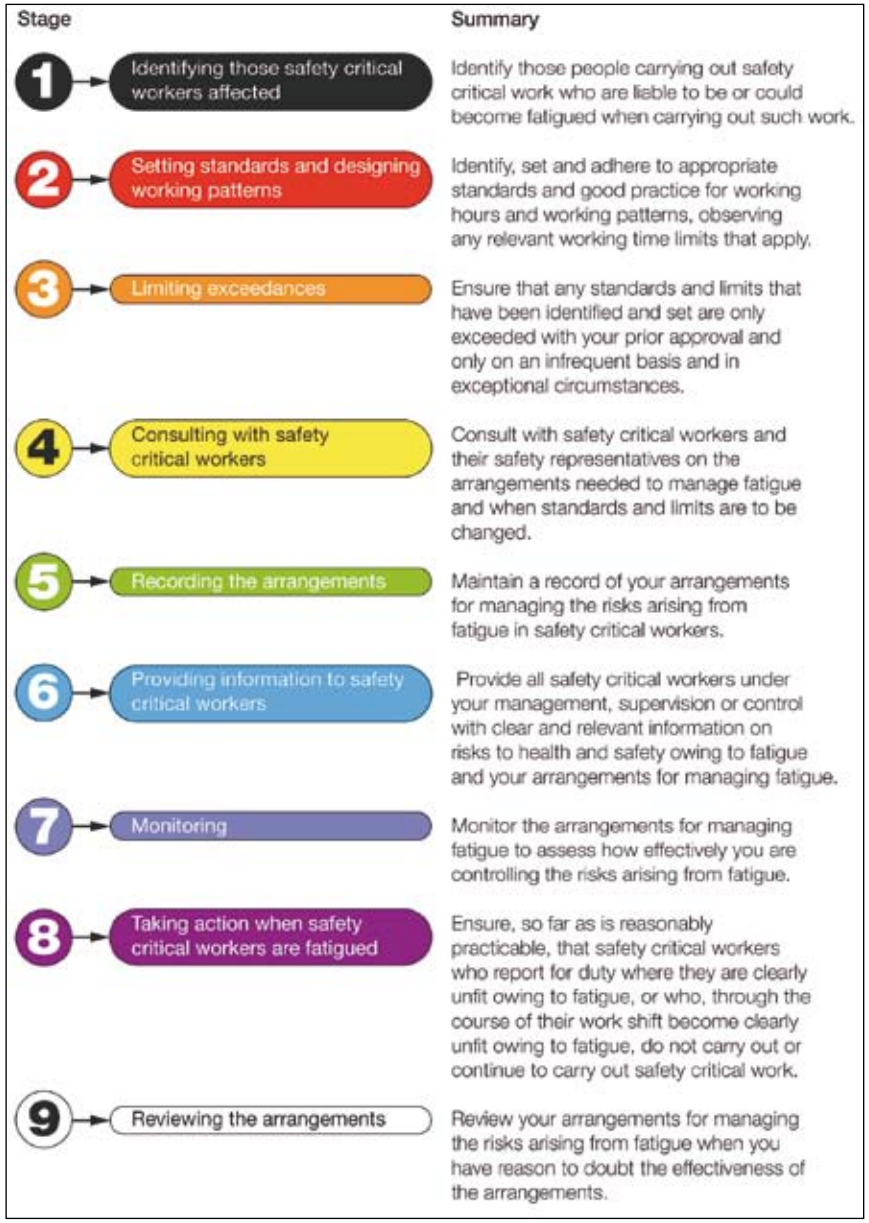
5 Number of consecutive shifts.

It provides scores for individual shifts, and these are then added up to give the total score for the roster pattern as a whole. It can thus be used to compare different shift patterns.

In addition to its use on the railways, The Health and Safety Laboratory has used the HSE Fatigue Index to compare fatigue levels associated with an 8-hour shift rota and a proposed 12-hour rota in other safety critical environments, including the offshore, nuclear, transport and chemical industries.

RSSB has published a series of resources aimed at combating fatigue through shift work – see *Further Information*.

Managing the risks arising from fatigue in safety critical workers (ROGS 2006)



Further information on shift work

1 ASLEF Shift work, lifestyle and health, ASLEF booklet

2 The London Chamber of Commerce and Industry: 24/7 Health effects: shift and night working – an employer's guide, Fact Sheet 10 July 2004

3 McGuffog A. Spencer M.B. Stone B.M. & Turner C. (2005) Guidelines for the management and reduction of fatigue in train drivers, for RSSB

4 RSSB (2005) 'Feeling tired' resources. As of May 2008 - www.rssb.co.uk/pdf/Feeling%20tired%20additional%20info.pdf

5 Railway Safety (1996), Railway (Safety Critical Work) Regulations 1994. Approved Code of Practice, HSE Books

6 Strategic Rail Authority (2003) Guidelines for the Implementation of the Working Time Directive, Aug 2003

7 Stone B.M. (2004) Evaluation of current tools and techniques used for estimating risks associated with shift patterns, QinetiQ Centre for Human Sciences Report, QinetiQ/KI/CHS/CR032327, for RSSB

8 Wedderburn A. (ed) (2000) Shift work and Health, Bulletin of European Studies on Time (BEST 1/2000), European Foundation for the Improvement of Living and Working Conditions www.eurofound.europa.eu/publications/htmlfiles/ef0009.htm (as of May 2008)

9 The Railways and Other Guided Transport Systems (Safety) Regulations 2006 can be accessed from the Office of Public Sector Information (OPSI) website at: www.opsi.gov.uk/si/si2006/uksi_20060599_en.pdf (as of May 2008)

10 The Railways and Other Guided Transport Systems (Safety) Regulations 2006 – Guidance on Regulations can be accessed from the Office of Rail Regulation (ORR) website at: www.rail-reg.gov.uk/server/show/ConWebDoc.7964 (as of May 2008)

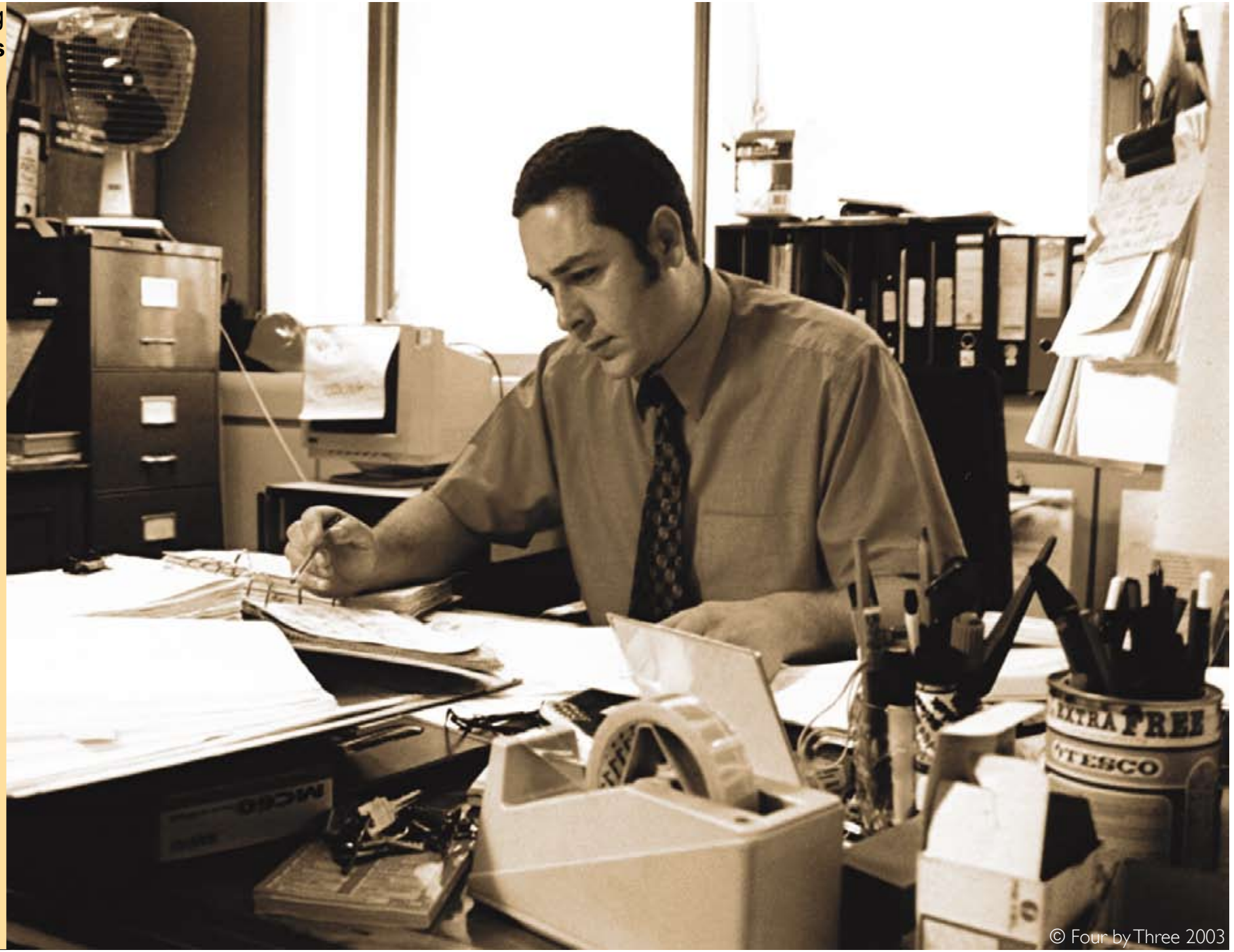
11 The development of a fatigue/risk index for shiftworkers, to be published by HSE Books in 2006

understanding
human factors

Techniques

understanding
human factors

Techniques



Part 3: Reference

Techniques

Parts 1 and 2 of this Guide describe a wide range of human factors issues that managers, designers, trainers and others on the railways are likely to encounter. They contain specific guidance and tools on how to deal with these issues. In addition, there are a large number of human factors techniques that can be used to answer particular questions.

In this section, a number of these techniques are introduced. They have been selected because you may find them of particular value in dealing with human factors issues on the railways. For each technique, you will find a description of when each technique might be of interest and what is involved in using it.

If you browse through the techniques, you will see that many of them have been developed to help with human factors issues associated with the introduction of new technologies – especially computer-based systems. These new systems have been having a major impact on the railways in recent years, and can be expected to have an even bigger impact in the coming years. Accordingly, the techniques described in this section are likely to have an increasing value in the railway industry and their use will become much more widespread than so far.

It is beyond the scope of this guide to describe how to carry out all these techniques in detail. If you are interested in a specific technique, we have provided references where you can find out more.

An authoritative collection of human factors techniques is summarised in DEFSTAN 00-25, the MOD's standard for human factors design.

A more detailed treatment of a comprehensive collection of these and other human factors techniques may be found in a book by Stanton et al published in 2005. In particular, this book describes the processes involved in using the techniques, as well as worked examples.

Many of these techniques are also summarised in Annex 3 of a recent major document on human factors integration published by the Ministry of Defence's Sea Systems Group published in 2006.

All three of these key references are provided below.

Alternatively you might want to talk with your organisation's human factors specialists. If so, the accounts of the techniques you find in this Guide may help you have a more informed discussion with them.

Key references

1. Def Stan 00-25 (2004) Human Factors for Designers of Systems Part 15 Issue 1, Principles and Processes. As of May 2008, you can download this document directly from the MOD's DefStan website here: www.dstan.mod.uk/data/00/025/15000100.pdf

2. Ministry of Defence (2006), MAP-01-011 Human Factors Integration Technical Guide, Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, MOD Abbey Wood, Bristol, BS34 8JH
As of May 2008, you can download this document directly from the HFI-DTC website here: www.hfidtc.com/pdf/MAP-01-011.pdf

3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Techniques

Which technique?

Technique	Input requirements	Output format	Primary users	Useful for...	Not useful if...
Applied Cognitive Task Analysis, p139	Structured interviews	Tabulated mental skills and demands	System designers	Understanding the mental skills and demands that a design will require from its users	No access to task expert
Brainstorming p140	Structured small group discussions	Structured list	Anyone	Generating ideas from a mixed group without letting status or seniority get in the way	Little chance of acting on results
Checklists p141	Structured paper or electronic form	Checked list	Anyone	Any kind of audit where a structure or systematic procedure is needed	Situation requires explanations of observed results
Cognitive Mapping p142	Interviews, workshops	Graphical representation of concepts	Anyone	Understanding the relationships between different perspectives or concepts – often useful to organise the results of a workshop	n/a
Cognitive Walk-through p143	Structured interviews	Video, audio or paper record of user responses	System designers	Evaluating the usability of user interface designs	Not enough time
Communications Usage Diagram, p143	Interviews and observations	Tabulated graphical data	System designers	Understanding the communications and collaborative requirements of geographically separated team members	Not enough time
Critical Decision Method, p144	Structured interviews	Annotated incident timeline	System designers Training designers	Understanding the mental skills and demands that were required by expert decision makers for past actual situations	No access to human factors experts who are also skilled interviewers
Critical Incident Technique, p145	Structured interviews	Annotated incident timeline	Incident investigators System designers	Understanding the decisions and rationale of participants in past actual situations	No access to skilled interviewer
Design Scenario Analysis, p145	Scenario storyboards	Video, audio or paper record of user responses	System designers	Proposing, evaluating and modifying design concepts without the need for expensive simulation	Design team unavailable to act out scenarios
Fault Trees p146	Actual incident report or detailed scenarios (for prospective events)	Graphical representation of root causes	Incident investigators Risk analysts	Analysing the root causes of actual or potential incidents	Incident involves large complex systems
Focus Groups p147	Structured small group discussions	Report	System designers	Understanding user or other stakeholder requirements	Process is not planned or participants are not representative
Groupware Task Analysis p147	Focus groups, brainstorming, scenario storyboards	Tabulated team task data	System designers	Understanding current team problems and migrating current team tasks to new system designs	Not enough time
Heuristic Analysis p148	Task-driven interview	Tabulated user response data	System designers	Rapidly obtaining user feedback about an interface design	Articulate task experts are unavailable
Hexagons p149	Structured small group discussions	Graphical representation	Anyone	Understanding the relationships between different perspectives or concepts - builds on cognitive mapping by revealing gaps	n/a
Hierarchical Task Analysis, p149	Interviews, focus groups, observation, questionnaires etc	Graphical representation and tabulated task data	Anyone	Understanding the detailed behavioural requirements, demands and procedures for successful task performance	Task is largely cognitive rather than behavioural
HEART p151	Structured process using pre-defined factors and scales	Tabulated error data and reduction strategies	System designers Risk analysts	Quantifying predicted human error in new systems	Task expert is not available

Which technique?					
Technique	**Input requirements**	**Output format**	**Primary users**	**Useful for...**	**Not useful if...**
Human Error HAZOP p152	Structured small group discussions	Tabulated error data	System designers Risk analysts	Prospectively assessing the likelihood and nature of errors in a system under design	Mixed team of engineers, operations staff, HF specialists unavailable
Human Reliability Analysis, p153	Interviews, focus groups, observation, questionnaires etc	Graphical representation and tabulated data	System designers Risk analysts	Analysing the probability of human error during system operation. HRA refers to a family that includes Fault Trees, HE HAZOP etc	Varies with its specific instances such as Fault Trees, HE HAZOP
Instantaneous Self-Assessment, p153	Operator's on-job use of electronic device at intervals	Workload profile across a shift	Anyone	Estimating operator workload throughout a work shift in both real world and simulated tasks	Specific sources of workload need to be identified
Integrated Performance Modelling Envt, p154	Task and system specifications, and performance requirements	Time and error forecasts	System designers Training designers	Modelling operator (and team) tasks, workload etc in normal, degraded and abnormal conditions for proposed complex systems	Task or human factors experts are not available
Interface Surveys p155	Structured survey form	Tabulated and summarised user response data	System designers	Evaluating the physical aspects of a user interface against available human factors criteria, guidelines and standards	No access to human factors expert
Interviews p155	One to one discussions	Structured or tabulated report	Anyone	Collecting both qualitative and quantitative data - in which people are asked open ended or closed questions respectively	Interviewer biases are not successfully addressed
Keystroke Level Model p156	Structured process applied to a task analysis	Keyboard task timings	System designers	Estimating times for keyboard-based tasks	Tasks are not computer-based or user performance is not serial
Layout Analysis p157	Interviews, walk-throughs and observation	Revised interface layout	System designers	Designing an interface based on the user's mental model of the way the task should be done	Users are unavailable or tasks are very complex
Link Analysis p157	Interviews, walk-throughs and observation	Tabulated and graphical interface design data	System designers	Designing an interface based on operational relationships (frequency and importance) between different task elements	Cognitive issues outweigh the physical relationships between task elements
Murphy Diagrams p158	Task analysis	Structured graphical root cause data	System designers Risk analysts	Analysing the root causes of past and potential errors for both single operator and team tasks	Task is large and complex
NASA Task Load Index p159	Operator's on-job response to probe questions	Overall workload score	System designers Risk analysts	Estimating operator mental workload, based on well validated principles	n/a
Observational Analysis p159	Video, audio or other data recording site preparation	Video, audio or paper record of user behaviour	Anyone	Collecting information about the visual or verbal aspects of an actual task or scenario	Properly trained observers who are also task experts are not available
Questionnaire p160	Structured design of the questionnaire form	Summary statistics	Anyone	Collecting large amounts of attitudinal data very cost-effectively for numerical analysis and summary	Analysis of performance is required (not analysis of what people say)
Qu. for Dist'd Assm't of Teams, p161	Team on-job response to questionnaires	Summary situation awareness scores	Anyone	Estimating the degree of mutual situational awareness of team members	Too much time has passed between task performance and use of technique
Qu. for User Interface Satisfaction, p161	Pre-defined questionnaire	Global and sub-scale usability scores	System designers	Assessing usability of user interfaces	n/a
Sequentially Timed Events Plotting, p162	Actual incident report; interviews	Graphical timeline	Incident investigators	Identifying the contributory events leading to an incident and facilitating discussion between investigators	Historical, time-based incident data is unavailable
Situation Awareness for SHAPE, p163	Operator's on-job response to probe questions	Summary situation awareness scores	System designers	Assessing situation awareness	Task expert who can conduct probe questions on-job is not available

Techniques

Which technique?

Technique	Input requirements	Output format	Primary users	Useful for...	Not useful if...
Situation Awareness Rating Technique, p164	Operator's on-job response to pre-defined rating scales	Overall situation awareness score for each team member	System designers Training designers	Estimating the degree of situational awareness of team members	Thorough analysis of situation awareness is required
Soft Systems Methodology, p164	Interviews and workshops with stakeholders	Model of the problem area and an action plan to deal with it	System designers Change managers	Establishing 'rich pictures' of complex organisational situations in order to characterise and solve problems	No access to experienced analysts - or the time to work with them
Software Usability Meas. Inventory, p165	Operator's post-task response to pre-defined questions	Global and sub-scale usability scores	System designers	Assessing usability of user interfaces in detail	Unwilling to spend €1,000 on the purchase price
Subjective Workload Assess. Technique, p166	Operator's response to pre-defined questions	Individual and overall workload scores for several dimensions	System designers	Estimating multiple aspects of workload for tasks based either on actual advanced system designs or a task analysis	Accurate detail is required for mental workload (vs time or stress)
System Usability Scale p167	Operator's post-task response to pre-defined questions	Simple overall usability score	System designers	Rapid, reliable, rough assessment of the usability of an interface design	Detailed usability analysis is required
Syst. Hum. Err. Red. & Pred. Approach, p167	Structured process using pre-defined error taxonomy	Tabulated errors and suggested remedies	System designers Risk analysts	Predicting human error from task analysis data, and identifying error reduction strategies	Cognitive components of error are critical to the task
Task and Training Reqts Methodology, p168	Structured process based on a task analysis	Tasks prone to skill fade, training gaps, required skills and teamwork	Training designers	Training needs analysis for team - especially for skills prone to skill fade	Task expert or sufficient time are not available
Task Centred System Design, p169	Structured process using an existing design	Principled re-design of system	System designers	Evaluating system design concepts using user-centred principles	Team of task expert, design engineers and system operators is not available
Team Cognitive Analysis p170	Observation and interviews using CDM-type structured process	Tabulated decision requirements	System designers Training designers	Understanding the decisions and decision making skills used by team members on a team task	Not enough time available or too much time elapsed since task
Team Decision Reqts Exercise, p171	Structured interviews	Tabulated decision requirements	System designers Training designers	Understanding the thought processes of team decision makers	Two skilled interviewers who are familiar with the technique not available
Team Workload Assessment, p171	Team member's on-job response to probe questions	Workload scores for each team member and the team as a whole	System designers	Estimating team workload, based on the NASA TLX technique	n/a
Teamworking Improv't Process, p172	Questionnaire and workshops	Prioritised remedies for specific teamworking problems	Change managers	Diagnosing and identifying cost-effective remedies to problems of teamworking within an organisation	n/a
User Trial p173	Interviews, focus groups, workshops, observation	Refined user requirements, training and skills recommendations	System designers Training designers	Evaluating a new system in terms of its usability and training requirements	n/a
Walk-through Analysis p173	Focus groups, workshops, interviews	Video, audio or paper record of user responses	System designers	Evaluating early system design concepts	Task experts are not available
Why-Because Analysis p174	Actual incident report	Annotated, graphical representation of the incident	Incident investigators	Analysing the root causes of actual incidents and suggesting countermeasures	Experienced incident analyst is not available
Workshops p175	Structured larger group discussions	Report	Anyone	Understanding user or other stakeholder requirements and feedback - and getting their ownership of a project	Process is not planned or participants are not representative

Applied Cognitive Task Analysis

Why is it useful?

Like most other areas, work on the railways has shifted over time from very physical work towards work that is much more 'mental' (also referred to as 'cognitive'). People are doing less in an obviously active way such as moving physical objects and controls. Instead they are doing much more work that goes on largely inside their heads: monitoring, thinking and deciding. Think, for example, of the difference between the work of a driver and fireman on a 1950s steam engine and the driver in the cab of a modern Pendolino train. Or between the work of a signaller in a traditional lever frame signal box and that of a signaller in an IECC signalling centre.

Much of this change can, of course, be attributed to the introduction of computer-based systems and equipment. The designers of these systems, and their associated jobs and training need to be able to understand and describe the cognitive tasks they are expecting people to undertake. But compared to traditional physical work, mental tasks are largely hidden, and one cannot see what the person is doing. It is to help make these tasks visible so they can be designed for and managed that the Applied Cognitive Task Analysis (ACTA) technique has been developed.

What does it do?

Cognitive Task Analysis is very useful for clarifying the thinking, decision making and judgement skills that tasks require, so that effective equipment and interface designs, and training, can be created. Applied Cognitive Task Analysis (ACTA) is one of the best of its class.

What does it involve?

ACTA is a suite of interview techniques designed to identify the thinking demands imposed by a task on an operator. The technique is aimed at situations where the most of the task goes on inside an operator's head (eg a train driver) rather than through observable behaviour (eg a trackman).

ACTA requires three kinds of interview with subject matter experts (SMEs) to be undertaken. First, the analyst works with one or more SME to prepare an overview of the task, usually set out as a diagram. Second, the analyst works with SMEs to clarify the knowledge needed by operators to perform each part of the task revealed in the task diagram. Third, the analyst works with the SME(s) through specific task scenarios in order to probe specific situations which are difficult or complex.

The results of these interviews are typically entered into a tabular format, which can then be used to inform either the design of the system or the design of training procedures.

Who can use it?

ACTA is primarily aimed at supporting the system design process. The success of the technique depends both on the availability of knowledgeable and articulate SMEs, as well as on ACTA analysts who are skilled at probing expert knowledge. While no specialist training in cognitive psychology is required, it is highly desirable to involve a human factors specialist in the use of the technique.

Finding out more

1. Militello L.G. & Militello J.B. (2000) Applied Cognitive Task Analysis (ACTA): A practitioner's toolkit for understanding cognitive task demands. In J. Annett & N. S Stanton (Eds) Task Analysis, 90-113, Taylor & Francis

2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Brainstorming

Why is it useful?

Safety on the railways can never be taken for granted. Circumstances are always changing and new ideas are constantly needed to ensure high levels of safety are maintained. Good ideas are not the monopoly of senior managers. Indeed, in relation to safety, it is often the staff at the sharp end – in the signal box, on the train, working on the line or on the platform – who have the best ideas on how safety can be improved. But these ideas can only be implemented if they are first brought to light. Often people in less senior positions are reluctant to make suggestions for fear of being criticised or because they think their ideas may seem foolish if they are not yet fully worked out. Brainstorming is a way of getting ideas from everyone out in the open so they can be developed and assessed.

What does it do?

Brainstorming is an easy to use discussion technique for generating ideas from a group without letting status or seniority get in the way. See also *Hexagons* for a complementary technique.

What does it involve?

A brainstorming session is a loosely structured discussion, in which group members are encouraged to float ideas. Although the group leader should have a clear idea of the problem to be solved, limited guidance is given and all participants are encouraged to put forward ideas without the fear of criticism. For example, an operations manager might conduct a session among engineering supervisors and COSSes in order to generate ideas and possible solutions for the management of a complex T3 possession.

A brainstorming session may typically last up to an hour or more. In the first phase, group members are encouraged to generate ideas without criticism. However outlandish they might seem, they are all noted without discussion where everyone can see them eg on a flip chart. In the second phase, the group members agree some evaluation criteria and then review each of the ideas, discarding any that appear to be infeasible. Sometimes it is helpful to use a formal vote (eg show of hands, secret ballot) to eliminate or prioritise ideas.

The result should be a list of ideas about what is involved in the problem, or what the possible solutions are.

Brainstorming is especially useful where everyone's views are equally important, but where discussions could be dominated by individuals of higher status. By seeking a wide range of views – initially, uncritically – over a range of ideas, brainstorming can achieve a comprehensive view of a problem and possible solutions.

Who can use it?

Anyone in the railway industry over wide range of problem areas. No special skills or resources are required other than a group of people, a quiet room for an hour or so and a flip chart.

Finding out more

1. Rawlinson J.G. (1981) Creative thinking and brainstorming, Gower
2. Van Gundy A.B. (1981) Techniques of structured problem solving, van Nostrand- Reinhold, New York

Checklists

Why is it useful?

There are many working situations on the railways where safety depends on ensuring that all necessary actions have been completed, and often completed in the right order. The process that a signaller and a PICOP have to go through when taking or handing back a possession is a good example here. Another example is the process that depot staff should follow in checking that a train is fit to enter service. Many safety-related incidents arise because a step has been missed out or not completed properly. Requiring staff to use a checklist is a straightforward way of minimising the risk that these types of error can occur.

What does it do?

A checklist is a simple and powerful tool that is in everyday use in a wide range of application areas. Its primary use is to check *situational status* eg of a possession or equipment.

What does it involve?

Checklists may already exist or else need to be developed from scratch for a particular purpose. Developing a checklist takes considerable attention and must be based on authoritative documentation and subject matter expert knowledge. *Brainstorming* and/or *workshops* can help in the checklist development process. This is to ensure that the items on the list are both relevant and appropriate for the purpose of the check. For example, a checklist to support a depot maintenance schedule for a train must contain all of the right items for that service interval without omissions. Similarly, the list should not allow simply a tick in the box if a more detailed investigative procedure is more appropriate. The flip side of this point is also important: checklists are not generally useful for explaining why things fail.

Checklists are useful in supporting the evaluation of designs of new equipments or interfaces. The references below provide some examples of evaluation checklists that have already been developed for this purpose. If you decide that a new checklist needs to be developed, you should ensure that input from designers, task experts, a range of users and subject matter experts is utilised in the checklist design. It is vital that the checklist is reviewed thoroughly by its target users and subject matter experts before being deployed.

Who can use it?

Anyone across the railway industry can use a preexisting checklist with minimal training, although they may need to be specially qualified to make the necessary technical judgments demanded. A more specialist group of subject matter experts is normally needed to design and evaluate a new checklist.

Finding out more

1. Ciavarelli A. (2002) Human Factors Checklist: An Aircraft Accident Investigation Tool, School of Aviation Safety, California
2. Human Engineering Ltd (2004) The Human Factors SPAD Hazard Checklist, Issue 2 HEL/RSSB/041123/RTB02, Network Rail
3. Kirwan B. & Ainsworth L.K. (eds) (1992) A guide to Task Analysis, Taylor & Francis
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Cognitive Mapping

Why is it useful?

Nearly every initiative to develop some feature of the railways involves groups of people working together, whether it is a group of designers working on a new system such as GSM-R, or a group of managers considering changes to the Rule Book. These groups often involve people from varied occupational backgrounds and experience. A major obstacle to progress is that all the participants see the topic they are addressing in totally different ways. Worse, they may be unaware that others see the issue so differently. This can often lead to misunderstanding, confusion – and even argument. What is needed is a way building up a way of visual representation of the topic or situation, so that different assumptions and viewpoints can become apparent, and eventually an agreed picture can be created. Cognitive mapping is one way of achieving this.

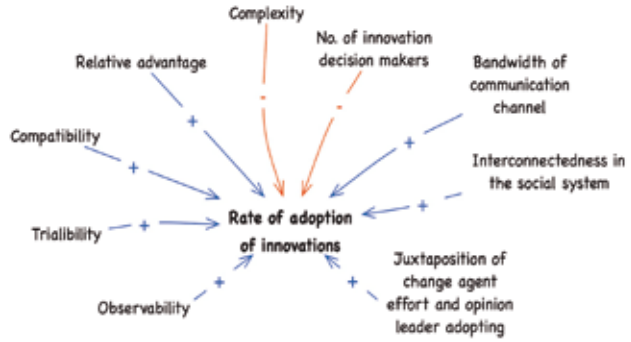
What does it do?

Cognitive mapping is a group activity that is useful for focusing the activity of discussion – eg in a *workshop* – where a key aim is to create a shared understanding of the different perspectives and requirements of the participants.

What does it involve?

Cognitive mapping produces a kind of map of how the participants see a situation or problem area. The map (also known as an influence diagram) is made up of concepts (represented as words or short phrases) and arrows that point from means to ends (ie from contributing factors to goals). A minus sign shows an inverse relationship between two concepts ie the more of one concept, the less of the other.

Example of a cognitive map (influence diagram)



This example shows the positive and negative influences held by a group of people on the rate by which organisational innovations (eg new IT systems) are likely to be adopted by staff. The diagram shows their belief for example that the more complex the system is, the less rapidly it will be adopted. Similarly, the greater the relative advantage of the new system, the more rapidly it will be adopted. Interesting and more complicated patterns of influence can be established when lines of influence can be drawn between many nodes. It is possible to calculate the effects of the influences on each other by representing the influence diagram in affordable computational systems thinking software such as STELLA™ or iTHINK™ (see References).

Who can use it?

Anyone capable of planning and running a workshop, although generating influence diagrams takes a little practice to get right.

Finding out more

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2. iSee Systems STELLA™ and iTHINK™ www.iseesystems.com/ (as of May 2008)

Cognitive Walk-through

Why is it useful?

Technology is providing the railways with many new forms of equipment and system. These can bring important benefits, but often, the new system is more complex than the one it replaces. This complexity may not be immediately obvious to the user, eg the IECC screen. The means by which the operator uses the equipment, how they communicate with it and how it communicates with them, is known as the 'human-machine interface' or 'human-computer interface' (HCI). The design of this interface is vital to ensuring safe and reliable performance. Before any design is finalised its usability must be assessed. One technique for conducting a usability assessment is the Cognitive Walk-through.

What does it do?

Cognitive Walk-through is a structured observation technique that helps an analyst evaluate the usability of an interface. The technique is a development of the traditional design walk-through method.

What does it involve?

The technique's emphasis is on examining the ease with which a new interface can be learned. The analyst makes this examination by applying a set of criteria that are concerned with the cognitive (thinking) processes required by the user to perform the task. Examples of these criteria include how obvious it is for the correct choice to be made, how clearly labels are linked to their associated actions, and how easy it is for the user to understand what they have done. The analyst 'walks through' each action that a user needs to take to carry out a task using prototype interfaces for driving a new type of train or using a new ticket machine. Each action is scrutinised in terms of technique's pre-defined criteria in order to estimate the impact made by the interface on the user's goals and actions.

Who can use it?

Cognitive Walk-through is primarily aimed at supporting the system design process. Its success depends both on the availability of knowledgeable and articulate task or subject matter experts, as well as on analysts who are skilled at applying the pre-defined criteria. It can also be quite time-intensive. While no specialist training in cognitive psychology is required, it is highly desirable to involve a human factors specialist.

Finding out more

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Communications Usage Diagram

Why is it useful?

Safety on the railways depends on teamwork. But many teams on the railways are not what people normally think of as teams. This is because teams on the railways often involve people working in different places and often only working together for a short time. For example, a train driver and a signaller may only be working together for a few minutes. During that time they share the same goals and they are dependent on each other. These arrangements are known as distributed teams. In such short-lived, physically separated teams the quality of communications is of the utmost importance. The Communications Usage Diagram can be a valuable aid for designers, trainers and managers responsible for ensuring that distributed teams can communicate when and how they need to.

What does it do?

A Communications Usage Diagram (CUD) is a technique for analysing and describing the communication aspects of distant *teamworking* (page 103).

What does it involve?

Creating a Communications Usage Diagram (CUD) involves specifying what is communicated between the geographical locations of each member or group that comprises a team. For each type of communication, the technology used is also specified, together with the pros and cons of that medium. The technique could potentially be applied in any domain involving communication or collaboration. For example, a CUD could be used to document the problems of communications and

supporting technologies between signallers, trackworkers, drivers and control at a particular location in order to determine the requirements for new communication procedures or technologies.

Who can use it?

Anyone involved in analysing communications problems and the potential for improvements. However, sufficient time should be allowed for the initial data collection, which can involve many interviews and observations.

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Critical Decision Method

Why is it useful?

In most situations signallers, train drivers, engineering supervisors, and other people working in safety critical roles on the railways can act in accordance with the Rule Book. But there are inevitably many situations in which the Rules do not apply, are conflicting or are unclear. This means rail workers have to make decisions which are often difficult and may have serious consequences if wrong. The Critical Decision Method is a means to help designers and planners understand these decisions in detail. It is a later version of the *Critical Incident Technique*.

What does it do?

The Critical Decision Method (CDM) is a relatively powerful, easy-to-use structured interview technique for revealing the thought processes of expert decision makers. It is useful for understanding task requirements for both system and training design.

What does it involve?

CDM works by means of a set of pre-defined probe questions that an analyst asks an expert about their decision-making. For example, an analyst could discover what cues the expert was using by asking *"How did you know that you needed to make the decision?"* Similarly, the expert's situational awareness could be probed with a question such as *"What information did you have available to you at the time of the decision?"* Video can be a useful means of ensuring that information generated by the probe questions is not missed, although video analysis can be time consuming. The information yielded can then be used to inform the development of new systems and/or associated training systems. CDM is useful at a very early stage in the design of a new operational or training system. For example, it could be used to infer the requirements for a new cab design from the actions of expert drivers using existing cabs.

Who can use it?

CDM requires at least two interviewers, preferably human factors specialists, who need to be reasonably skilled in the technique in order to get the most out of it.

Finding out more

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2. Klein G.A. Calderwood R. & MacGregor D. (1989) Critical Decision Method for Eliciting Knowledge. IEEE Transactions on Systems, Man and Cybernetics, 19(3), 462-472

3. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

4. O'Hare D. Wiggins M. Williams A. & Wong W. (2000) Cognitive task analyses for decision centred design and training. In J. Annett & N. Stanton (eds) Task Analysis, pp 170-190, Taylor & Francis

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Critical Incident Technique

Why is it useful?

In many situations on the railways it is important to know why people made the decisions that they did. This may be necessary to understand how a particular incident was caused, or it may be necessary when developing systems or procedures intended to help railway staff in safety critical roles to make better decisions. For example, the increased use of computer-based systems can not only provide staff with better quality information, such systems can also actively help staff predict how events will unfold in the future. This technique enables an analyst to explore in a systematic way how railway personnel have made particular incidents in critical situations in the past.

What does it do?

Critical Incident Technique (CIT) is an interview technique designed to help people reconstruct their roles, decisions and reasons for acting in the way they did, during the critical phases of a past, actual incident. CIT is an older techniques that has been developed more recently into the *Critical Decision Method* (CDM).

What does it involve?

CIT involves an analyst using a set of pre-defined probes within an interview convened for the purpose. The probes are a forerunner of the much more extensive probes used in CDM. They are simply aimed at eliciting information about the circumstances leading up to an incident, the critical actions or inactions, the results and other actions or inactions that might have made a difference. Today, such questions form the basis of debriefing railway staff after an incident affecting safety. However, like all retrospective techniques, it is subject to the unreliability of human memory and the interviewee's tendency to distort history by trying to make sense of things after an event. It is sometimes difficult to build a good timeline unless other corroborating data are available. A key value of CIT is that it can reveal poor design of both equipment and processes.

Who can use it?

CIT is a very useful and inexpensive investigative technique for someone already trained in interviewing skills. It is not necessary to be a human factors specialist to use the technique, although access to this specialism is of undoubted assistance in interpreting the results – and possibly guiding some of the questions.

Finding out more

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Design Scenario Analysis

Why is it useful?

Like any business, the railways need to constantly innovate to improve performance and safety. Being able to imagine not only new design concepts but also their use in a variety of settings is a powerful way to innovate. Design scenario analysis provides the means to explore new concepts in a wide range of new contexts.

What does it do?

Design scenario analysis is a technique that design teams can use to help generate, review and refine design concepts.

What does it involve?

Design scenario analysis works best with several - even many - members of a design team present. Together, they generate a new concept and set out a storyboard for it within some operational context which they also generate for the purpose. As they probe and challenge it, new parts of the 'story' are added and changes made to the design as a result. The techniques is not limited to equipment design. For example, design scenario analysis would be just as suited to the design of new procedures for the rule book as it would be for the design of catering trolleys for on-train use or new signalling panels. While it may sometimes be difficult to get all of the design team together in one place, the technique itself is inexpensive, flexible, highly creative (and enjoyable!), often leading to innovative results.

Who can use it?
Design teams.

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Fault Trees

Why is it useful?
Incidents on the railways typically involve some component failing or a person making an error. Many engineers and designers on the railways will be familiar with fault trees for describing how an incident was caused or for assessing the likelihood of a physical component or sub-system going wrong at some future point. Fault trees can also be used to examine how a procedure or other human action has gone wrong or could go wrong. For example, Rule Book designers could use the technique to discover errors that might occur when a signaller and COSS are arranging T12 protection, and estimating the probability of these errors occurring.

What does it do?
Fault trees are a relatively simple but effective root cause analysis technique for understanding and sometimes predicting multiple causes of failure events.

What does it involve?
The analyst creates a tree-like diagram to represent hardware failures and human errors. The contributing causes are linked together by AND and OR relations and each contributing cause is further analysed in terms of its own contributing causes. Care needs to be taken to keep the analysis going until the root causes (rather than the preceding causes) are properly documented.

The original use of this technique was to identify the root causes of actual incidents. However, it is also possible to use it throughout design in a predictive way, in order to try to eradicate failures before they arise.

Who can use it?
Anyone faced with the task of analysing the actual or likely causes of failure within an operational system. Little training is required, although a logical, systematic approach helps a lot. While the analysis of simple incidents generally requires modest amounts of time, more complex incident analyses can be quite time consuming.

Finding out more

1. Kirwan B. & Ainsworth L.K. (1992) A Guide to Task Analysis, Taylor & Francis

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Focus Groups

Why is it useful?

Focus groups have become mainly known for their use in the worlds of market research and politics. Market researchers use them to gauge consumer reaction to products and to work out how they can be presented more attractively. Political parties use focus groups to assess public opinion in relation to some issue of interest. If participants are correctly chosen, the right questions asked, and the right procedures followed, it has been found that a focus group with a small number of participants can be as accurate as a more traditional survey involving large numbers of people. There are many potential uses of focus groups in the railways. As well as finding out the views of, say, members of the public or staff members, focus groups can be used by more specialist groups such as trainers or system designers to establish how users will respond to a specific issue.

What does it do?

A focus group is a structured discussion that uses a small group of stakeholders to discuss a particular set of pre-defined topics. It is a smaller and more highly constrained version of a *workshop*.

What does it involve?

Focus groups normally involve a group of up to 8 people and 1 to 2 facilitators, and typically last for 2 to 4 hours. Typically, the facilitators encourage discussion of each topic by describing situations or scenarios and asking probe questions designed to reveal participant views and their rationale. In a railway setting, system designers might use them to elicit user requirements for a proposed system or to understand usability or workload issues of a new prototype; training designers might use them to modify a training method among a group of trainers.

Who can use it?

Experienced facilitators can enable focus groups to be a very useful, trustworthy and economic source of stakeholder information.

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Groupware Task Analysis

Why is it useful?

Groupware refers to a class of technical systems designed to improve the work of any collection of people who have to work together to achieve some defined set of goals. Groupware supports the more rapid and efficient sharing of information and passing of documents so that different individuals can each make their particular contribution to the on-going work. So far groupware has been mainly used for traditional office tasks, but there is immense scope for wider exploitation across the railways. For example, groupware offers the potential for much more reliable passing of information between staff involved in planning engineering works, the staff who will actually carry out the work, the signallers who must arrange protection with the PICOP, and the TOC staff who may be affected by the engineering works. Groupware systems are inevitably complex and careful analysis is required to ensure they will work correctly.

What does it do?

Groupware Task Analysis (GTA) is a technique for team task analysis. It is designed to migrate current team tasks to new system designs.

What does it involve?

The GTA analyst uses structured interviews and observation of team activities within current systems, The results are used to contribute to the design of new team-based systems. GTA provides a framework for a two part analysis. In the first part, the analyst describes the current system, eg signalling. This is done in order to ensure that the design team understands the current workflows

and communication patterns between signallers, drivers, control etc. In the second part, the analyst re-designs the current team task using new technologies to solve any problems and requirements presented by the current situation. The result is a representation of a proposed system together will all its assumptions for the future scenario(s) in which it will operate.

Who can use it?

Design teams – but it should be noted that the technique is time-intensive and resource-hungry.

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Heuristic Analysis

Why is it useful?

New equipment and systems – especially those that are computer-based – often provide many more facilities and features than the old equipment or system. The price paid for this new capability is that the interface (the means whereby the user interacts with the equipment or system) becomes much more complex and therefore more difficult. There are numerous techniques described elsewhere in Part 3 that provide thorough but time-consuming means of assessing user interfaces. The value of Heuristic Analysis is that it is quick and easy to use, although limited in certain respects.

What does it do?

Heuristic analysis is a rapid, simple, subjective technique for recording opinion about (eg) a task interface.

What does it involve?

The analyst walks the user through their task as systematically as possible and tries to spot the opportunities for error and other design weaknesses as they go. The technique can be re-used throughout the design process. The walk-through can be structured by the analyst in any way they choose, and any such structuring is likely to improve the quality of the results. Note, though, that any undesirable effects arising from complex interactions with other tasks or events are unlikely to arise or be spotted.

Who can use it?

Anyone can use heuristic analysis, but its results will only be as good as the analyst's ability and imagination to spot the negative aspects of the task during the walk-through.

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1. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

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Hexagons

Why is it useful?

There are many situations on the railways where a group of people need to come up with good ideas. *Brainstorming* is perhaps the most commonly used technique to generate lots of ideas. While writing ideas that the group comes up with on a flipchart or whiteboard will often work well, what is even better is to be able to move ideas around, so similar ideas can be grouped together. Being able to see what ideas have in common or how they differ, can often enable the group to develop the ideas further. Hexagons is a simple technique for helping with this process.

What does it do?

Hexagons is a simple technique which can be used to support *brainstorming*. It helps with the structuring of emergent ideas and the evaluation of their completeness.

What does it involve?

Hexagons involves a workshop session in which issues written on magnetic hexagons (alternatively, coloured post-it notes) can be grouped and classified. It is a way for a group to get a comprehensive picture of the problem they are tackling and it pushes the group into thinking about the gaps in the discussion so far.

Who can use it?

Anyone in the railway industry over a wide range of problem areas. If a magnetic whiteboard and magnets are not available, post-it notes are a good substitute.

Finding out more

1. Hodgson A.M. (1992) Hexagons for systems thinking, European Journal of Operational Research, 59, 220-230

Hierarchical Task Analysis

Why is it useful?

There are many situations in designing equipments, systems, training and jobs on the railways where it is necessary to have a clear understanding of what the various tasks entail. One of the most widely used techniques for doing this is hierarchical task analysis (HTA). HTA is based on the fact that most tasks can be decomposed into a hierarchy of goals. For example, a signaller's main task is to ensure the safe movement of trains. To achieve this goal he must carry out a number of sub-tasks: set routes, manage the taking of possessions, monitor level crossings, and so on. Each of these sub-tasks can be further broken down still further into smaller tasks (eg communicating with PICOP, protecting signals, placing reminders, completing forms). Tasks, sub-tasks and so on are progressively analysed until all the actions that form the fundamental building blocks have been identified. These basic acts can then form the basis of equipment design, training material development, and so on. HTA is often performed as a first step in many of the other techniques described here.

What does it do?

Hierarchical Task Analysis (HTA) is a systematic and well used method of *task analysis* (page 47) for comprehensively representing tasks as a hierarchical structure of goals and sub-goals. It works especially well for tasks that emphasise what operators must do rather than what they must think and the way they should think it.

Techniques

What does it involve?

HTA involves representing the task of interest as a tree-like structure of goals, operations and plans.

- *Goals* – These provide the purpose for carrying out the task - or some piece of it
- *Operations* – These are all the observable activities that must be carried out by the operator in order to achieve the goal
- *Plans* – These are the conditions for, and sequences by which, the operator carries out the operations.

Carrying out a HTA for a large or complicated task like driving a train or operating a signaller's NX panel can be quite time-consuming. While HTA affords many insights into a task, a key problem is that even when all the operations have been specified, it is often by no means obvious what should be done about the results – in terms of risk detection, error prevention or training – without a lot of further analysis.

Who can use it?

Anyone capable of applying a logical and systematic approach. While it is not necessary to be a human factors specialist to use the technique, such specialists are usually essential in interpreting and applying the results of the analysis eg via interventions in training, system or job design. In view of this it is recommended to involve human factors people on the analysis team from the very beginning,

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Human Error Assessment and Reduction Technique

Why is it useful?

Many people on the railways fulfil safety-critical roles – drivers, signallers, track workers, crossing keepers, station staff, and others. Safety on the railways depends critically upon identifying the kinds of errors these staff (and sometimes other groups, such as passengers) can make. The Human Error and Assessment Technique (HEART) is a relatively simple technique that not only helps railway personnel identify types of error, but also to assess the probability of each type of error occurring. This analysis provides a basis for then looking at ways of reducing the risks these errors occurring.

What does it do?

Human Error Assessment and Reduction Technique (HEART) is a technique for estimating the type and amount of human error likely to occur within a system, and helping to avert it.

What does it involve?

HEART is easy to understand and quick to apply. It requires the definition of representative task scenarios and then provides a straightforward process for assessing these scenarios with respect to the likelihood of human error. For example, a depot manager might examine all of the tasks that need to be undertaken by a fitter in carrying out a maintenance programme for a new train. The assessment process involves making judgements about human reliability in carrying out the main elements of the task by choosing between a number of pre-defined factors such as *"complex skill requiring high level of comprehension and skill"* or *"fairly simple task performed rapidly or given scant attention"*. Each statement is associated with a pre-defined weighting score. At the end, all of the weighting scores are multiplied to produce an overall score, which helps inform the identification remedial measures. These might include interventions which involve re-designing the maintenance schedule or re-training for it; improving the fitter's perception of risk; or assigning more experienced fitters etc. Helpfully, the remedial measures can themselves be calculated to determine their likely contribution to the reduction of the calculated probability of human error. The technique has been specially adapted for use in the railway industry.

Who can use it?

Anyone who can apply a logical, systematic approach: little training is required, although a human factors specialist is highly desirable as part of the training process, and a subject matter expert is needed to define the scenario(s) and assess the tasks within the scenario(s) against the HEART framework of statements.

Finding out more

1. Kirwan B. (1996) The validation of 3 Human Reliability Quantification techniques – THERP, HEART and JHEDI: Part 1 – technique descriptions and validation issues, Applied Ergonomics, Vol 27, 6, 359-373
2. Kirwan B. (1997) The validation of 3 Human Reliability Quantification techniques – THERP, HEART and JHEDI: Part 2 – Results of validation exercise, Applied Ergonomics, Vol 28, 1, 17-25
3. Kirwan B. (1997) The validation of 3 Human Reliability Quantification techniques – THERP, HEART and JHEDI: Part 3 – Practical aspects of the usage of the techniques, Applied Ergonomics, Vol 28, 1, 27-39
4. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol
5. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)
6. Williams J.C. (1986) HEART – a proposed method for assessing and reducing human error. In 9th Advances in Reliability Technology Symposium, Uni of Bradford

Human Error HAZOP

Why is it useful?

The concept of HAZOP (Hazard and Operability) has been widely used on the railways for some time. Human Error HAZOP is a particular form of HAZOP that focuses on the risks to safety posed by errors made by people. Human Error HAZOP thus has similarities to *HEART* but is more comprehensive and detailed, although also more demanding in time and effort.

What does it do?

Human Error HAZOP (Hazard and Operability) is a comprehensive and well accepted technique for assessing the likelihood and nature of human errors arising from fairly complex plant or plant processes at an advanced stage of their design.

What does it involve?

The Human Error HAZOP procedure needs to be applied by a team of design, engineering, operational and human factors personnel, specially assembled for the purpose, and led by someone who has had experience with the technique. Such a team might be assembled to review the way a new maintenance delivery depot will be operated. The team agrees a set of guide words (such as *'sooner than'*; *'later than'*, *'not done'*) that they then use to evaluate depot operations that have been systematically described beforehand – often as a hierarchical structure using a technique such as *HTA*. In our example, for each section of the depot or depot process, potential operational deviations are considered using the guide words to identify weak points and recommend ways of strengthening them.

The technique is apparently exhaustive, but it should be noted that even a team-based assessment will not be completely sensitive to the way in which the 'holes in the Swiss cheese' (as described in *Why do accidents happen?* on page 18) can suddenly line up.

Who can use it?

The Human Error HAZOP technique is resource-hungry. It requires a team of specially appointed disciplines to carry it out – including a human factors specialist. Crucially, the team leader needs to be experienced in the technique for it to be successfully applied in new situation. It is also time-intensive to carry out, typically requiring several weeks of team effort.

Finding out more

1. Kennedy R. & Kirwan B. (1998) Development of a Hazard and Operability-based method for identifying safety management vulnerabilities in high risk systems, Safety Science, Vol. 30, 249-274
2. Kirwan B. & Ainsworth L.K. (1992) A guide to Task Analysis, Taylor & Francis
3. Kirwan B. (1992) Human error identification in human reliability assessment. Part 1: Overview of approaches. Applied Ergonomics Vol. 23(5), 299 – 318
4. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol
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6. Swann C.D. & Preston M.L. (1995) Twenty-five years of HAZOPs. Journal of Loss Prevention in the Process Industries, Vol. 8, Issue 6, 1995, 349-353
7. Whalley (1988) Minimising the cause of human error. In B. Kirwan & L. K. Ainsworth (eds.) A Guide to Task Analysis. Taylor & Francis

Human Reliability Analysis

Why is it useful?

Although automation is an increasing feature of railway operations (eg ATPS, ATWS, ARS), safety on the railways still depends heavily on the reliability of the people who work on the trains, in signal boxes, on platforms, and on the track. Any initiatives to improve current safety or to raise safety levels in the future must take account of how reliably staff can carry out the tasks for which they remain responsible. A variety of techniques – collectively known as Human Reliability Analysis – are now available to help human factors and safety specialists assess how reliably humans can operate in a given situation.

What does it do?

Human reliability analysis (HRA) refers to a family of techniques, all of which are aimed at identifying the probability of different types of human error during system operation. Such information then forms the basis for system re-design and other error reduction measures.

What does it involve?

Several techniques are available for human reliability analysis. These techniques include *Fault Trees*, *HEART* and *HE HAZOP*. The techniques vary in terms of the skills and knowledge they require and the time they take to carry out. However, all of them require some form of task analysis (page 47) to be carried out first so that the tasks and their associated demands are clarified.

Generally speaking, HRA works by associating task inputs, actions and outputs to categories of error. The probability of errors occurring is calculated either by generating a fault tree or through the use of principles based on actual data, if available. The overall probability of error is calculated by multiplying the individual task results together. If the final result reveals a potential problem, then the design or training assumptions can be changed and the analysis re-run. If Tasks and system design components associated with unacceptable potential error rates may need to be subject to more detailed modelling.

Who can use it?

Varies with the specific technique, although human factors specialists should generally be involved in order to ensure the technique is used effectively and its results interpreted accurately. RSSB is currently developing a rail specific HRA technique. This is initially driver based, but will be extended to other operational groups in due course.

Finding out more

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2. Kirwan B. (1994) A Guide to Practical Human Reliability Assessment, Taylor & Francis

3. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

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Instantaneous Self-Assessment (of workload)

Why is it useful?

There are many situations on the railways where it is necessary to assess the workload of a given member of staff. For example, as a result of re-signalling it may be proposed to move a two man team (signaller and crossing keeper) from a mechanical signal box to an area signalling centre, and as part of this move to integrate both old jobs into a single new job. The question then is can one person now perform the tasks previously carried out by two while maintaining safety levels? This is a problem for workload assessment. Instantaneous Self Assessment of Workload is one of a number of techniques that can be used to make an estimate of the level of workload associated with a particular job.

What does it do?

Instantaneous self-assessment (ISA) of *workload* (page 125) is a very cheap and reasonably effective way of estimating patterns of operator workload throughout a work shift on real-world, as well as simulated, tasks.

What does it involve?

ISA involves operators (eg signallers at an NX panel or control room operators) briefly pausing in their tasks every few minutes in order to rate their workload on a simple scale of 1 (low) to 5 (high). Very often, arrangements can be made for participants to rate themselves using a simple keypad that can be made to flash whenever it is time to provide a rating. More simply, the analyst can simply obtain ratings verbally. When the

shift is completed, the collected data can be graphically summarised to show the workload peaks and troughs.

Who can use it?

Anyone, although a human factors specialist is of benefit in order to ensure its correct use, and to assist in results interpretation and options for action.

Finding out more

1. Kirwan B. Evans A. Donohoe L. Kilner A. Lamoureux T. Atkinson T. & MacKendrick H. (1997) Human Factors in the ATM System Design Life Cycle. FAA/Eurocontrol ATM R&D Seminar, Paris, France http://atm-seminar-97.eurocontrol.fr/ (as of May 2008)
2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol
3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Integrated Performance Modelling Environment

Why is it useful?

In changing working arrangements or developing new systems it is often desirable to assess how well people can perform in a range of situations eg can they work quickly, reliably and safely enough? Human performance is influenced by many different factors. Factors such as time on shift, workload, and individual experience are just a few of the important factors affecting work on the railways. Taking all of these into account when making estimates can often be difficult. Increasingly, computer models are available which enable a range of factors to be represented and which can be used to explore human performance rapidly and reliably. The Integrated Performance Modelling Environment (IPME) was originally developed to assess human performance in highly demanding military situations, but is also relevant for use by railway system designers and others.

What does it do?

IPME is a sophisticated software-based environment for modelling designs for prospective systems comprising teams of people and technology. It is a commercial product and probably the best of its class in terms of *usability* (page 28), validity and reliability.

What does it involve?

The Integrated Performance Modelling Environment (IPME) uses simulation of the operator(s), the task, the task environment and the prospective system design to answer questions about human performance in terms of speed, error rates and accuracy. In the railway industry, IPME might be used to model a new design for an operations control room, complete with human team, computers, displays and communications equipment. Notably, IPME can be made to connect with other simulations through industry standard protocols. This means that the new design for a control room could be connected to manned NX panel simulators in order to increase functionality and thereby, the scope of the evaluation.

When the simulation is run, the task network uses the underlying micro-models to determine what happens. The performance of the network is also influenced by the way the environment model, the team model and the performance shaping functions are set up. The simulation can be run thousands of times in a short time in order to build up a set of results for a whole simulated population of operators.

Who can use it?

Analysts need training in IPME before they can use it and the user team will need to include both a subject matter expert and a human factors specialist.

Finding out more

1. Micro Analysis & Design Inc, Boulder Colorado, www.maad.com/index.pl/ipme (as of May 2008)

Interface Surveys

Why is it useful?
The usability of facilities provided to train drivers, signallers and other staff is a key factor – not only in safety, but also in job satisfaction, stress levels, amount of training needed, and so on. Assessing the quality of a new user interface or one under development can be a time consuming activity. Interface Surveys offer one reasonably quick and simple means of gaining a representative sample of data about user reactions to a system.

What does it do?
Interface surveys are a straightforward approach to detecting a wide range of human-machine interface design flaws in existing systems or advanced prototypes.

What does it involve?
The technique involves surveying one or more aspects of the human-machine design, which needs to exist as a working operational or prototype system. Examples include advanced prototypes for a new signalling panel or train cab design. The aspects to be reviewed might include areas such as controls and displays, coding conventions (eg colours and symbols, and environmental factors such as noise, illumination, temperature and humidity levels). A further, often fruitful, aspect for investigation includes an examination of what modifications operators have made to similar existing systems in order to overcome design flaws eg the use of notes stuck on displays and self-made aids. For each survey deemed relevant, the analyst needs to produce a survey data collection form, drawing upon available human factors criteria, guidelines and standards, as well as known sources of interface problems.

Who can use it?
Human factors specialists are needed to design the survey forms, which can then be used by a much wider range of personnel.

Finding out more
1. Kirwan B. & Ainsworth L.K. (1992) A guide to Task Analysis, Taylor & Francis

2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

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Interviews

Why is it useful?
Interviews are already used for many purposes on the railway, eg in recruitment, performance appraisal and incident investigation. Many interviews 'just happen'. But to be truly effective an interview needs to be properly planned and structured. The objectives of the interview need to be clear and the questions need to be chosen to best achieve the objectives. The interviewer and the interviewee need to have prepared themselves for the interview. Good interviewing needs to be seen as a technique that must be learned.

What does it do?
The interview is a well-used one-to-one technique for gathering, probing and confirming subjectively reported information in a very wide range of application areas.

What does it involve?
Interviews need to be well structured, with considerable prior thought being given to their objectives and logic. Interviews may be *qualitative* – in which people are asked open-ended questions designed to get at their opinions, beliefs and values; or they may be *quantitative* – in which people are asked closed questions designed to elicit yes/no or rating scale type responses.

In most cases, the interview design should be piloted and fine-tuned before being carried out for real. The interviewer should be clear about how they are going to record the information that will be generated. At the start of each interview, the interviewer should also clarify for the interviewee what use will be made of the information

and how far it will be attributable. When conducting an interview, it is a good idea to start on a particular topic with an open-ended question, and then once the interviewee has answered, use a probing question to gather further information. Closed questions should be used to confirm understanding and obtain agreement.

Generally speaking, a qualitative interview should last no more than an hour. A quantitative interview should last no more than 15 or 20 minutes.

Who can use it?

Interviews should be conducted by skilled individuals in order to avoid interviewer biases, to generate reliable information and to deduce trustworthy conclusions. Within human factors, the technique has many important uses including *selection* (page 79), appraisal, *training needs analysis* (page 55), system design, system *usability* (page 28), attitudes, job analysis, *task analysis* (page 47), and error and incident investigation.

Finding out more

1. Network Rail, DSM Post-SPAD Interview Process – Interview Technique and Checklist

2. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Keystroke Level Model

Why is it useful?

More and more jobs on the railways involve the use of computers, and therefore also usually, keyboards and associated devices such as a mouse. One of the most prominent examples is the change in the signaller's job from one of using levers, telephone and bell codes in a traditional mechanical box to one in which nearly all operations are carried out via a computer terminal in an IECC signalling centre. One can also point to the common use nowadays of laptop computers by PICOPs. Train drivers and other on-train staff will also increasingly become computer users as new systems such as ERTMS and GSM-R become operational. Where rail computer users are performing safety critical tasks it is often important to know how long the various operations they must carry out will take. The Keystroke Level Model is a way of doing this.

What does it do?

The Keystroke Level Model (KLM) is an easy way of estimating times for serial keyboard-based user tasks.

What does it involve?

KLM provides data on the time it takes for a common range of individual keyboard operations to be carried out by users with differing levels of expertise. The technique also specifies a number of rules for applying the time data to the keyboard operations and a formula for combining the results into an overall performance time for the keyboard task.

Who can use it?

Anyone can learn to use this technique, which requires very little training.

Finding out more

1. Card S.K. Moran T.P. & Newell A. (1983) The psychology of human computer interaction, Lawrence Erlbaum Associates, NJ

2. Salvendy G. (1997) Handbook of human factors and ergonomics, 2nd edition, John Wiley, Canada

3. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

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Layout Analysis

Why is it useful?

The layout of controls and equipment in traditional signal boxes and train cabs has been refined over many years of experience. The shift to totally new types of controls and equipment largely made possible through the introduction of computer-based systems has meant designers must now to rely on careful analysis to decide the best layout of controls and displays – especially since relevant operational experience is often lacking. Layout Analysis is one technique to support the work of the designer in this area.

What does it do?

Layout Analysis is a technique for arranging the components of an interface for simple to moderately complex tasks in a way that is consistent with the operator's mental model, so that the controls, displays and information are positioned where they are expected.

What does it involve?

The technique involves the analyst working with one or more representative operators through a number of re-organisations of the interface components. In the first re-organisation, the components are arranged into functional groups eg in an NX panel, all the points switches would be located on one place, while level crossing CCTV controls might be placed in another, relative to the CCTV display. In subsequent re-organisations, these groups are arranged in terms of their *importance*, followed by their *sequence*, and finally their *frequency* of access. The resulting final arrangement is likely to be the one that best fits the mental model of the user involved in the analysis. It follows that other operators may differ, and that different results might also arise for operations during abnormal, degraded, or emergency conditions, or indeed any conditions that are not considered during the analysis.

Who can use it?

Anyone with access to a representative (group of) expert users. Little training is required. However, it will usually be of benefit to check on the interpretation of the results with a human factors specialist.

Finding out more

1. Easterby R. (1984) Tasks, processes and display design. In R. Easterby & H. Zwaga (Eds.), Information Design (pp. 19-36). John Wiley

2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Link Analysis

Why is it useful?

Train drivers and signallers have constantly to shift their attention from one aspect of their work to another. For example, a driver has to monitor his various instruments while maintaining continuous awareness of signals and what is happening on the track. Designers of new systems must ensure that the components are organised in a way that enables the driver or signaller to allocate his attention in the most appropriate and efficient manner at any moment in time. This is what Link Analysis can help to accomplish.

What does it do?

Link Analysis is an easy-to-use and systematic technique for *interface design* (page 33). It reveals the actual relationships for the user between components in operational or prototype systems. This information can be used to create a user interface that is simpler to learn and use.

What does it involve?

Links are movements of the human operator's focus of attention eg a driver's gaze that moves between the train speed gauge, the AWS sunflower display and a signal on the route ahead. A link analysis systematically records these movements as an operator performs their task eg driving with a new cab design. Data capture can be achieved by a walk-through or observation analysis. Where rapid or fine attentional shifts are used by the operator, data capture may require more specialist eye or head movement recording apparatus.

The results of the analysis are usually captured in a diagram or table of the system components, annotated to show their importance, frequency, function and sequence of use. This table can then be studied to suggest more effective workstation layouts.

Who can use it?

Link analysis is primarily aimed at helping system and training designers to analyse the layout of panel displays for eg cab driving, control rooms, signal boxes etc. No special skills are required, although rehearsal in the technique is beneficial before its use to collect important data.

Finding out more

1. Drury C.G. (1990) Methods for direct observation of performance, In Wilson, J. And Corlett, E. N. Evaluation of Human Work: A practical Ergonomics Methodology, 2nd Edition, Taylor & Francis, 45–68
2. Kirwan B. (1994) A guide to practical human reliability Assessment, Taylor & Francis
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Murphy Diagrams

Why is it useful?

It is common on the railways to have to find out why something has gone wrong or why someone made an error. Simply blaming the culprit may be satisfying but rarely brings about any underlying improvement. What is needed is a means for going deeper, to identify the underlying or root cause. This basic cause may be hard to find, perhaps originating some time before the problem becomes visible. The Ladbroke Grove accident provides a clear example. One of the train drivers did not see a red signal. Was this just carelessness? Was it simply a result of his inexperience and lack of training? Examination of the records showed that a number of other drivers had also passed this signal at danger. Were they all careless and badly trained? Or was there some problem with this particular signal and its sighting? Murphy Diagrams are one of several ways of analysing incidents to get to the real cause rather than just the immediately obvious one.

What does it do?

Murphy diagrams is used for analysing human error – for individual operators or teams. It was developed to analyse past errors, although it can also be used predictively.

What does it involve?

Murphy diagrams get their name from the common saying that 'if anything can go wrong, it will'. Starting with a comprehensive description of the task, the analyst classifies each task step into one of a number of decision making categories. For example, the analyst might assign the signaller's step of looking at their NX panel as *"Identification of system state"* and then calling a driver on the cab radio for information as *"Interpretation of situation"*. The analyst then breaks each task step down into successes and failures. As in the *Fault Trees* technique, each of the failures are analysed further to identify the sources of error eg 'wrong train driver called' or 'wrong code used'. In turn, these errors can be further analysed into problems that could be addressed eg 'train code data unavailable' or 'lack of training in train code information'.

Who can use it?

Anyone faced with the task of analysing the causes of incidents. The technique requires little training. However, it is not practicable for large and complex tasks.

Finding out more

1. Kirwan B. & Ainsworth L.K (1992) A guide to Task Analysis, Taylor & Francis
2. Kirwan B. (1992a) Human error identification in human reliability assessment. Part 1: Overview of approaches. Applied Ergonomics Vol. 23(5), 299 – 318
3. Kirwan B. (1992b) Human error identification in human reliability assessment. Part 2: detailed comparison of techniques. App. Erg, 23, 371-381
4. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol
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NASA-Task Load Index

Why is it useful?

For some workers on the railways, workload can be a real problem. A signaller responsible for a busy section of track with a complicated layout (a number of junctions and cross-overs) may find they are stretched to their limit when also required to deal with two or more gangs of workers wanting to work on the line. Such a person is suffering from *overload*. In contrast, a lookout on a quiet stretch of track may suffer from the problems of *underload*. With little to do and nothing much happening his level of vigilance may drop, so that his attention has wandered when a train finally appears and he must warn the gang of workers on the line. The more accurately one can characterise and measure workload, the more appropriate measures can be taken to ensure levels of workload remain within the optimal range. The NASA Task Load Index is one of the more sophisticated techniques for measuring workload.

What does it do?

The NASA Task Load Index (TLX) is one of the best known, best performing and best respected mental workload assessment techniques.

What does it involve?

The NASA TLX technique involves observing operators at work – often via an experimental trial – and then asking them to rate their experience using six workload scales. For example, signallers could be observed at their panels during busy and off-peak periods, or during simulator sessions at one of the Signalling Training Centres at Watford or Leeds. The six workload scales are concerned with different kinds of workload and include mental demand, physical demand, time pressure, effort, performance effectiveness and level of frustration. The six scales are then combined to produce an overall workload rating score. The technique can be used in both software and paper forms.

Who can use it?

Human factors specialists are required – both to design or confirm the adequacy of the experimental trial and to administer the technique. The mental workload measurement methods developed for use by the UK railway industry have been largely based on NASA-TLX.

Finding out more

1. Hart S.G. & Staveland L.E. (1988) Development of a multi-dimensional workload rating scale: Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), Human Mental Workload. Elsevier, Amsterdam

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4. Vidulich, M. A. & Tsang, P. S. (1986) Technique of subjective workload assessment: A comparison of SWAT and the NASA bipolar method. Ergonomics, 29 (11), 1385-1398

Observational Analysis

Why is it useful?

Like *interviewing*, a lot of observation is carried out on the railways and for a similar variety of purposes. Managers observe train drivers and signallers to check on their competence; LOMs monitor voice recordings to see that proper communication procedures are being followed; and many more besides. Again as with interviewing, good observation requires careful planning and preparation. Who is to be observed? Doing what? Who should be the observer? What should the observer be looking for? How will the observational data be captured? And analysed? Sound guidance is available for all these questions.

What does it do?

Observational analysis is a technique for the systematic collection of behavioural information generated during task performance. It is already in wide use across the railway industry eg through competence assessment programmes. Observational analysis is useful in many of the human factors areas covered by this Guide, especially design, training and staffing. Very often, observational data constitutes the groundwork for other human factors analyses, such as *task analysis* (page 47), error analysis and *communications* (page 106) analysis.

What does it involve?

Observation can take place directly through co-location with the operators or remotely, via one-way glass or video. Note, however, that the perceived presence of observers (whether direct or remote) often changes the performance that would have otherwise taken place. Successful application of this technique depends

principally on adequately structuring the observation (eg via a *checklist* or other form); the familiarity of the observers with what is being observed; and awareness of observer biases (see sections on *selection* (page 79) and *risk* (page 15)). It should also be noted that the technique often needs considerable amounts of time to analyse recorded data – up to a day to process an hour's worth of video, for example.

Who can use it?

Anyone who can apply a logical, systematic approach. However, human factors specialists can be of great benefit in assisting with structuring the observation so as to guard against observer bias, as well as in helping to analyse and interpret the results.

Finding out more

1. Baber C. & Stanton N.A. (1996) Observation as a technique for Usability Evaluations. In P. Jordan et al (eds.), Usability in Industry, pp 85-94, Taylor & Francis
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Questionnaire

Why is it useful?

Passengers on trains are frequently asked to fill in a questionnaire, and many companies use questionnaires to obtain a variety of types of information from their staff. As well as gathering factual information, questionnaires are especially useful in finding out opinions and attitudes. Rail organisations increasingly realise that staff attitudes are an important element in both safety and performance. Staff and public attitudes need particularly to be taken into account when the organisation is seeking to introduce change. As with *interviews* and *observation*, the familiarity of questionnaires often means they are used without sufficient forethought. Clarity of objectives, care in formulating questions, proper definition of the sample to receive the questionnaire, choice of appropriate forms of analysis are all factors that must be considered if the results obtained are to be trustworthy. Several questionnaires that have been developed for specific purposes are described in this Part of the Guide.

What does it do?

Questionnaires are a very powerful and cost-effective technique for measuring the attitudes and feelings of a large number of people in a very wide range of application areas.

What does it involve?

Designing an effective questionnaire – eg to support a staff feedback process – requires a wide ranging set of skills. It involves being very clear about the purpose of the questionnaire, being realistic about the scope and type of information that can be collected; being clear about the way the information will be analysed – and the type of conclusions that can be drawn; and designing and promoting the questionnaire in a way which maximises the response rate from its target audience. Piloting the design – sometimes through several versions – is often an important component of effective design. One of the most important considerations is that questionnaires reflect what people say, which is by no means what they do. For some applications, analysts may be able to use pre-defined questionnaires such as *SUS* (System Usability Scale), *QUIS* (Questionnaire for User Interface Satisfaction) and *SUMI* (Software Usability Measurement Inventory). It is often best to check out the results and apparent implications of questionnaire results by reflecting them back to representatives of the target groups, eg via *focus groups* or *workshops*.

Who can use it?

While anyone can apparently utilise this technique, effective questionnaire design, followed by fair analysis and reporting of resulting data requires a range of skills. People in most organisations' HR Departments or human factors specialists will be able to provide good advice.

Finding out more

1. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol
2. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Questionnaires for Distributed Assessment of Team Mutual Awareness

Why is it useful?

Teamwork is a factor that is increasingly recognised as an essential ingredient of safe work on the railways. Train drivers, signallers, station staff, track workers and others all depend on each other to ensure accidents do not happen. A feature of teamwork that has been receiving increasing attention is team awareness. Different individuals working collaboratively together can only do this effectively and safely if they share a common appreciation of the overall situation. Without such a shared awareness, the right actions cannot be chosen, and the actions of different participants cannot be coordinated with each other. This questionnaire has been designed to help team leaders, trainers and others assess how well their teams perform in terms of building up a shared awareness of each other and the situation they are all working within.

What does it do?

The Questionnaires for Distributed Assessment of Team Mutual Awareness is a technique for eliciting information from team members about their degree of mutual awareness during performance of the team task.

What does it involve?

The technique involves administering three pre-defined questionnaires covering different aspects of the mutual awareness of team members. The first questionnaire is concerned with team *task* awareness; the second is concerned with team *workload* awareness; and the third is concerned with *teamwork* awareness. The results of each questionnaire are combined to provide an overall measure of team mutual awareness.

The questionnaires need to be administered immediately after a team task session - either operational or simulated. For example, a training manager might wish to assess the degree of team mutual awareness within a control room under different operational conditions. The results could be used to modify training programme content for new trainees. Alternatively, a systems design manager might use the technique in the same setting in order to inform a new control room design.

Who can use it?

This is an easy technique for almost any analyst to use with few training requirements.

Finding out more

1. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

2. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Questionnaire for User Interface Satisfaction

Why is it useful?

As computer-based systems become ever more widespread on the railways, it becomes important not only to assess their ease of use, but also how satisfactory these systems are for their users. A system that is easy to use does not necessarily lead to user satisfaction. For example, a system that requires its users to complete many small steps to carry out a given transaction, may lead to frustration if there is no way for the more experienced user to make short-cuts. This questionnaire provides a standard means for assessing user satisfaction.

What does it do?

The Questionnaire for User Interface Satisfaction (QUIS) is an inexpensive and easy-to-use technique for assessing the acceptability of interfaces. The technique compares well with *SUS*, which is even simpler – see *Usability testing*, page 28.

What does it involve?

Using QUIS involves asking operators to carry out a computer-based task and then provide ratings on around 30 separate aspects of their satisfaction with the interface. These aspects include such items as the confusability of the information on the screen; the difficulty with which the interface can be operated; and the frequency with which the computer provides information about what it is doing. The technique might be very useful, for example, in assessing the user acceptability of advanced prototypes for internal railway information systems such as TRUST or

the RIMINI planning system; or else external systems such as passenger ticket machines.

Who can use it?

This is an easy technique for almost any analyst to use with few training requirements.

Finding out more

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2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Sequentially Timed Events Plotting

Why is it useful?

Many hundreds of incidents occur on the railways each year that require a formal investigation. Many managers find themselves involved in carrying out these investigations. Even apparently simple incidents often turn out to be much more complex than expected on closer inspection. Large volumes of data need to be gathered and scrutinised. These typically include interview reports, statements, voice recordings, forms, logs, and so on. Organising all these data into a form where the all-important question 'why did this incident happen?' can be a daunting challenge. This technique is one means of arranging and presenting a large volume of data in forms that aid interpretation and diagnosis.

What does it do?

STEP addresses the problem of how to focus on relevant information within the high volumes of data generated by accident or incident investigation. STEP develops a visual representation of the event, allowing the investigator to identify what happened and why.

What does it involve?

Using STEP involves creating a diagram of the main actors, events and relationships plotted against time. The resulting matrix can answer 'where', 'what', 'when' and 'how' questions involved in an accident or incident investigation. The information from the analysis of safety problems can be used to identify appropriate recommendations and actions, which if carried out would prevent the incident occurring again.

The technique lends itself well to both simple and more complex investigations. If the incident or accident is complex, it is useful to split the analysis into sections, for example, design of equipment, planning of the work, and the work carried out before the incident.

Who can use it?

The STEP technique can be readily used by rail accident investigators with little training, although it can be quite time consuming to complete since it may require a number of iterations to correctly identify the sequence of events, and the safety problems or failures.

Finding out more

1. Hendrick, K. & Benner, L. (1987) Investigating accidents with STEP. New York: Marcel Decker

2. Johnson, S. O., Herrera, I. A., Jersin, E., Rosness, R., Vatn, J., Veiseth, M., Tungland, M., Bergersen, C. E. B. (2004) The Track to Safety Culture (SafeCulture) – a toolkit for operability analysis of cross border rail traffic, focusing on safety culture. SINTEF for the UIC

Situation Awareness for SHAPE

Why is it useful?

Compared to earlier times, today's railway worker has to keep a lot more in mind at any one time. Think, for example, of signallers in a modern power box. The length of the section for which they are responsible may be many times longer than that of their predecessors working in a mechanical box. They are also likely to be monitoring the movements of many more trains. Panel or IECC technology helps them to do this, but they must also build up and maintain a mental picture of the situation. This mental picture or model is essential to be able to project how the situation will develop into the future, thus enabling timely action to ensure a smooth service without unnecessary disruption or other problems. Train drivers also need to maintain awareness of complex and rapidly changing situations, and the demands on them will increase as new communication and information systems provide them with much more information than they have had historically.

Designers, trainers, managers and others have an increasing need to assess the demands for situation awareness of new or changed jobs. The two techniques described here were developed in the field of air traffic management to help analyse and assess situation awareness aspects of tasks.

What does it do?

The Situation Awareness for SHAPE (SASHA) methodology consists of two complementary techniques for assessing an operator's *situational awareness* (SA) (page 33). The methodology was developed for air traffic control but could be developed for use with real-time display-based railway tasks quite well, eg signalling, control room operation, cab driving.

What does it involve?

The first of the two SASHA techniques is SASHA_L. This generates probes to the operator during the task, which can be either operational or simulated. These probes are issued either by the analyst or (if the task is simulated) possibly by computer. In either case, there is no requirement for the task to be stopped. The idea is to measures both accuracy and response times to the probes to help infer the operator's situation awareness. For example, SASHA_L probes to a signaller might include questions such as: *"Which train needs to be attended to next?"; "Which train is moving faster?";* or *"Which train would benefit from a direct route?"*.

The second technique is SASHA_Q. This is a short questionnaire that is presented to the operator immediately after task performance. The questions are answered using 5-point scales from 'Never' to 'Always' or 'Often'. For example, SASHA_Q questions to a signaller might include: *"Did you have the feeling that you were able to plan and organise your work as you wanted?"*; and *"Were you surprised by a call that you were not expecting?"*

Who can use it?

While the SASHA techniques are simple to apply, the training time could be high for the non-computerised version. This reflects the time taken for the analyst (who should be a subject matter expert) to become proficient at generating relevant SA probes during the task.

Finding out more

1. Jeannot, E. Kelly, C. & Thompson, D. (2003) The development of Situation Awareness measures in ATM systems. EATMP report. HRS/HSP-005-REP-01

2. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Situation Awareness Rating Technique

Why is it useful?

Most safety critical jobs on the railways require the person doing the job to maintain a high level of awareness of the situation that not only provides a picture of the present situation but also how the situation will develop in the future. Where two or more people need to collaborate on a task in a dynamic situation, they can only do this as long as they share a common awareness of the aspects that affect them both. This technique is designed to help designers and others assess the shared situation awareness requirements of a task.

What does it do?

The Situation Awareness Rating Technique (SART) is a technique for assessing team members' *situation awareness* (page 33). It can provide useful input to team workstation design and training.

What does it involve?

SART involves the analyst eliciting ratings on ten aspects of situational awareness from team members immediately after they have completed a task. The ten aspects include factors such as the perceived familiarity, complexity and instability of the situation, and quantity and quality of information.

There is also a quicker version of the technique which collapses the ten SART factors into just three. These three groupings are concerned with demands on the operator's attention; the attentional resources available to the operator; and the ability of the operator to understand the situation.

Who can use it?

SART is quick and easy to use with few training requirements.

Finding out more

1. Selcon S.J. & Taylor R.M. (1989) Evaluation of the Situation Awareness Rating Technique (SART) as a tool for aircrew system design, Proceedings of AGARD Symposium on Situational Awareness in Aerospace operation, Copenhagen

2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

4. Taylor R.M. (1990) Situational Awareness Rating Technique (SART): The development of a tool for aircrew systems design. In Situational Awareness in Aerospace Operations (AGARD-CP-478) pp3/1 –3/17, Neuilly Sur Seine, France: NATO-AGARD

Soft Systems Methodology

Why is it useful?

Recent history in the railway industry (and in many other industries) shows that it is exceedingly difficult to design and introduce complex systems. Of course, under the impact of new technologies, systems have become much more complex in recent years and are destined to become still more complex. The most common cause of failure in developing complex systems lies in the definition of the system requirements. People across an organisation often do not agree what the system is for or how it should work. Often, they are never all consulted. The Soft Systems Methodology is a well-worked out process by which stakeholders in a new system work together to build up an agreed conceptual model of the system: what it should be and what it should do. This conceptual model then provides a more reliable foundation for the subsequent detailed specification of the system.

What does it do?

Soft Systems Methodology (SSM) is an approach to general problem solving that emphasises interpretation and meaning rather than hard measurement and quantitative analysis. It is based on systems thinking and is especially useful for user requirements analysis, but it has also been used to support organisational restructuring and performance indicator development.

What does it involve?

The SSM analyst starts with a stakeholder analysis and then creates conceptual models of system activities based on root definitions of key system elements. A cornerstone of SSM is its emphasis on taking a number

of different viewpoints of the system. The stakeholders provide two such viewpoints – *users* and *beneficiaries*. Other viewpoints include the system *function*, its *context* and its *environmental constraints*. When the models have been developed, they are compared with reality in order to determine how any gaps between the two can be reduced. SSM underlines the view that systems arises out of an organisational need and must fit into an organisation and its culture by servicing multiple perspectives. In the railways, the technique would be suited to the development of a wide range of processes for which user requirements needed to be defined in a multi-stakeholder context eg the Rule Book or possession management.

Who can use it?

SSM analysts do not need to be trained in any particular discipline in order to use the technique, although an affinity for systems thinking helps a lot. However, the technique itself requires significant training time and a complex application may take several months to complete.

Finding out more

1. Checkland P. (1989) Soft systems methodology, in Rosenhead J. (Ed.), Rational analysis for a problematic world, 71-120, John Wiley
2. Checkland P. & Scholes J. (1990) Soft systems methodology in action, John Wiley
3. Checkland P. (1981, 1998) Systems Thinking, Systems Practice, John Wiley

Software Usability Measurement Inventory

Why is it useful?

Increasingly, railway workers are users of software systems, even though they may not always be aware of software embedded in a piece of equipment that is not obviously a computer. In very many situations safety may depend on the usability of the software. This technique is designed to assess the usability of software measured against a set of attitude statements.

What does it do?

The Software Usability Measurement Inventory (SUMI) is a commercial, comprehensive and quick *usability testing* (page 28) technique that provides a much more fine-grained analysis than its even quicker (and free) stablemate, *SUS* (System Usability Scale).

What does it involve?

SUMI involves people using a software application and then rating their experience in terms of 50 attitude statements. Each statements requires one of three responses: 'agree', 'don't know' or 'disagree'. Examples of SUMI statements are:

- *This software responds slowly to inputs.*
- *The instructions and prompts are helpful.*
- *The way that system information is presented is clear and understandable.*
- *I would not like to use this software every day.*

SUMI's output includes a global usability score, several more specialised usability scores for aspects such as the software's helpfulness, control and learnability, and a benchmark score that allows the analyst to know if any aspects of the software under test are very different from expected norms.

This technique would be very useful as part of the testing suite of anyone responsible for the design, usability or acceptability of any new software system proposed for deployment within the railways.

Who can use it?

Anyone - requires very little training. SUMI is a commercial product that requires a licence fee of over €1,000.

Finding out more

1. Kirakowski J. (1996) The Software usability measurement inventory: background and usage. In P. Jordan, B. Thomas, & B. Weerdmeester (eds) Usability Evaluation in Industry. Taylor & Francis
2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol
3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)
4. SUMI website (as of May 2008) www.ucc.ie/hfrg/questionnaires/sumi/index.html

Subjective Workload Assessment Technique

Why is it useful?

Safety can be affected by workload that is too low as well as too high. Workload is essentially the experience of the person doing the work. What might be high workload for one person may be perfectly tolerable to another. This workload assessment technique relies upon asking workers to assess their own workload using rating scales that they are first helped to develop specially for their specific task.

What does it do?

Subjective Workload Assessment Technique (SWAT) is a commonly used alternative to NASA TLX, offering greater insight into the reasons for high *workload* (page 125). However, it is not very sensitive to mental workload.

What does it involve?

SWAT involves measuring three aspects of operator workload: time load is concerned with time limits and the extent to which tasks must be carried out together; mental effort load is concerned with attention and mental processing; and stress load is concerned with operator characteristics that are known to affect task performance, (eg training, fatigue).

The process by which these three measures are taken lends considerable power to the results, but is a little involved. In particular, the scale to be used must be customised for each task of interest by the operators, who then perform the task and use the scale to rate the workload they experience.

Who can use it?

The technique is time-consuming to set up, and preferably requires an analyst with previous experience with it. A human factors specialist is of benefit to assist with technique administration and interpretation.

Finding out more

1. Cha D.W. (2001) Comparative study of subjective workload assessment techniques for the evaluation of ITS-orientated human-machine interface systems. Journal of Korean Society of Transportation. Vol 19 (3), 45-58

2. Dean T.F. (1997) Directory of Design support methods, Defence Technical Information Centre, DTIC-AM. MATRIS Office, ADA 328 375, September

3. Hart S.G. & Staveland L.E. (1988) Development of a multi-dimensional workload rating scale: Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), Human Mental Workload, Elsevier, Amsterdam

4. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

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6. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

7. Vidulich M.A. & Tsang P.S. (1986) Collecting NASA Workload Ratings. Moffett Field, CA. NASA Ames Research Center

8. Vidulich M.A. & Tsang P.S. (1986) Technique of subjective workload assessment: A comparison of SWAT and the NASA bipolar method. Ergonomics, 29 (11), 1385-1398

System Usability Scale

Why is it useful?

System usability is central to safety. This is true whether the system in question is a trackman with the right tools for changing a fishplate, the operator and their road-rail machine, a signaller with an IECC workstation, a driver of a Voyager train, a train crew operating the refreshments trolley, or passengers trying to find their way in and out of Pendolino toilets. Techniques for assessing usability vary greatly in the detail they provide and the effort required for their use. This is perhaps the simplest usability assessment technique currently available.

What does it do?

The System Usability Scale (SUS) is a simple questionnaire, used to rate the *usability* (page 28) of an existing system or advanced prototype product.

What does it involve?

SUS consists of ten usability statements with which participants are asked to indicate the extent of their agreement after completing a task using the system under test. Answers are coded according to a simple procedure and a total score is calculated for overall usability.

Who can use it?

Anyone - requires very little training and very little time to apply. It is the simplest and quickest means of assessing the overall usability of a product or device.

Finding out more

1. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

2. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Systematic Human Error Reduction and Prediction Approach

Why is it useful?

People working on the railways perform many different types of task. As with all human acts, errors can occur. In many situations it is desirable to know in what ways the task can go wrong, how probable it is it will go wrong, and how much it matters if it goes wrong. For example, many human errors on the railway are related to communication. Communications can go wrong in many ways: you can forget to tell somebody something they need to know, you can mix up numbers, you can speak unclearly, the person you are talking to may interpret what you say in a way other than what you intended, and so on. If you are talking to a colleague about next week's roster, little harm may result from the error. If you are an IWA reporting your position to a signaller, then any misunderstanding might put you in serious danger. This technique allows potential errors to be identified and described in a way that allows measures to be taken to reduce the risk of this error actually occurring.

What does it do?

Systematic Human Error Reduction and Prediction (SHERPA) is one of the best techniques that has been produced for human error analysis, prediction and reduction.

What does it involve?

SHERPA starts with a *task analysis* (page 47) and, commencing with the lowest level, classifies operations into one of several types of human activity, including action, retrieval, checking, selection or communication. For each classification made, the analyst decides the likely errors, their potential consequences, the recovery path, and the probability and criticality of their occurrence. Finally, the analyst considers how the identified errors could be best avoided eg by equipment re-design, training, new procedures, or organisational changes.

Who can use it?

Human factors specialists working in conjunction with subject matter experts.

Finding out more

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2. Embrey D.E. (1986) SHERPA: A systematic human error reduction and prediction approach. Paper presented at the International Meeting on Advances in Nuclear Power Systems, Knoxville, Tennessee
3. Embrey D.E. (1993) Quantitative and qualitative prediction of human error in safety assessments. Institute of Chemical Engineers Symposium Series, 130, 329-350
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Task and Training Requirements Methodology

Why is it useful?

One of the main means of helping to ensure that railway staff can do their jobs reliably is training. Tasks vary in terms of what type, and how much, training they require. There are many forms of training, and finding the right form to develop the knowledge and skills required needs careful analysis. Once learned, tasks also vary in whether they need to be re-learned at intervals. Proverbially, once you have learned to ride a bike you never forget how. But other tasks, for example, those requiring the application of complex rules, can get 'rusty' if not regularly practiced. This methodology is one of a number designed to analyse training requirements, but has particular features that make it valuable in the identification of training solutions in a team context.

What does it do?

The Task and Training Requirements Methodology (TTRAM) is a kind of *training needs analysis* (TNA) (page 55) and is oriented towards TNA for teams. It is very useful for identifying tasks prone to *skill fade* (page 64) as well as training gaps. It identifies the underlying skills associated with each task and helps with the identification of training solutions. Finally, it rates the level of teamwork required for each task step.

What does it involve?

TTRAM requires an analyst to apply two pre-defined scales for skill fade and skill practice to task information gained from interviews with subject matter experts.

The skill fade score addresses task difficulty, degree of prior learning and frequency of task performance. The practice score addresses the amount, frequency and quality of practice. The results are two scores which are compared to identify training gaps. For example, the technique could help to determine refresher intervals for different signalling panels in a signal box, or for different maintenance tasks for train fitters in a depot. TTRAM provides further tools to help identify how training gaps can be filled with suitable training technologies and media.

Who can use it?

TTRAM requires considerable access to subject matter experts and greatly benefits from human factors or training specialists. It is also very time-consuming to use.

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Task-Centred System Design

Why is it useful?

As work systems in trains, signalling, stations, and track work become ever more complex, it becomes increasingly difficult to ensure that the system will do what it is supposed to do, safely and reliably. This methodology is more than a technique, but is a whole design approach that enables a thorough assessment to be made of an emerging system design.

What does it do?

Task-Centred System Design (TCSD) is a methodology for evaluating new system design that incorporates the principles of *user-centred design* (page 25) from the start.

What does it involve?

TCSD involves a multi-disciplinary design team going through a number of analytic phases. The team first uses interviews and workshops to identify user groups and example tasks for the proposed new system. Next the team develops a number of representative task scenarios. One by one, these are used to test the design until the team is satisfied. The team collectively walks-through the scenarios, using role-play and imagination to 'experience' the system from the point of view of the identified users. The output of the technique is a refined system design which can also contribute to job design as well as training requirements specification.

One application of TCSD on the railways might be in the design of a new control room that can cope with normal, abnormal, degraded and emergency conditions. Another example is the design of a new multi-section signal box.

Who can use it?

The power of the technique depends on the quality of the design team members and their ability to select and utilise the right scenarios to test the evolving design. It also depends on their imagination when they walk-through the scenarios. For the most accurate and reliable conclusions, the team needs to include subject matter experts, designers, human factors specialists and operators.

Finding out more

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3. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

4. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Team Cognitive Task Analysis

Why is it useful?

Two trends are noticeable on the railways. One is that work is becoming more cognitive (ie mental) rather than physical. The other is that the numbers of groups of railway workers that can be considered as teams is increasing as new technologies let different occupations work together in a more direct and responsive manner. For example, a train driver and a signaller can already be considered as a team while the driver's train is passing through the signaller's section. As new technologies such as ERTMS enter service, this working relationship will become even closer and more dynamic. The form of analysis described here integrates several techniques to enable the tasks carried out by teams rather than individuals to be examined to support design and training initiatives.

What does it do?

Team Cognitive Task Analysis (TCTA) adapts and combines *cognitive task analysis* (page 49), *Critical Decision Method (CDM)* and *Team Decision Requirements Exercise (TDRE)* to improve understanding of how a team makes decisions as they work together on a team task. It is particularly useful in understanding *teamworking* (page 107) and in helping to design team workflows and diagnose team training needs.

What does it involve?

TCTA should be carried out for some defined purpose, such as error reduction, improving performance efficiency or making changes to team numbers or quality. A TCTA analysis involves observing performance of an existing team task and interviewing team members. Observed incidents and decisions made by team members are classified in terms of several factors that underpin team task performance such as shared situation awareness and planning skills. For each incident classified in this way, the analyst documents the information and resources used by the team member(s) in making their decisions. The analyst also records any difficulties experienced by the decision makers eg failures in communication or technology. The output of the technique is a decision requirements table which sets out how more effective decisions can be made in similar team tasks and environments in the future.

TCTA could be profitably employed in the many areas of the railway industry that rely on teamwork, eg railway control rooms, signal boxes, trackwork. The outcome would be improvements to the training of teams, and/or changes to the team structure or procedures that support the teamwork.

Who can use it?

TCTA requires analysts who are well trained and experienced in the technique and its related techniques (*CDM* and *TDRE*). Such people are likely to be human factors specialists.

Finding out more

1. Klein G. (2000) Cognitive Task Analysis of Teams. In J. M. Schraagen, S. F. Chipman, V. L. Shalin (Eds) Cognitive Task Analysis. pp417-431, Lawrence Erlbaum Associates

2. Klein G. & Armstrong, A.A. (In Press) Critical Decision Method. In Stanton et al (Eds) Handbook of Human Factors and Ergonomics methods, Taylor & Francis

3. Klein G.A. Calderwood R. & MacGregor D. (1989) Critical Decision Method for Eliciting Knowledge. IEEE Transactions on Systems, Man and Cybernetics, 19(3), 462-472

4. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

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Team Decision Requirements Exercise

Why is it useful?

In some important situations, especially such as after a major incident, decisions are not made not just by individuals but by groups of people working together as a team. In preparing for such instances it is important to have worked out how the team should operate together to make the decision, what information they will require, how and when they should communicate, and so on. This technique is one way of gaining a necessary understanding of these team decision making requirements.

What does it do?

The Team Decision Requirements Exercise (TDRE) is a relatively powerful, easy-to-use structured interview technique for revealing how critical decisions are made by a team during task performance. It is useful for understanding task requirements for both system and training design. TDRE is a variation of *Critical Decision Method* (CDM) (itself a development of *Critical Incidents Technique* CIT). The technique is also a component of *Team Cognitive Task Analysis*.

What does it involve?

TDRE involves carrying out one or more group interviews with the team under analysis. The team is probed with questions aimed at eliciting their approach to decision making and its associated information sources, difficulties, errors and potential improvements. The output of the technique is a decision requirements table which sets out how more effective decisions can be made in similar team tasks and environments in the future.

As for Team Cognitive Task Analysis, TDRE could be profitably employed in the many areas of the railway industry that rely on teamwork, eg railway control rooms, signal boxes, trackwork. The outcome would be improvements to the training of teams, based on a better understanding of the objectives, roles, procedures, difficulties, communications and expertise of existing team members.

Who can use it?

TDRE requires two analysts who are skilled in the technique – and particularly interviewing – in order to get the most out of it. Other than prior experience with the technique, it is of some benefit if the analysts are also subject matter experts.

Finding out more

1. Klinger D.W. & Hahn B.B. (In Press) Team Decision Requirement Exercise: Making Team Decision Requirements Explicit

2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Team Workload Assessment

Why is it useful?

The workload of an individual worker on the railways is obviously important in planning jobs, systems, and so on. One reason why teamwork can be so effective is that workload can be shared amongst members of the team, helping to ensure that no one person is either over-loaded or under-loaded. In setting up working arrangements and system support to teams it is valuable to be able to estimate the workload on the entire team under varying working conditions. This technique helps designers and planners estimate team workload, as well as individual workload.

What does it do?

Team Workload Assessment (TWA) is a technique that extends the respected *NASA-TLX* workload assessment instrument for use in team settings.

What does it involve?

In addition to the standard *NASA-TLX* procedure, the TWA extension requires team members to make two assessments: one is of their own workload while the second is of the workload of the whole team. The assessments from each are team member are then combined, using a prescribed formula, to create a team task workload score.

The mental workload measurement methods developed for use by the UK railway industry have been largely based on NASA-TLX. The TWA is capable of providing a highly relevant extension, increasing its utility for railway environments – not only control rooms and

signal boxes where team members are co-located, but also for distributed teams such as drivers, signallers and trackworkers who must work together eg for the duration of an incident.

Who can use it?

Human factors specialists are required – to design or confirm the adequacy of the experimental trial and to administer the technique.

Finding out more

1. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

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Teamworking Improvement Process

Why is it useful?

Many safety critical tasks on the railways depend on good quality teamwork. For example, the COSS, lookout and site warden must work closely together to ensure the safety of a gang of track workers. Good teamwork depends on many factors: training, motivation, willingness to communicate, openness to learning, and so on. There is almost always scope for improving teamwork. This methodology takes a company in the railway industry through assessment and diagnosis activities, which lay the foundations for choosing the most cost-effective method for improving teamwork.

What does it do?

The Teamworking Improvement Process (TIP) was developed specifically for the railway industry from an analysis of best practice in *teamworking* (page 103). It is a highly practical process that requires a small project team drawn from the organisation under analysis.

What does it involve?

TIP involves a three phase process that takes place over 12 months or so. The technique provides survey, spreadsheet and workshop tools to perform a diagnosis of the organisation's teamworking proficiency, to analyse the best improvement route, and then to measure the benefits following implementation of the teamworking interventions selected.

Who can use it?

The technique can be implemented by a small team of railway line managers, a training or HR manager and front-line staff. While the technique requires little resource or training to implement, the teamworking interventions generated by the process may require significant organisational resource to implement should the organisation decide to do so.

Finding out more

1. Gregory D. & Shanahan P. (2004) Teamworking best practice in the railway industry: The Journey Guide, Gregory Harland Ltd, for RSSB, Euston

User Trial

Why is it useful?

Any change or innovation on the railways always entails an element of risk. The railways comprise a complex system of people, rules, infrastructure, technology, rolling stock, procedures and working practices. How well any change will work is often hard to predict. Changes often have unexpected and unwelcome side effects. The introduction of any new or changed feature of work which is safety critical must be properly evaluated through a carefully controlled user trial.

What does it do?

A user trial is structured session in which a new system, process or procedure is tested with its intended users for the purpose of generating feedback to its designers. Types of feedback may include *usability* (page 28), *workload* (page 125) and *situation awareness* (page 33).

What does it involve?

Conducting an effective user trial involves setting clear trial objectives, defining representative trial tasks, choosing representative users, selecting and applying appropriate within-trial techniques (eg *SUMI*, *ISA*, *SASHA*), interviewing participants (if necessary), analysing and summarising the trial data, and making clear, practicable recommendations.

Who can use it?

Designing and running a user trial requires a wide range of skills. Statisticians may be needed to design balanced trials that can simultaneously examine several different factors of interest. Subject matter experts may be needed to design representative tasks. Human factors specialists may be needed to identify some of the factors for study and/or control for human biases within the user trial, specialists may be needed to administer the selected technique(s), and designers will be needed to configure the trial system and consider the trial's conclusions.

Finding out more

1. Salvendy G. (1997) Handbook of human factors and ergonomics, 2nd edition, John Wiley, Canada
2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol
3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Walk-through Analysis

Why is it useful?

Developing new systems for the railways requires major investment in time, effort and money. The later the need for any change to a developing system, the greater the cost entailed in going back and doing things differently. The earlier any potential problems with, say, usability or maintainability, are identified, the better. This technique has been created to assist designers and developers pick up any problems at the earliest opportunity when the costs of remedial action are lowest.

What does it do?

Walk-through Analysis is a technique in which qualified personnel 'walk-through' a representative task using a prototype system or process. It is a powerful, cheap and re-usable technique for evaluating a new design. It is limited only by the imagination and creativity of its users.

What does it involve?

A walk-through involves someone stepping through a task, facilitated by a system or process, explaining their reactions, decisions and actions as they go. The technique is useful to explain practice with systems or to examine likely practice in future ones. Importantly, the technique can be used effectively (subject to the participants' imagination) even with no actual task or system present, which makes it very useful at very early stages of design.

Who can use it?
Design teams, including subject matter experts and/or experienced operators of existing or prospective replacement systems.

Finding out more

1. Kirwan B. & Ainsworth L.K. (Eds) (1992) A guide to Task Analysis, Taylor & Francis

2. MOD (2006), MAP-01-011 Human Factors Integration Technical Guide (Annex 3), Sea Systems Group, TES-SSG-ShipDes, Defence Procurement Agency, Bristol

3. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Why-Because Analysis

Why is it useful?
Investigators of incidents on the railways are required to follow laid down procedures. In particular, investigators are required to go beneath the obvious causes and attempt to unearth the root cause – the fundamental reason why something went wrong. For example, as soon as it becomes apparent that a railway worker made an error, investigations in the past were happy to stop at that point, labelling the cause of the incident as 'human error'. To simply label a cause as human error gives no indication as to what measures are needed to prevent the error (and the resulting incident) from happening again. The conclusion 'human error' should be the beginning of an investigative process, not the end. The interesting question is 'why did this person make this error at this time?' Further digging may reveal deficiencies in, say, the training process, the process for assessing competency, or source of stress in the worker's private life. This technique is a simple means of going beyond the obvious to find a cause which can be the subject of remedial action.

What does it do?
Why-Because Analysis is an easy-to-use form of root cause analysis that was developed specifically for line managers in the railway industry to investigate past near misses. The technique also allows the development of countermeasures, and tracks their implementation status.

What does it involve?
Why-Because Analysis involves creating a diagram that represents the factors involved in a past incident eg a near miss. The diagrams are a little like *Fault Trees*.

For each problem (eg trackworker's late escape from the path of a train), they capture the direct causes (eg lookout at wrong sighting distance + train horn masked lookout's warning), the external causes (eg trackwork task running late + insufficient trackwork resource to do the job); and countermeasures – ie those interventions which would, if made, prevent recurrence of the incident (eg implementation of prohibited red zone).

For complex incidents where a simple Why-Because diagram is not enough, a simple documentation scheme can be used. This scheme makes extensive use of the hyperlink facility in MS Office™ tools to connect the elements of the diagram with supporting reports and recommendations. This also makes it very easy to track progress against any recommended countermeasures which have been accepted for action.

Who can use it?
This technique was developed specifically for line managers in the railway industry and is easy to understand and use. However, the technique requires reasonable proficiency with MS Office™ tools.

Finding out more

1. Braband J. & Brehmke B. (2002) Human factors application area of Why-Because Graphs to Railway Near-Misses, In Workshop on the Investigation and Reporting of Accidents 2002, (IRIA 2002) Ed C. W. Johnson. GIST Technical Report F2002-2, Dept Of Computing Science, University Of Glasgow, Scotland

2. Ladkin P. (2001) Causal System Analysis – Formal Reasoning About Safety and Failure, Uni. of Bielefeld

Workshops

Why is it useful?

In many areas of change and development in the railways the views of a wide range of stakeholders need to be taken into account. Meetings are the usual means for bringing together the various interested parties. But meetings tend to be very time-consuming and can sometimes lack focus. Often meetings finish without the desired objectives having been reached. The workshop can be considered as a much more structured meeting. It should have been carefully planned, its objectives defined properly and the steps required to achieve these objectives designed in detail. The required outputs from the workshop will have been specified and a trained facilitator will take responsibility for the conduct of the workshop.

What does it do?

A workshop is a structured discussion that can be used for a very wide range of applications. When it is composed of the right stakeholders and run by experienced facilitators, a workshop is one of the most powerful tools available for eliciting, refining and prioritising information. The technique is also invaluable for securing agreement and building trust between project stakeholders.

What does it involve?

A workshop involves the design and execution of a process by which a group of stakeholders share information about a set of topics. The process should always have a clear aim and a series of logical stages through which the facilitators move the participants.

Workshops tend to take place of longer periods of time than *Focus Groups* and can run from a half-day through to several days duration. They may also involve more participants – typically 8 to 20 or so.

The longer durations and more people mean that workshops can profitably use combinations of plenary groups (everyone) and syndicates (sub-groups) for different kinds of activity. Often, syndicates are used to work on different aspects of a complex problem. At other times, they can be used to work on the same problem so that the group as a whole ends up with more options. Either way, syndicate work is usually shared and discussed in the plenary group, which can also be used for *brainstorming* and keynote presentations.

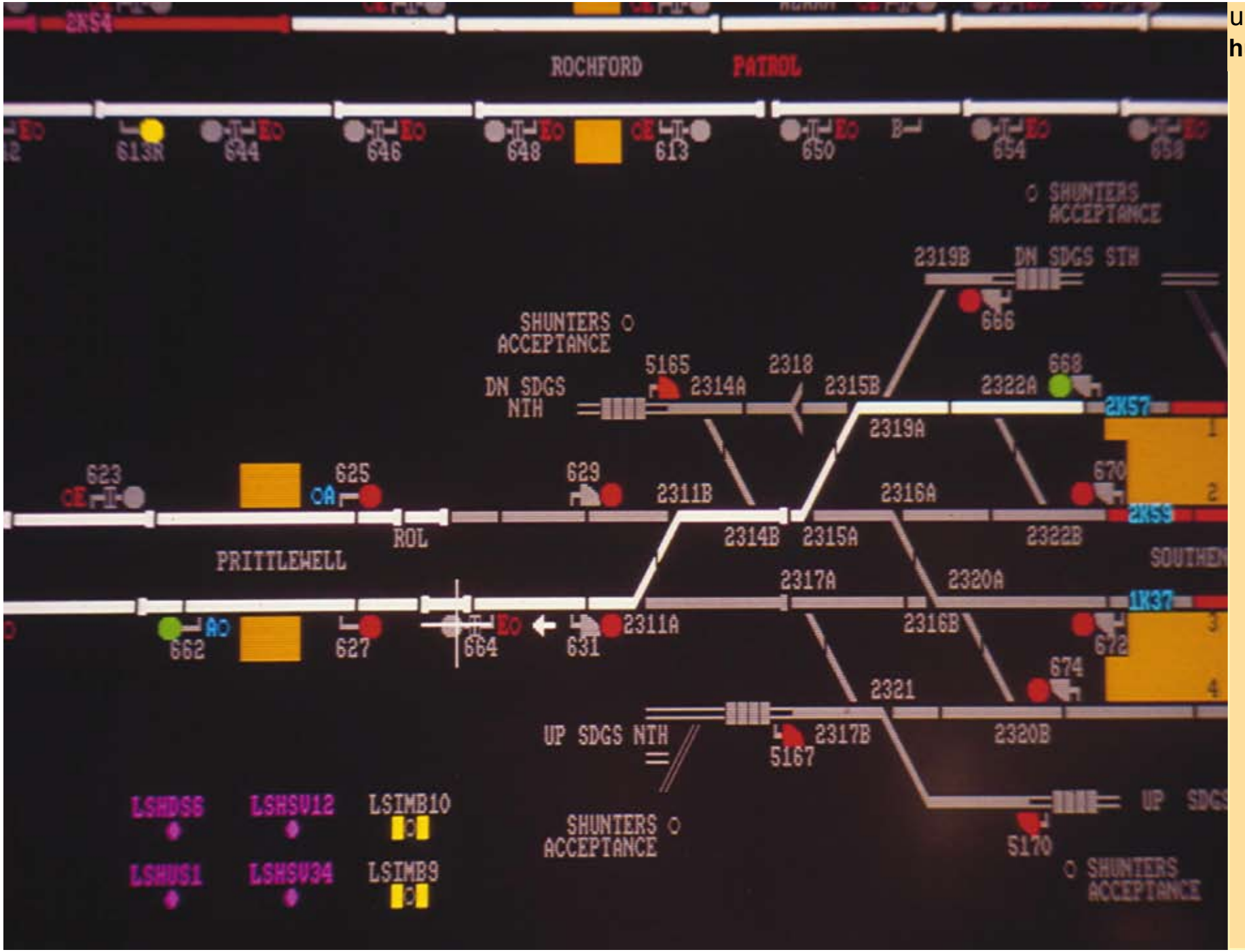
Who can use it?

Anyone can use this technique. However, workshops benefit greatly from careful design so that a clear process is put in place that will lead to a clearly defined objective. This helps identify the exact requirements for the participants. Experienced facilitators make a huge difference to the value, enjoyment and ultimate success of workshops.

Finding out more

1. Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., Jenkins, D. P. (2005). Human Factors Methods: A Practical Guide for Engineering and Design. Ashgate, Aldershot. ISBN 0-7546-4660-2 (HBk), 0-7546-4661-0 (PBk)

Techniques



understanding
human factors

Jargon buster

understanding
human factors

Jargon buster

Jargon buster

Ability
'Ability' is used loosely both in the literature and everyday life either to refer to actual performance, or else (more commonly) to a capability for performance. In the former case, 'ability' can be replaced with 'skill'; in the latter case, 'ability' can be replaced with 'aptitude'.

Abnormal operating conditions
State of continuing railway operations with specific planned changes to its configuration or equipment (such as special events, engineering works in traffic hours or within station public areas).

Accident
An unintended event, often resulting in injury and/or loss. Accidents usually have several antecedents, many of which may have originated some considerable time before the accident, and whose combination was never anticipated.

ACTA
Applied Cognitive Task Analysis - see Techniques.

Anthropometry
The measurement of human body dimensions.

Aptitude
The natural propensity of an individual to acquire and utilise specific knowledge, skills and attitudes.

Arousal
A state of body and mind that sensitises an individual to the search for, and receipt and processing of, information, and which prepares an individual for action. Too much arousal can result in stress, which can overload the individual and render them increasingly unable to deal with, or act on, information.

Attitude
A manner of acting, conduct or interactional style which is representative of feelings, opinions or beliefs.

Behaviour modification
The replacement of undesirable behaviour with desirable responses using programmes that redirect existing behaviour via various kinds of conditioning. The conditioning that works best is based on reward for desired responses, rather than punishment for undesired responses. Behaviour modification focuses only on behaviour rather than the thinking that lies behind the behaviour. The success of behaviour modification programmes can be considerably enhanced by taking the thinking side into account as well. In a clinical setting, this multiple approach is called cognitive behaviour therapy.

Brainstorming
Brainstorming – see Techniques.

Brightness
The subjective response to luminance in the field of view, dependent upon the adaptation of the eye.

CDM
Critical Decision Method - see Techniques.

Checklist
Checklist – see Techniques.

CIE
Commission International de l'Eclairage, (International Commission on Illumination). An international organisation responsible for colour and light measurement standards.

CIT
Critical Incident Technique - see Techniques.

Cognitive mapping
Cognitive mapping – see Techniques.

Cognitive task analysis
The elicitation and representation of the conscious thought processes that underlie the performance of tasks and thinking skills needed to respond to complex situations. (See *Applied Cognitive Task Analysis* in Techniques).

Cognitive walk-through
Cognitive walk-through – see Techniques.

Contrast
Subjectively used, contrast describes the perceived difference in appearance between two parts of a visual field seen simultaneously or successively. The difference may be one of brightness or colour or both. Objectively used, the term expresses the measurable difference in luminance between two parts of the visual field (eg target and background).

Colour coding
Colour coding is a process by which different colours are used to represent different categories of information. For example, a red signal means 'Stop' while a green signal means 'Proceed'. If colour provides a completely unique source of information, the coding is called non-redundant. Colour can also be combined with other coding dimensions such that two or more codes correlate with one another, eg hand signalling arrangements. This is referred to as redundant coding.

Jargon buster

Competence
The orchestration of the knowledge, skills and attitudes required to perform a specific range of tasks, job or role to a prescribed standard.

Competence assessment
A management process designed to ensure that staff have the knowledge, skills and attitudes necessary to perform their work to the standard expected.

Concentrator
A telephonic device used on the railways (eg in signal boxes) that ensures only one phone call from potentially many sources (land-line, SPT, mobile) can be received at one time – thus reducing attentional demand.

Context-Sensitive Help
Help in which the help text or range of help users is derived from the contextual information associated with the user's last input, selected object, or the current location within the system or application.

CRM
Crew Resource Management – an aviation industry programme designed to assure the quality of teamworking amongst all the crew of an aircraft.

CUD
Communications Usage Diagram - see Techniques.

Culture
The set of values and norms that govern how people understand – and what they expect from – each other within an organisation. Culture is both an input and output of behaviour. It determines and facilitates it as well as emerging from, and changing (albeit slowly) as a result of it.

Degraded operating conditions
State of continuing railway operations with significant equipment failures (such as track related failures or communication system failures).

Design scenario analysis
Design scenario analysis – see Techniques

Dialogue
An interaction between a user and an interface to achieve a particular goal.

Diffuse lighting
Lighting which comes from many directions, none of which predominates.

Disability
Any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being.

Disability glare
Glare produced directly or by reflection that impairs the vision of objects without necessarily causing discomfort.

Discrimination
The detection of a just noticeable difference between stimuli (eg colour differences between visual stimuli).

Display resolution
The number of separately addressable pixels on a display screen.

Economy
The relationship between cost and resources: it is the cost by which a resource produces a required output.

Effectiveness
The relationship between the output produced and the outcome intended: it is a measure of how far a pre-existing situation is improved by the product of a resource. Alternatively, it is a measure of how far the product of the resource has achieved a pre-specified goal.

Efficiency
The relationship between resources and output: it is a measure either of how fast the resource produces a required output, or how little resource is required.

Emergency operating conditions
State of the railway in response to a major safety or security-related event. Introduction of contingency plans at a moment's notice.

Ergonomics
The study of human capabilities and limitations, human interaction with technologies and environments, and the application of this knowledge to products, processes and environments.

Error
A mismatch between the user's goal and the response of the system or environment of which the user is part. Errors can include navigation errors, syntax errors, and conceptual errors.

Fault trees
Fault trees – See Techniques.

Feedback
Output presented by the interface in reaction to the user's input.

Fitness for purpose
The capability of a product to serve the purpose for which it was designed, in the way it was designed to be used.

FOC
Freight Operating Company.

Focus groups
Focus groups – see Techniques.

Front-end analysis
Collective term for those analyses conducted at the earliest stages of system design and concerned with a system's personnel, training and logistics requirements.

Function allocation
The process of deciding how system functions should be assigned to the human and machine elements of a system. Fixed function allocation means that these decisions are made at design time and remain fixed for the system's life. In this case, function allocation is the most basic of system design decisions since it establishes the framework within which the design of the system (equipment, workspace, training, etc) is developed. Dynamic function allocation takes place during the task. Between people and machines, it is known as adaptive automation; between people it is known as teamworking.

Function analysis
The analysis of system functions. Functions describe activities which may be implemented by personnel alone (control a signalling section), by equipment alone (self-test/equipment circuitry), or, as in most cases, by some combination of both (pre-flight checks). Functions can be instantaneous (set route) or prolonged (monitor panel), simple (accelerate) or complex (assess emergency situation).

Glare
The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.

Groupware Task Analysis
See Techniques.

HE HAZOP
Human Error HAZard Operability - see Techniques.

HEART
Human Error Assessment and Reduction Technique - see Techniques.

HEP
Human Error Probability.

Heuristic analysis
Heuristic analysis – see Techniques.

Hertz (Hz)
SI unit of frequency, indicating the number of cycles per second (c/s).

Hexagons
Hexagons – see Techniques.

HFACS
Human Factors Analysis and Classification System. A comprehensive method of root cause analysis used to identify and classify the human causes of incidents.

HFIP
Human Factors Integration Plan. A plan that defines the integration of human factors into system development and appropriate assurance procedures to ensure that these activities are completed.

HRA
Human Reliability Analysis - see Techniques.

HRO
High Reliability Organisation. This is a safety-critical organisation which has far fewer safety incidents than might be expected due to its staff having learned to manage the unexpected – mainly though sensitivity to error and decision making that depends on expertise rather than hierarchy.

HSE
Health and Safety Executive.

HTA
Hierarchical Task Analysis - see Techniques.

Hue
The term that most closely resembles our notion of 'colour', for example, red, green and blue. It is that quality of a colour that cannot be accounted for by brightness or saturation differences. An objective measure of hue is provided by the dominant wavelength of that colour's spectral power distribution.

Human factors
All of the 'people' issues that must be considered to assure the lifelong safety and effectiveness of a system or organisation.

Jargon buster

Human interface
The controls, devices and displays which an operator uses to control, monitor, or otherwise interact with, the rest of the system. Also known as the Man-Machine Interface (MMI).

Icon
A pictorial representation consisting of an image, with or without a label, presented on a display screen, designed to provide a visual reminder of the name, structure, appearance or purpose of the entity that it represents.

IECC
Integrated Electronic Control Centre. A computer workstation equipped with a series of software-animated vdu-based diagrams used by signallers to track the progress and status of trains in a specified geographical area under their control.

Interface surveys
Interface surveys – see Techniques.

Interview
Interview – see Techniques.

IPME
Integrated Performance Modelling Environment - see Techniques.

ISA
Instantaneous Self-Assessment (of workload) – see Techniques.

Job
The grouping of tasks, roles and responsibilities constituting the principal work assignment of one person.

KLM
Keystroke Level Model - see Techniques

Knowledge
Knowledge constitutes a representation of something in a way that the knower can utilise for some purpose. This representation may or may not be articulable and the purpose for which it is used may or may not be predetermined. This allows for the fact that knowledge can be used innovatively and inductively (re-purposed).

KSA
Knowledge, skills and attitudes.

Layout Analysis
Layout analysis – see Techniques.

Lifecycle
The development, operation and maintenance of a system, spanning its life from the definition of its requirements to its disposal following the termination of its use.

Link analysis
Link analysis – see Techniques.

Methodology
An integrated set of tools, techniques and procedures, collectively aimed at a specified goal.

Maintainability
The ability to carry out rapid and reliable system restoration, using people trained to a specified level, and specified support facilities to maintain the equipment at a specified level of performance.

Maintenance
All activities necessary to keep materiel in, or restore it to, a specified condition.

Morale
A state of mind that at one extreme can allow a group of people to commit to a shared objective with complete disregard for the potential cost to themselves. At the other extreme it can account for little or no effective or organised action in the face of clear situational demands.

Motivation
A state of mind that releases the necessary emotional energy for an individual to commit themselves to act effectively towards a declared objective.

Murphy Diagrams
Murphy diagrams – see Techniques.

NASA – TLX
NASA Task Load Index – see Techniques.

Normal operating conditions
State of continuing railway operations according to normal timetables, incorporating minor disturbances and delays to the service in traffic hours and operations in non-traffic hours.

NX panel
eNtry eXit panel. A type of electrically operated display panel set out as a diagram and used by signallers to track the progress and status of trains and set their routes in a specified geographical area under their control. NX panels are equipped with push-pull switches for route setting and other switches to control point settings, level crossing cameras etc.

Observational analysis
Observational analysis – see Techniques.

Performance appraisal
A management process designed to ensure that staff are motivated in their jobs and are developed to their full potential.

Pixel
The smallest addressable display element that is capable of generating the full colour and/or luminance ranges of the display.

Product
Any equipment, process, procedure, rule or instruction that has been designed to serve some pre-defined purpose.

Prototype
Any artefact created for the purpose of demonstration to users in order to elicit or test user feedback. This includes demonstrators, mock-ups, paper prototypes, simulations, role-plays, dummy systems or documents, and scenarios.

Psychometric test
A test of a specific mental ability or process, eg spatial ability, numerical reasoning, critical thinking.

Questionnaire
Questionnaire – see Techniques.

QUIS
Questionnaire for User Interface Satisfaction - see Techniques.

Responsibility
A set of tasks and duties for which an individual is accountable in terms of their conduct, performance and management.

Risk
An estimate of the propensity for an otherwise stable situation to suddenly fail. The estimate may be a formal one, based on a risk assessment methodology, or it may be entirely intuitive, based on subjective feelings. The presence of perceived risk in a situation is often fundamental to its interest for humans. Without it, people become bored and/or indulge in behaviour to increase the risk level. The perceived level of risk in a situation can be affected by a large range of different factors.

Role
A set of expectations placed upon an individual by an organisation and realised by that individual through the execution of their job.

RSSB
Rail Safety and Standards Board.

SA
Situation awareness. The ability to know what is going on around you, and to use this information to project accurately into the future, resulting in successful plans for predicted events and their contingencies.

Safety culture
The set of values and priorities placed on all aspects of safety by everyone at every level of an organisation.

SAGAT
Situation Awareness Global Assessment Technique. A simulation-based technique in which the task is stopped periodically so that the user can be asked about their perception of the situation at that instant.

SART
Situation Awareness Rating Technique - see Techniques.

SASHA
Situational Awareness for SHAPE – see Techniques.

Saturation
The quality that distinguishes a hue from white. Pastel shades are de-saturated, vivid colours are saturated. An objective measure of saturation is purity.

SHAPE
Solutions for Human-Automation Partnerships in European (Air Traffic Management Systems).

SHERPA
Systematic Human Error Reduction and Prediction Approach - see Techniques.

Skill
An organised and co-ordinated pattern of mental and/or physical activity, which becomes more accomplished with training or other experience.

Skill fade
The tendency of learned skills to degrade without sufficient practice. Different skills fade at different rates and are affected by multiple factors.

Jargon buster

SME
Subject Matter Expert. A person with task knowledge, skills and accepted qualification in a specific domain.

SPAD Hazard Checklist
A tool developed by RSSB to identify working practices and communications procedures that should be adopted by both signallers and drivers to help prevent SPADs occurring.

Staffing
A continuous process by which an organisation arranges for appropriate numbers of people with the appropriate qualities to be available, so that it may operate its business safely and effectively.

Stakeholder
Any individual who is affected by the output from, provides the input to, develops, maintains, uses or manages the use of a system or product.

Stress
An adverse reaction people have to excessive arousal or pressure. Stress is not a disease, but if it goes on unchecked, it can lead to mental and physical ill-health.

Stressor
An impelling force which produces a demand upon physical or mental energy.

SSM
Soft Systems Methodology - see Techniques.

Style guide
A document which sets out the design principles, rules and conventions agreed by all of the stakeholders.

SUMI
Software Usability Measurement Inventory – see Techniques.

SUS
System Usability Scale - see Techniques.

SWAT
Subjective Workload Assessment Technique - see Techniques.

System
Any set of elements, including physical equipment, computer software, human users and procedures, interacting and organised in relation to a goal.

Systems analysis
A generic term for the various analytic techniques applied before or during the system design stage, eg requirements analysis, function analysis, front end analysis etc.

Systems engineering
The processes by which system requirements are developed into a system performance, design, and production specification; and by which that specification is then transformed into a fabricated, prototyped, integrated and tested product.

TAD
Target Audience Description. A descriptive profile of the characteristics, skills and abilities of the 'end-user' of a designed system.

Task
The set of physical and mental interactions that are required within a work environment in order to achieve a prescribed goal.

Task analysis
The elicitation and representation of a set of tasks in order to understand the relationships between their constituent activities, performance criteria and objectives.

Task synthesis
The process of specifying and putting together the tasks of which a system function consists.

TCSD
Task-Centred System Design - see Techniques.

TCTA
Team Cognitive Task Analysis - see Techniques.

TDRE
Team Decision Requirements Exercise - see Techniques.

Teamworking
A team is a set of two or more individuals who interact adaptively with each other to achieve specified, shared and valued objectives. The period of interaction may be anything from a few seconds (eg a driver and signaller) to many years (eg a large infrastructure project team). Teamwork refers to the activities performed by team members in response to each other's needs and expectations, to enable the team to achieve its shared objectives.

TIP
Teamworking Improvement Process - see Techniques.

TNA
Training Needs Analysis.

TOC
Train Operating Company.

Training
A continuous process by which an organisation arranges for appropriate knowledge, skills and attitudes to be available to its workforce, so that it may operate its business safely and effectively.

TRUST
Train Running System TOPS. Network Rail's system for monitoring the punctuality of trains, mainly fed by automatic inputs from signalling systems.

TTRAM
Task and training requirements methodology - see Techniques.

TWA
Team Workload Assessment - see Techniques.

Usability
The ability of a product to be understood and operated efficiently, safely and effectively by its intended users. Usability also includes how well the use of the product fits with related products and their users within and across organisations.

User
Anyone who employs an artefact to carry out a task.

User-centred
Approaches (generally to design) which have as their primary focus the consideration of the interests of the individuals who will work with, or use the output from, a piece of equipment.

User trial
User trial – see Techniques.

Validation (internal)
The ability of a test, rule, procedure or system to achieve the objectives set for it. For example, a selection test is internally valid if it successfully discriminates between the people it sets out to discriminate between; a system is internally valid if it successfully implements all of the specifications drawn up for it.

Validation (external)
The ability of a test, rule, procedure or design to achieve operational objectives. For example, a selection test is externally valid if the people it predicts will do well actually do so; a system is externally valid if it allows the organisation to achieve the operational objectives set out for it. It is possible for something to be highly internally valid (ie it does exactly what it is supposed to) but of low external validity (ie what it does has little value in an operational setting).

VDU
Visual Display Unit (typically, a computer screen).

Verification
The process of ascertaining that a test, rule, procedure or system does what its designers intended. Verification is the process needed to demonstrate internal validity.

Virtual environment
An artificial environment generated by an immersive display (eg goggles) which presents information in such a way as is appropriate to give the operator the perception of viewing and interacting with objects in three-dimensional surroundings.

Visual acuity
The capacity for discriminating between objects which are very close together. The expression more commonly used for an individual's visual acuity is the ratio of the distance at which the individual can read a line on a standard optician's chart to the standard distance at which a person of normal sight can read that line (eg 6/12 means that the individual can just read at 6 m the line which a normally sighted person can just read at 12 m).

Visual impairment
Any loss or abnormality of psychological, physiological or anatomical structure or function relating to vision.

Visual field
The full extent in space of what can be seen when looking in a given direction.

Walk-through Analysis
Walk-through analysis – see Techniques.

Why-because Analysis
Why-because analysis – see Techniques.

Workload
The effort demanded from people by the tasks they have to do. It can be the effort demanded at a single point in time, or over a whole shift. Workload can be physical or mental. It can be the physical demands created by working in a particular posture, manual labour or working in particular environmental conditions; or it can be the mental demands created by the need to attend to sources of information and then process the information – often against time pressure.

Jargon buster

Workplace
The complete working environment within which the operator(s) and equipment(s) are arranged to function as a unit.

Workshop
Workshop – see Techniques.

understanding
human factors

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This bibliography includes all of the references listed at the end of the sections in Part 2. It has been extended with many other references that were used in the development of this Guide and by other material that may be of use to readers who wish to delve deeper into any of the issues or techniques presented in these pages.

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