HUMAN FACTORS

BRIEFING NOTE No. 13

Human reliability analysis

Methods for determining the reliability of human performance in specific tasks. These can be 'qualitative' (describes reliability in words only) or 'quantitative' (estimates the probability of human error in a task).

Why human reliability analysis?

Human reliability analysis comprises a group of methods used together to better understand and control human performance. They are advanced methods and this briefing note only provides an introduction to them – it does not provide all the skills needed to conduct an analysis, but will help in understanding them.

The likelihood of a human error in a task is directly related to the way the task itself is designed, and the quality of the following key factors:

- Workplace design (including the working environment, tools, controls, displays etc.).
- Documentation (written procedures, signs, labels).
- Operator competence (level of training, qualification, experience, etc., in the task).

Human reliability analysis is used to gather and present information on these factors in a logical way. Organisations use human reliability analysis to examine the extent to which they have those factors under good control. If the level of control (and therefore human reliability) can be improved, the analysis should point to how this can be achieved. Certain techniques can generate 'human error probabilities' for tasks giving an estimate of the chance of a human error.

Why carry out a human reliability analysis?

"…up to 80% of accidents are often attributed to human error, which suggests a great deal more can be done to prevent them." Source: HSE website – human factors pages http://www.hse.gov.uk/humanfactors/index.htm

The quote above relates to accidents, but human error is a major cause of disruption in the workplace - not just injuries, but plant downtime, defects in product quality and environmental damage. It should be understood how errors occur and how to reduce their likelihood. Safety cases required by the UK Health and Safety Executive (HSE) should show that the organisation is acting responsibly to reduce human errors.

Advantages of human reliability analysis

- Provides a logical comprehensive analysis of factors influencing human performance.
- Leads to recommendations for improvement.
- Supports the safety case: forces attention on safety critical tasks.

Disadvantages of human reliability analysis

- Can be time-consuming and costly, given the level of risk from human error in a task.
- May require specialist input.
- Some of its methods are not fully validated.

How do I carry out a human reliability analysis?

There are five basic steps (with the exception of step 4, these steps are covered in more detail in the seven-step process outlined in Reference 1):

1. Identify critical tasks

Errors happen every day at work and most are harmless, though some can result in fatalities, injury, plant damage or other losses. These can occur immediately in the case of operational or emergency response tasks, or some time later if, for example, a maintenance error renders a vital but infrequently used device inoperable. 'Critical' errors such as these can be identified in several ways:

- Through formal hazard and operability studies (HAZOPs) which inevitably raise human error as a source of risk.
- From probabilistic safety assessment (PSA) which may identify specific errors that need to be controlled.
- By examining historical data, accident and near miss records to find out what happened in the past and establish whether it is under better control now.
- By 'brainstorming' – ask experts (designers or users of systems and equipment) which errors could lead to a major problem.
- By behavioural safety observation.

The above may result in a large list of tasks. It may be necessary to further screen this, so as to examine in detail only a sample of the tasks, whilst ensuring that examples of all types of task performed in your workplace are chosen.

2. Perform a hierarchical task analysis (HTA)

Briefing Note 11 explains HTA in more detail. HTA consists of describing a task in terms of all the sub-tasks needed to carry it out. Tasks and sub-tasks can be shown in either a 'tree' – similar to an organisation chart – or as a set of headings and sub-headings in a table (see the example on page 3 of this note – moving a load using a crane).

3. Identify errors, consequences and defences

Using the task analysis as a starting point, identify feasible types of error in the tasks and sub-tasks. This can be done using available human error identification methods. They provide keywords to prompt ideas – can the task be omitted, can the action be performed on the wrong object, in the wrong order, etc.? This information is usually recorded in a table, also recording the possible consequences of the identified errors and the safeguards and recovery mechanisms in place to prevent errors or to detect and correct them (an example table is shown in the crane example later).

4. Estimate human error probabilities (HEPs)

The techniques for generating HEPs are highly specialised and should be used only by an expert (Reference 2). All are based on two principles: 1) any task, even if it is performed under the best achievable conditions, has a finite probability of failure and 2) less than ideal conditions will increase that probability of failure.

Techniques fall into two types: data-based and expert-judgement based – although both types require some level of expert judgement. The data-based techniques provide lists of types of tasks and provide a HEP associated with it. For example, the human error assessment and reduction technique (HEART method, Reference 3) describes types of task such as 'Complex task requiring high level of comprehension and skill'. Tasks fitting this description have an average failure probability of 0,16 and certain error producing conditions will raise this. If, for example, the operator has to perform the task under time pressure, the failure probability can increase 11-fold (note that this can generate probabilities of more than 1, in which case, the probability of failure is taken to be 1 or certain failure).

Technique for human error rate prediction (THERP) (Reference 4) contains tables of errors at a more detailed task level, for example: 'select wrong control on a panel from an array of similar-appearing controls… identified by labels only'. The HEP for this is 0,003 with an error factor of 3. Again, the analyst would judge whether certain conditions could affect performance and can multiply or divide this HEP by a factor of up to 3 depending upon whether conditions are considered to be worse or better than average. Expert judgement methods involve groups of task experts in a structured discussion of the tasks and conditions and estimating the probability of failure from the information considered (see Reference 5).

5. Develop conclusions and make recommendations for reducing error

The information gathered in steps 1 to 4 should show whether the task is under good control or not. It should also show what could be done to improve human performance in the task by indicating any factors (task design, workplace design, competence or procedures) that are particularly poor. Step 4 – generating HEPs – is optional, but reducing errors is the same whether the errors are quantified or not, and consists of examining the information to determine which aspects of the tasks and conditions under which the task is performed are less than optimal. For example, if the complex task could be simplified, this should reduce error probabilities and, similarly, if the task schedule could be reorganised to reduce time pressure on operators, this should also improve performance in the task.

Worked example

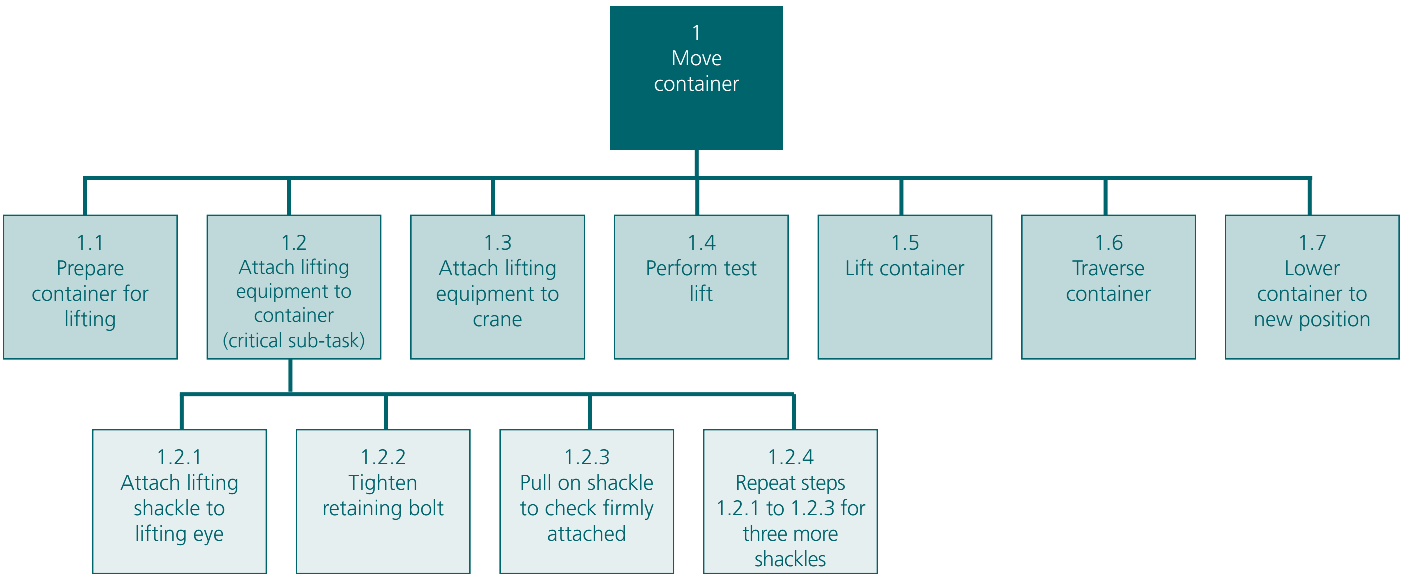
The example below is an extract of an analysis performed for a crane operation. It shows how the five steps in the analysis are actually conducted, but some of the detail has been removed. Before attempting a full analysis, more detailed familiarisation and training would be needed.

1. Identify critical tasks

The task is to move a container by crane to a new location. This task is 'critical' because the only available route for the load is over a production area. If the load drops during transit, it could break vessels and pipework releasing highly flammable gas.

2. Perform a hierarchical task analysis

To perform the task analysis, the analysis team went to the site where these tasks are carried out, accompanied by a crane operating crew. There they noted the main tasks and sub-tasks, recording the information on paper. This was later checked by the crew who corrected and clarified some of the detail – such as the order in which the tasks are actually performed, who carries out each one, etc. This resulted in the final task analysis description below.



3. Identify errors, consequences and defences

An expert group (crane operators, supervisor, trainers, etc.) considered each sub-task to identify errors. They used a checklist - found in reference books - as a prompt ('can the task be omitted?', 'can the task be carried out on the wrong equipment?' etc.). The findings from this group were then presented in a human error table (extract shown next):

Task	Possible errors	Consequences	Defences		Comments
			Safeguards	Recovery	
1.3 Attach lifting equipment	Use incorrectly rated sling	Load drops because sling is too light for the load	Procedure requires supervisor to check and sign off that equipment is appropriate and 'in date'. Equipment is colour-coded and the codes are well known	Test lift (raising load 0,5 m initially), is specifically to check that the load hangs level and that lifting equipment is sound	Lifting containers is a common task. Data show that errors are rare at this site
1.6 Traverse container	Move too rapidly	Lose control of load and crash into equipment	Crane is set at slow speed by key system which supervisor retains.	None if load impacts vulnerable equipment or plant	The consequences of error in such lifts are well-known to crane operators. Emergency arrangements should reduce severity of consequences
1.2.3 Pull shackle	Omit to check attachment	Shackle fails during lift	Check is simple, routine. Final visual check before lift will show any major problems	Test lift should reveal any problems	

4. Estimate human error probabilities

HEART was used to produce an HEP for this task (Reference 2). In the HEART data tables, moving a load is described as 'Task F - Restore or shift a system to original or new state following procedures, with some checking'. The HEP given for this is 0,003; that is, in 1 000 lifts, three errors on average can be expected. Taking this as a starting figure, the analysis team felt that the task of moving the container in this case would be done under time pressure. HEART describes anything that can increase the probability of error as an 'error producing condition' (EPC). HEART contains a long list of EPCs with associated multiplying factors. For example, extreme time pressure in a task could multiply the HEP by as much as 11 times. It was decided by the team that the effect of time pressure was not extreme and, in this case would increase the likelihood of error by a factor of 6 (HEART provides guidance on how to make this judgement) thus HEP was estimated as 0.018 – meaning that for every 1 000 movements of a container under the conditions that exist at this site, 18 errors can be expected.

Having generated an HEP, the team concluded that this rate of error in such a critical task was unacceptable and that the task or working conditions must be improved.

As an alternative to HEART, expert judgement could be applied to take advantage of the organisation's knowledge of how it conducts crane operations. An HEP can be generated in this way using the absolute probability judgement (APJ) expert judgement method (Reference 4).

THERP could also be used, which provides probabilities for individual parts of a task (for example, the probability of failing to perform a check correctly (sub-task 1.2.3 in the example) could be, according to THERP, around 0.05 (one in 20 probability). THERP describes many different types of check, however, and many different possible conditions under which checks could be performed. Interpreting THERP data and finding an overall probability from the individual probabilities of all of the sub-tasks requires a great deal of skill and experience. The novice user should not attempt a full THERP analysis although the THERP handbook (Reference 3) is very useful to read for general information on human reliability.

5. Develop conclusions and recommendations for reducing error

The process of breaking down the task for a task analysis and gathering information on safeguards and recovery mechanisms (defences) provided the analysis team with a clear insight into the problems with this task. Their recommendations focused on relieving the time pressure problem but also on improving communications between those involved in the task and making changes to the procedure for checking lifting equipment. Experts in crane tasks were asked to check these recommendations to ensure that they were acceptable and realistic.

All of the above material can be presented in a safety case to provide a clear history of the decisions made about this task and possible errors that could arise.

References

1. Energy Institute (2011), *Guidance on human factors safety critical task analysis*, http://www.energyinst.org/SCTA.
2. Kirwan, B (1994), *A guide to practical human reliability assessment,* Taylor and Francis.
3. Williams, J.C. (1985), *HEART A proposed method for achieving high reliability in process operation by means of human factors engineering technology,* in *Proceeding of a symposium on the achievement of reliability in operating plant,* Safety and Reliability Society, 16 September 1985.
4. Swain, A.D., and Guttmann, H.E. (1983), *Handbook of human reliability analysis with emphasis on nuclear power plant applications,* NUREG/CR-2744, US Nuclear Regulatory Commission.
5. Comer, M.K., Seaver, D.A., Stillwell, W.G. and Gaddy, C.D. (1984), *Generating human reliability estimates using expert judgement,* Vol. 1, NUREG CR 3688/10F2.5 and 84 7115, GP R 213022, USNRC.

Further reading

- Health and Safety Commission (1991), *Human reliability assessment: a critical overview,* Second Report of ACSNI Study Group on Human Factors, HMSO.
- HSE (2009) *Review of human reliability assessment methods,* RR679 HSL, HSE Books.

For background information on this resource pack, please see Briefing note 1 *Introduction*.