MANAGERS’ TOOL KIT FOR ADDRESSING HUMAN FACTORS

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SUMMARY

This paper outlines the human factors methodologies which were presented at the Human Factors in Maintenance seminar on 8 December 2000. The author was involved in the development of these methodologies. They are all solution driven, and were developed to be used by the non-human factors specialists. Many were developed to specifically address maintenance issues, however, some are general purpose tools with applications in both maintenance and operational areas. These methodologies are summarised below:

Methodologies addressing design issues:

The ECSC Principles in Design for Maintainability
The Bretby Maintainability Index

Methodologies addressing the wider Human Factors issues:

The HFRG report on Improving Maintenance - A Guide to Reducing Human Error
The HFRG report on Improving Compliance with Safety Procedures
The HSEC Ltd Human Factors Solutions CD-ROM

ERGONOMIC PRINCIPLES IN DESIGNING FOR MAINTAINABILITY
The European Coal & Steel Community report

A set of design guidelines were developed following a research project co-funded by the ECSC and the NCB. It was apparent that machinery entering the mining industry had insufficient attention given to features which made them ‘maintenance friendly’. A review of the literature reveals major flaws in both the contents and presentation of available ergonomic guidelines.

One critical aspect of the available guidelines were that information was presented in a ‘Maximum - Minimum’ or ‘Optimum’ format. It was readily apparent that designers would seldom be able to meet these ‘ideal’ human factors requirements having taken into consideration the range of other demands on the product. A major problem was therefore apparent in that the designers would then have no idea whether his/her compromise had minimal or severe impact on the performance of the maintainer. It was decided to develop a set of guidelines which provided, as far as possible, the performance information to enable the designer to identify the nature of the performance decrement which could be expected if, say, the ideal access to certain fasteners was not provided. Much better trade-off decisions could therefore be made.

As a result a number of basic pieces of research had to be undertaken. The resulting guidelines provided performance related information on the following design issues:

1. Access requirements for tool applications - spanners/wrenches
2. Access requirements for tool applications - screwdrivers
3. Access requirements for manual tasks
4. Locating components in cavities for optimum maintenance access
5. Fastener choice - taking into consideration the maximum force application to tools
6. Manual lifting - taking into consideration the postures adopted by the maintainer
7. Manual lifting - implications for hatch cover design
8. Facilities for the use of powered hand tools
9. Fault diagnosis job aids
10. Labelling - reducing the potential for error
11. Mechanical handling - choice and location of lifting points

Further details can be found in:

Mason S, Ferguson CA, Pethick AJ 1986
Ergonomic principles in designing for maintainability. Community Ergonomics Action Report no.8 Series 3. Luxembourg: European Coal and Steel Community.

An updated and shortened version of the guidelines can be found in:

Mason S 1995
The Ergonomics of Workplaces and Machines - a Design Manual, second edition. Chapter 'Maintainability', Ed TS Clark & EN Corlett, Taylor & Francis.

THE BRETBY MAINTAINABILITY INDEX

Maintenance has a major relevance to the business performance of industry. Whenever a machine stops due to a breakdown, or for essential routine maintenance, it incurs a cost. The cost may simply be the costs of labour and the cost of any materials, or it may be much higher if the stoppage disrupts production. As modern machines become more complex and expensive, the consequences of machine failure become more critical.

Industry has generally recognised this for some time and is striving to increase machine availability through improvements in machine reliability, as well as through improved planning. Although recent improvements in reliability have had some effect, until machines need no routine maintenance, designing "maintenance friendly" machinery is important if industry is to reduce these costs.

As maintenance can significantly reduce a machine's availability, engineers and designers ideally need quantitative information on the quality of the maintainability of complete machines. Existing maintainability indices (eg Dept of Defence, MIL-HDBK-472, or Society of Automotive Engineers, SAE J817a) are either excessively time consuming to use or are incomplete. The Bretby Maintainability Index (BMI) was developed to specifically overcome the limitation of the current indices. It was based on the SAE index, but extensively modified to make it make it time based, and much more comprehensive.

Its basic elements are shown below:

SECTION A: ACCESS

Part 1:	Hatches & Covers
Part 2:	Apertures
Part 3:	Location

SECTION B: OPERATIONS

Part 1:	Removal & Replacement
Part 2:	Slackening & Tightening
Part 3:	Carrying & Lifting
Part 4:	Preparation
Part 5:	Fluid Compartment Checks
Part 6:	Component Checking
Part 7:	Lubrication
Part 8:	Draining
Part 9:	Filling
Part 10:	Cleaning
Part 11:	Adjustment
Part 12:	Miscellaneous

SECTION C: ADDITIONAL ALLOWANCES
Percentage modifiers to take account of energy expenditure, posture, head room, visual demand, task requiring more than one man

SECTION D: FREQUENCY MULTIPLIER
Used to weight scores depending on whether job is done, for example, shiftly or weekly

In order to use the BMI, each task on the maintenance schedule must first be identified in terms of the actions needing to be performed and the recommended maintenance intervals. Each task is then assessed independently against each section of the BMI. Points are allocated depending on the number of body motions, degree of difficulty etc. The total of the scores for each part of Sections 1 and 2 are then increased by the percentage modifier of Section 3. This allows for energy expenditure estimates, postural difficulty, etc. Finally this score is then modified to take into account the different maintenance intervals. For example a task which is performed on a daily basis is weighted more heavily than a similar task which is only performed monthly.

The weighted scores for all tasks in the maintenance schedule and then totalled to give the final BMI result for the machine.

The BMI can be interpreted in a number of ways depending on whether it is part of a design process, whether it is used to help select a new machine, or whether it is used to determine if it would be cost effective to modify existing plant to improve their maintainability characteristics.

Reviewing Routine Maintenance Schedules

A vehicle was assessed using the BMI against the routine maintenance schedule recommended in the engine and vehicle manufacturer's maintenance manuals, and also against others specified by the colliery. The Index score showed that these routine tasks would require approximately 196 minutes each day, or around 786 man-hours per annum.
Compared with other vehicles, the routine maintenance demand for this machine appeared high. The Index was able to highlight that a small proportion of the tasks accounted for the majority of the total index score for the vehicle. As a result it enabled the manufacturer and company engineer to review and revise their schedules and reduce the total maintenance demand by 45%, or approximately 88 minutes per vehicle per day.

Revising the routine maintenance schedules to meet the real needs of machinery can be a very easy means of achieving immediate increases in availability and reducing the demands on the maintenance crew.

Selecting Machinery with the Lowest Maintenance Demand

Traditionally factors such as purchase price, performance, and reliability have been taken into consideration when selecting new machinery. The costs of maintaining machinery is however less often considered despite these cumulative costs frequently exceeding the initial purchasing costs.

Table 1, summarises the annual time required for the routine oiling and greasing tasks on six modern mining machines.

Table 1 Index scores (in hours per annum) for routine oiling and greasing tasks

Machine	1	2	3	4	5	6
Oiling	58	90	127	147	123	83
Greasing	102	26	140	20	174	255
Total	160	116	267	167	297	338

NB. These time are determined both by design features and the maintenance schedules

It can be seen that the highest scoring machine requires nearly three times as long (an extra 222 hours each year) to conduct the routine oiling and greasing tasks than the lowest scoring machine. However a closer look at the results shows that if a "hybrid" machine were manufactured using the best features of the six machines, then its score would be only 78 hours a year, or a further saving of 33% over the current best design.

Such information, when used with initial purchasing costs, reliability data, and machine performance, allows the engineer to better estimate the long term cost of ownership and therefore enable him to make better purchasing decisions.

Improving Existing Equipment Design

Any analysis of the causes of machine stoppage for maintenance or repair are likely to show that a large proportion of the stoppages are caused by a relatively small number of failures. For example, data from one site revealed that 25% of all maintenance time was spent replacing hydraulic lines, water hoses and power cables. It was estimated that the average time to replace these items would be reduced from 2.2 hours to under 1 hour if a quarter of the hoses and cables were relocated to give improved access.

The BMI has been used to help engineers identify where they need to focus their attention to make improvements, and once they have identified potential design changes, the Index can then be used to predict the benefits which would be expected following any specific design alterations.
Further details of the Index can be found in:

> Mason S 1990
> Improving plant and machinery maintainability, Applied Ergonomics March, 1990
> (NB the version described in this publication does not provide the final version with improved health and safety indicators)

An example of its application can be found in:

> Mason S 1991
> Improving mining machinery maintainability, Mintech 91 - The Annual Review of International Mining Technology and Development, 1991.

IMPROVING MAINTENANCE - A GUIDE TO REDUCING HUMAN ERROR, Human Factors in Reliability Group (HFRG) Report

The Human Factors in Reliability Group (HFRG) is a forum for individuals from industry, regulatory and academic institutions who have an interest and expertise in human factors, associated with reliability. It was inaugurated in 1981 to:

- foster collaboration between organisations with a direct interest in optimising and assessing human reliability in human-machine systems, and

- to support research and dissemination of information in these areas.

The main output from the HFRG has been reports produced by specialist sub-groups. A subgroup was formed specifically to address human reliability in maintenance. The sub-group first met around 1997 and the work has recently been published in the HSE report “Improving maintenance - a guide to reducing human error”, ISBN 0-7176-1818-8.

Although it is never possible to totally eliminate human error, it is possible through good maintenance management and an understanding of the issues that affect error, to move towards this goal and to control the likelihood of error.

The HFRG set out to produce a document which would have utility for most industries and provide a methodology which could be applied by the non-human factor specialist and which was solution orientated. The Guide seeks to provide practical advice and a methodology to help managers, engineers and others who are responsible for, or involved in, the management of maintenance within their organisation and who are concerned with the performance of people undertaking maintenance activities improve the quality of maintenance activities through the reduction of human error.

The underlying model was developed from the combined experience of the authors and aspects of the resulting methodology had been previously proven in a number of industrial applications. The finished methodology received a full peer review by the HFRG and was used in limited trials before publication.

The Guide has four sections. The first two provide an overview of the importance of human factors in maintenance and list the main issues under management control. The third section provides a method for identifying the key issues which will adversely affect maintenance in an organisation. This is based on the application of a questionnaire and/or an incident review procedure. The fourth section provides guidance, on addressing each of the identified issues. The sections are colour coded to help the user use this document.

Maintenance Risks & **Human Performance in Maintenance**

The publication is focussed on 18 human factors issues which can impact on safety and maintenance performance. These are based on the HSE HSG(65) model under 'policy', 'planning/implementing', and 'audit/review'. The issues are listed below:

Policy & Organising	Policy Resource Allocation Roles, Responsibilities & Accountabilities Formal Communications Management of Change Organisational Learning
Planning & Implementing	Procedures and Permits (Contents) Procedures (Presentation, Understanding, Usability) Work Design Crew/Shift Handover & Shift Work Individual Capabilities Competence (Technical and Interpersonal Skills) Teamwork Supervisory Effectiveness Environmental Factors Plant & Equipment Design
Measuring Performance	Routine Checking of Maintenance Performance
Audit & Review	Review of Maintenance Performance

Assessment Method

The description and instructions for using the methodology are provided in the Appendices of the report. They are in three stages.

1. The first stage is for the manager/engineer to identify the specific areas of concern. This could be in terms of the physical location of the maintenance work, the type of work (eg routine/breakdown, or electrical/mechanical), and the main consequences (eg plant reliability, safety to the public, safety to employees etc).

2. The second stage is the application of the questionnaire and/or incident review process. Instructions are provided on the scoring of each method. It is suggested that both processes are used, however, it is acknowledged that each have their strengths and weakness and that is some situations it may only be prudent to apply one process. For example, an incident review will not be successful if there have only been a small number of incidents and if the incidents have not been well documented. They will also have limited value if aspects of the general nature of the industry is changing, for example, if a significant part of the work is become automated or mechanised. In such circumstances the causes of past problems may have limited value to the causes of future problems.

3. The third stage involves a simple method for harnessing the output from the two processes to identify the priority areas for improvement. In this way, managers and engineers can develop a suitable action plan.

Maintenance Management Issues

The assessment method will usually identify 3 to 5 of the 18 issues which would benefit from review by management. The final section of the guide provides useful information and suggestions on each of the 18 issues in a way that management can select those relevant and then identify a number of practical suggestions relating to making improvements in each area. Worked examples are provided.

Assessment Forms

A number of forms are used in the examples given in the Guide. Blank forms are provided at the end of the report and these can be freely copied.

Sub-Group Members

The main authors were:

Steve Mason,	Health Safety & Engineering Consultants Ltd (HSEC)
Jon Berman,	Greenstreet Berman
Greg Gibson,	Nuclear Industry

Other contributors were:

David Clarke,	Rolls Royce & Associates
Huw Gibson,	The University of Birmingham
Gareth Hughes,	Det Norske Veritas
Ronny Lardner,	The Keil Centre
Nigel Finch,	Civil Aviation Authority (CAA)

(Sadly, Nigel died before the report was published)

This report is available from HSE Books for £16. Full details are: Improving Maintenance - A Guide to Reducing Human Error, HSE Books, ISBN 0 7176 1818 8. HSE Books can be contacted by Fax on 01787 313995

IMPROVING COMPLIANCE WITH SAFETY PROCEDURES
Human Factors in Reliability Group (HFRG) Report

The author chaired another sub-group of the HFRG which specifically addressed the organisational factors which increased the likelihood of safety rules and procedures being intentionally not followed. The methodology is based around a workforce questionnaire. It has equal applicability to maintenance operations as to other tasks. The report was published in 1995.

This report is available from HSE Books for £20. Full details are: Improving Compliance with Safety Procedures - Reducing Industrial Violations, HSE Books, ISBN 0 7176 0970 7. HSE Books can be contacted by Fax on 01787 313995

THE HSEC LTD HUMAN FACTORS SOLUTIONS CD-ROM

HSEC have recently developed a computer-based tool to allow managers and engineers to gain a deeper insight into the many human factor issues which can affect health and safety. It is equally applicable to maintenance and operating efficiency and reliability. It can be very quick to apply and produces a hard copy detailing all the potential latent failings in the system and provides selected guidance and recommendations for managers/engineers to select their own action plan.

This new tool was originally visualised as having its main use as part of risk assessments for specific major operations, although there are clearly many other potential applications. It is sufficiently quick to use to encourage its routine application on selected major operations.

The methodology focuses on the following aspects of human factors:

1. Safety Commitment of Team Leaders and Managers
2. Perceived Impracticality of Safety Rules
3. Communications
4. Job Design
5. Plant & Equipment Ergonomics
6. Knowledge and Skills
7. Rules: Application: Relevance and Accuracy
8. Organisational Support
9. Working Conditions
10. Safety Commitment of Workforce
11. Complacency
12. Supervision: Setting Standards, Monitoring & Detection
13. Organisational Learning
14. Committed Resources
15. Participation
16. Quality Training
17. Balance of Productivity and Safety
18. Management Style

An assessor would first input details of the task and workgroup being assessed. The assessor then chooses whether to base the human factors assessment on his own views of this operator or to apply a short questionnaire to the workforce who will be involved in that operation. We recommend that the questionnaire should be applied, however, we recognise that this may not always be possible.

In its simplest form, the assessor rates his/her level of agreement with 44 issues using a Likert Scale. A ‘hint’ facility is provided for each issue to help the assessor fully appreciate the factors which should be considered for each issue.

The input information is used to produce an overview of the workgroup’s positive and potentially negative features. The negative statements are then treated in greater detail.

Individual statements are given for each potentially negative aspect. These are presented in a standardised format providing a summary of the problem along with supporting statements derived from the assessor ratings and questionnaires. This is intended to help the assessor fully appreciate the human factors issues associated with each negative aspect. These cover:

- Key factors which support the conclusion of the root problem
- Further supporting information
- Factors which could have caused or contributed to the problem
- Any factors which would lessen the impact of the root problem

An option is given for each negative aspects for the assessor to view our recommended management actions for that problem. These will be very dependant on the exact input material provided for each workgroup and task being assessed. These recommendations are then summarised in terms of: those which should be considered immediately; those which should be considered during the actual task; those which should be considered immediately following completion of the task; and further longer term considerations. We recommend that this list is reviewed by the manager/engineer responsible and recommendations selected for action. The resulting page then forms the agreed management action list to safely manage that job. This can then be signed and dated. The agreed action plan then forms the management controls to minimise human factors problems and effectively maintain or promote a positive safety culture for the work group. It may also provide useful information for any permit to work scheme. The document can then be audited as necessary.

The tool is available on a CD-ROM and the price includes 12 months telephone support from HSEC Ltd’s Principal Human Factors Consultant and software engineers.

HSEC also have a wide range of specialist tools which are routinely used in addressing human factors problems in a number of industries. Those wishing to know more about these management tools should contact Steve Mason (HSEC’s Principal Human Factors Consultant) at the address given below.

Contact details:

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