"GUIDANCE ON HUMAN FACTORS CRITICAL TASK ANALYSIS"

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INTRODUCTION

For at least a decade it has been argued that the assessment of human tasks in relation to Major Accident Hazards has lagged behind the analysis of process and engineering safety issues. There is widespread awareness in the energy industry that human failures in the performance of safety critical tasks have contributed to major accidents such as Piper Alpha, Chernobyl and Texas City. These failures have been exhaustively described in accident reports. Less well reported, but known through anecdotes and some near miss data, are the large number of events where human actions have prevented major accidents through timely interventions. Better management of the risk of human failures will improve safety and reduce losses suffered in the energy and process industries.

Safety critical task analysis has historically not been well documented in safety cases and reports. In recognition of this, recent regulatory guidance in the UK, directed at both the onshore and offshore industries, has reflected the importance of managing this risk of human failures and clarified the requirement for a convincing demonstration that human performance in safety critical tasks will be controlled to prevent foreseeable failures.

Although there are clear benefits in encouraging deeper analysis of safety critical tasks, there is a lack of available material to help those without a human factors (HF) background. It is vital that staff other than HF specialists are knowledgeable enough in safety critical task analysis to participate in projects, commission work and to use the results from these analyses. Therefore the Human and Organisational Factors Committee (HOFCOM) of the Energy Institute (EI) commissioned DNV to prepare a guidance document to help fill this gap. The intention is that HF safety critical task analysis will become part of the wider safety assessment toolbox leading to better integration of human failure assessment into safety studies.

This paper presents some of the background to the development of the guidance document, provides an overview of some of its contents and describes its intended use.

BACKGROUND AND PREVIOUS FRAMEWORKS FOR HF SAFETY CRITICAL TASK ANALYSIS (SCTA)

Historically there has been a disparity in Major Accident Hazard (MAH) safety reports between the level of analysis of technical failures and human failures. The analysis of technical failures has usually dominated even though the importance of human failures is well known. There are some signs that this is beginning to change with a higher volume of human factors safety critical task analyses being conducted.

Shorrock and Hughes [Ref. 1] presented an eight step process for assessing human failures with an emphasis on what is practical. The UK HSE, as part of its HF toolkit, produced a paper titled "Identifying human failures" [Ref. 2]. The seven step process from this HSE paper is shown in Figure 1 below. Both the method from Ref. 1 and from an Offshore Technology Report, OTO 1999 092 [Ref. 3] have large degrees of overlap with the HSE process.

There are also an increasing number of practical applications of safety critical task analysis. An example from the offshore industry is described in Ref. 4, and at Hazards XXI a paper by Ellis and Holt [Ref. 5] describes an application at a COMAH site. With this increasing interest comes an increased need for guidance and training material.

PROPOSED FRAMEWORK FOR SCTA

The process of SCTA was interpreted by the Energy Institute's HOFCOM as:

- Determining which tasks are safety critical.
- Understanding which human action or inaction might make a failure more likely or more serious.
- Identifying and installing adequate layers of protection for these safety critical tasks in order to reduce the likelihood or consequences of human failure.

A simple step-wise process for SCTA has been developed (see Figure 2):

1. Identify main site hazards.
2. Identify safety critical tasks.
3. Understand the tasks.
4. Represent the safety critical tasks.
5. Identify human failures and performance influencing factors.
6. Determine safety measures to control risk of human failures.
7. Review the effectiveness of the process.

The focus for the guidance is on major hazard safety rather than occupational safety. It links to the type of major hazard safety analysis that would be conducted at a project design stage or for safety report/safety case updates.

The guidance covers analysis of tasks, human error assessment (qualitative) and risk reduction/control. It does not cover all possible task analysis techniques, although does cover the most widely used techniques, such as Hierarchical Task Analysis and Human HAZOP. Task analysis can be used in many different ways, e.g. assessing staffing levels, determining the optimum balance of automation and human involvement, improving training regimes, etc.

Figure 1. HSE process for managing human failures [Ref. 2]

These are well covered in specialist publications (e.g. [Ref. 6] and [Ref. 7]).

KEY ISSUES FOR EACH STEP

STEP 1: IDENTIFY MAIN SITE HAZARDS

In order to recognise their safety critical tasks, a site must first identify their major accident hazards. This could be a relatively straightforward step of extracting them from existing safety reports/cases or relevant risk assessments. However in the case of a new facility where such documents do not yet exist, the SCTA will need to be scheduled to start once the main site hazards become clear.

This step is likely to involve consultation with site personnel and authors of the risk assessments to ensure that all the correct and most up-to-date documentation has been reviewed and that the MAH identification is comprehensive. If an organisation is conducting SCTA for the first time at a major site where there are many MAHs it may be necessary to prioritise and start with the highest risk units.

STEP 2: IDENTIFY SAFETY CRITICAL TASKS

This is a critical step where the process can easily collapse unless carefully managed. At a large site with several MAHs potentially a very large number of safety critical tasks (SCTs) could be identified. This can become unmanageable or attention on larger risks could become diluted.

It is important for an organisation to define what is a "safety critical task". For example does it cover just active "sharp end" tasks which, if not carried out correctly, would lead to serious consequences? Does it cover checking tasks, shift handovers, the development and approval of standards, the management of emergencies, etc.? The definition will have a large impact on the scale of SCTA to be undertaken. There will inevitably be some trade-off between thoroughness and practicality and this needs to be managed to ensure that the whole process is completed. That may mean focussing on a sub-set of SCTs initially with a plan for completing the others in subsequent phases.

There are various approaches of varying complexity to identifying SCTs which are reviewed in the guidance document:

- Some sites/organisations may already have identified and linked SCTs to MAHs in existing documentation. However, it is unusual for safety reports/cases to include sufficient granularity to identify all relevant SCTs.
- Screening matrices linking existing procedures to MAHs (see Figure 3). However, it should be noted that certain safety critical tasks may not be covered by existing procedures. In such a situation it is likely that

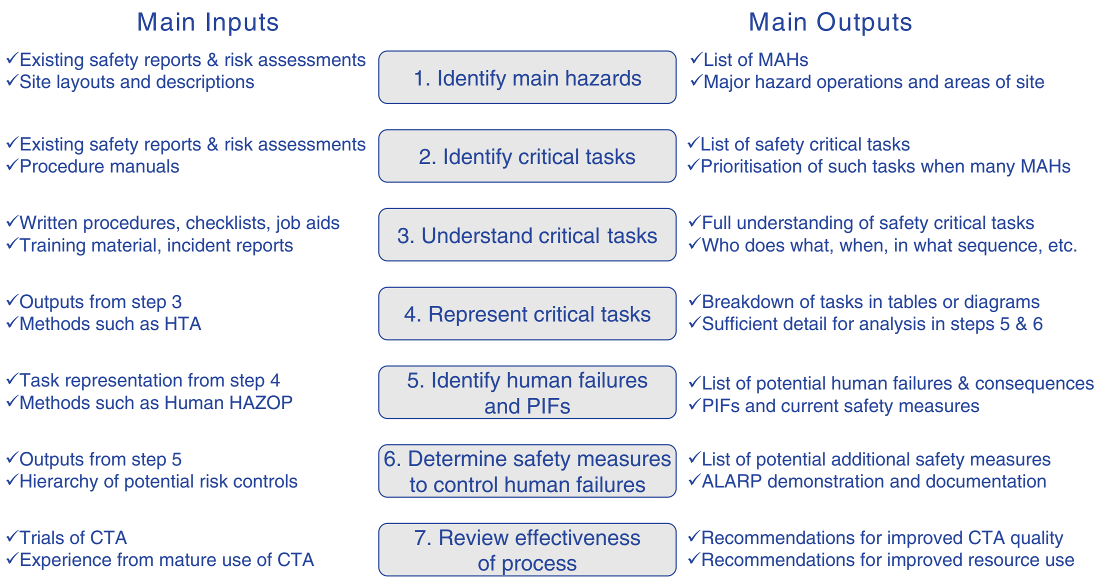

Figure 2. EI safety critical task analysis

COMAH Hazards	Roadcar gantry: pipework or hose failure	Transfer pipework failure	Storage vessels: pipework/ vessel failure	Storage vessel overfill	Roadcar overfill	Dropped load
Operating Procedures						
1. Propane road tanker loading direct from depot import line	✓				✓	✓
2. Butane road tanker loading direct from depot import line	✓				✓	✓
3. Propane import to site storage vessels				✓		

Figure 3. Example onshore procedure screening matrix

a procedure would need to be developed as a remedial measure before the SCTA could proceed.

- "Risk" matrices linking the consequences of human failure, task complexity, task frequency, level of human/manual involvement, etc. to prioritise and identify SCTs.
- Scoring systems where values are allocated to the hazardous material involved, introduction of ignition sources, level of change to the operating configuration, and other factors.

The identification of safety critical tasks should consider routine and non-routine tasks. For example operational tasks (e.g. filling a storage tank) and maintenance tasks (e.g. breaking into a pipeline) could have the potential for initiating a major accident such as loss of containment. In addition tasks relating to event escalation and emergency response should also be considered. Tables are provided in the EI guidance document covering examples of all these types of task. It should be noted that some users restrict application of SCTA to low level skill based tasks and tend to generate recommendations focussed on improving training and procedures. Others extend the application to covering managerial type tasks such as managing an emergency.

It is very important to check the final list of SCTs with site personnel for any gaps.

STEP 3: UNDERSTAND THE TASKS

The aim of this step is to establish in simple terms a short but comprehensive description of the identified safety critical task(s). This includes:

- What is done by whom in which sequence.
- What tools and information are needed.
- What interactions with other people are required.
- Factors with the potential to affect human performance, e.g. work conditions (noise, lighting), any time pressure, interface design, lack of stimulation during monotonous supervisory task. These are known as Performance Influencing Factors (PIFs).

The EI guidance highlights that in gathering information it is very important to interview personnel and observe tasks. Written procedures, while providing a convenient first source, may not be followed or may be out of date. Having operators talk through or walk through a SCT is usually far more informative and revealing than just reviewing a written procedure.

STEP 4: REPRESENT THE SAFETY CRITICAL TASKS

The safety critical tasks need to be represented in such a way that they can then be systematically analysed. At the simplest level this can involve listing the steps in a task. Descriptions of tasks should always start with a verb; this rule helps the analysis to focus on tasks rather than vaguer concepts such as a person's job or work.

For well understood, relatively straightforward tasks this may be sufficient to proceed to Step 5 of the SCTA. For more complex tasks, or to help obtain an overview of all the task steps, it may be helpful to employ additional techniques. A popular technique is Hierarchical Task Analysis (HTA). HTA represents tasks in terms of top down hierarchies. These can be shown as a tree diagram (good for visualisation) or as a table (better for detailed description). Not every step in a SCT is necessarily worthy of detailed analysis. Thus, one output of this step is the identification of the critical steps/sub-tasks (see Figure 4).

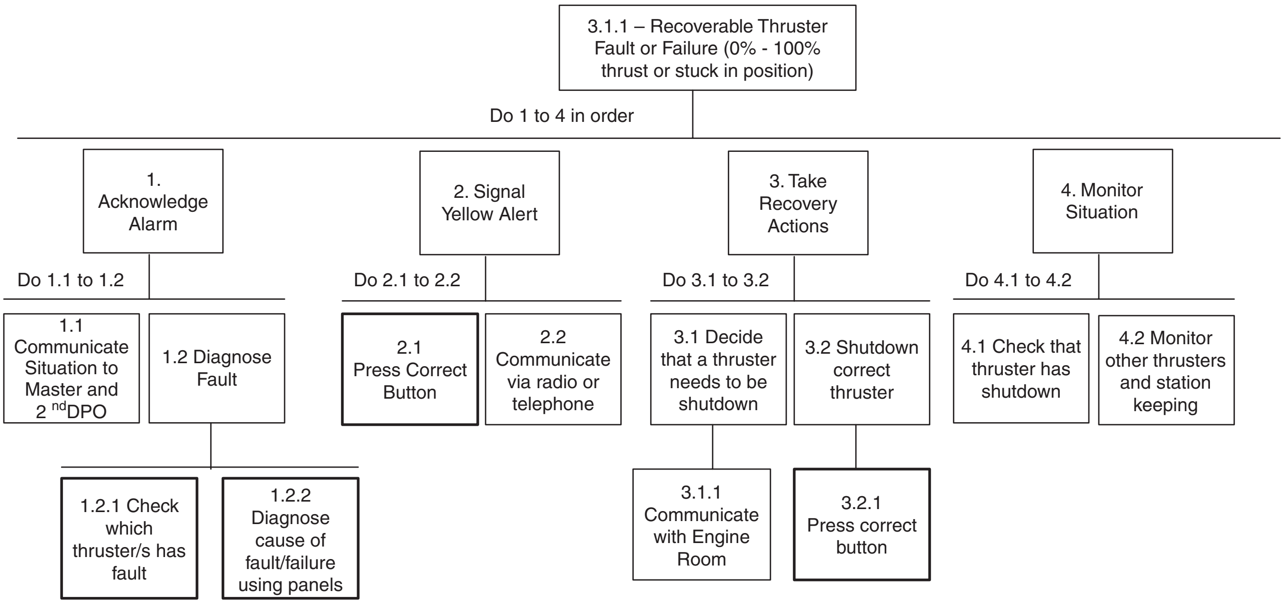

Figure 4. Example offshore HTA diagram – critical steps highlighted

STEP 5: IDENTIFY HUMAN FAILURES AND PERFORMANCE INFLUENCING FACTORS

For each of the critical task steps represented above, potential human errors need to be identified. There are a variety of techniques to do this including group based methods and techniques typically used by single analysts.

One method is Human-HAZOP where a group with an appropriate mix of experience and knowledge applies a set of HF orientated guidewords or prompts for each task step. Example guidewords include "*Operation mistimed*" and "*Right operation on wrong object*". Many more examples are given by the HSE [Ref. 2]. However, applying a long list systematically for every safety critical task step is usually not practical in a group setting. The HAZOP chair will usually apply some judgement to ensure that the most appropriate guidewords are considered by the group. A full guideword list might be applied if a task is totally new to a site or as a learning exercise when an organisation is developing its expertise in SCTA.

Some organisations have found that use of a group based approach is not necessarily most effective or efficient. Particularly for more routine or familiar SCTs, suitably trained individuals may be able to work through many of the process steps drawing on others as required to fill in any gaps.

Associated with the identification of errors, it is usual to include (see example Table 1):

- The existing safety measures in place including the current potential for recovery from that particular error.
- The potential consequences of the error if recovery is not achieved.
- The PIFs relevant to the error. A list of PIFs is provided in Ref. 8. Typically they would include ambient environment, training, tools, Human Machine Interface, supervision, work patterns, team and social issues, etc. These should be included as part of the data collection in Step 3 and analysed in more detail in this step. Typically a subset of the most relevant PIFs is associated with each potential failure. This will then help guide the analysts in determining whether effective safety measures are already in place or whether additional measures are needed.

Having completed this step the SCTA will have analysed the current situation at the site with respect to safety critical tasks and be ready to determine if further risk reduction is required.

STEP 6: DETERMINE SAFETY MEASURES TO CONTROL RISK OF HUMAN FAILURES

A hierarchy of additional risk controls to be considered is a useful aid once potential human failures have been identified. Such a hierarchy usually starts with "Can a hazard be removed?" and extends down to addressing and trying to optimise the PIFs. In determining what additional safety measures would be effective it is important to understand whether the human failures identified in step 5 would be classified as slips, lapses, mistakes, and violations (see Ref. 9). Improving training, for example, is unlikely to have a big impact on reducing slips and lapses whereas it could potentially have an impact on mistakes and violations. In contrast reducing distractions through a less cluttered workplace could have a significant effect on slips and lapses, but is unlikely to be relevant to violation reduction.

Matching additional safety measures to error types and PIFs is probably the element of SCTA that will be

Table 1. Example of task analysis relating to accident initiation – maintenance – pipeline interventions

SCTA of current situation					Additional measures to deal with HF issues		Notes
Task or task step description	Potential human failures	PIFs	Safety measures and recovery mechanisms	Consequences (if failure not recovered)	Measures to prevent or further reduce chance of failure	Measures to reduce consequences or improve recovery potential	Comments/ recommendations/ open issues
Isolate relevant section of pipeline	**Right Operation on Wrong Object:** Isolate wrong pipeline	Procedures	Job controlled under Permit-to-Work	Potential for loss of containment	Introduce a task risk assessment before such interventions		
		Communications	Interface with pipeline operators established		Review communication flows between relevant parties		
		Clarity of signs	Pipelines on site clearly labelled (but are they consistent across site)		Check consistency of pipeline labelling across site		
		Competence	Approved training programme for maintenance technicians		Review contractor training	Enhance supervision of contractors by site staff – should notice failure	

new for a non-HF specialist. Many of the other steps in the SCTA process are similar in broad terms to traditional risk assessment steps.

Workforce involvement, though important during the whole process of SCTA, is essential in this step. Operators and design personnel will understand, accept and act according to the resulting safety measures when they have had input to the development of these measures.

STEP 7: REVIEW THE EFFECTIVENESS OF THE PROCESS

The process summarised above needs to be adapted to fit within a site's Safety Management System. In particular it needs to be matched and integrated into the site's process for safety risk assessment. For a site that has done little or no SCTA of the sort described above, it would be worthwhile developing a process based on initial trials as follows:

- Choose a task(s) that clearly does link to MAHs or that clearly is high priority due to past incidents. Use this for the initial trial.
- Conduct SCTA as per steps 3–6 above. Get personnel involved, informed, trained and committed.
- Review trial for lessons learnt.
- Adapt process so that it is suited to the site and leads to outputs that are beneficial and practical. Use the trial as a case study to help "sell" wider use of SCTA.
- Obtain management commitment to conduct comprehensive SCTA for all MAHs.

As the process becomes established regular reviews should be carried out to check that the SCTAs are producing good quality outputs and that the benefits obtained (e.g. reduced incidents, reduced costly re-design, etc.) justify the resources used. Linked to this last point it is likely that various optimisations will be possible as experience is built-up. It should be possible to develop a library of generic SCTAs that could be re-used for different MAHs around the site or between an organisation's multiple sites.

CASE STUDIES

The EI guidance document incorporates two case studies that illustrate the SCTA steps described above. One is a chemical offloading operation using a group based approach [Ref. 5]. The other is from a power plant control room conducted mainly by a single analyst with input as required from experts [Ref. 6]. Table 2 summarises the case studies showing what methods and approaches were used in the seven steps by these different studies.

DOS AND DON'TS

A list of points is provided in the EI document which can be used by readers to benchmark their work and ensure that they do not fall into common traps. It is also intended to help organisations specify what they want from a SCTA and what questions to ask during a SCTA. A flavour of this is provided by the following list of potential illustrative pitfalls:

- The study looks like a theoretical exercise with little sign of personnel involvement.
- It gets bogged down in details of procedures with little relevance to MAHs.
- There are obvious missing tasks (e.g. a focus on operational tasks, but nothing on maintenance and non-routine tasks).
- Failure to take account of past incidents with an HF component (either at the site or well known in industry).
- Evidence of gaps in the team knowledge (e.g. plenty of offshore major hazard experience but lack of marine experience in a Floating Production and Storage unit analysis).
- PIFs not identified or not mapped across to additional measures to demonstrate that they are being optimised.
- Inappropriate use of risk control hierarchy (e.g. consistently asking if certain PIFs can be improved such as training, without considering if the hazard could be removed completely).
- Lots of quantitative analysis without a solid underlying qualitative analysis.

INTENDED USE AND AUDIENCE FOR EI GUIDANCE DOCUMENT

In broad terms the main purposes of the EI guidance document are:

- To raise awareness of SCTA particularly amongst non-HF specialists to encourage its increased use.
- To assist organisations in determining and demonstrating adequate safety measures (e.g. within offshore safety cases and COMAH safety reports).

In terms of expected users the guidance is aimed at those who:

- Participate in a SCTA, e.g. someone who is asked to provide discipline expertise in a group identification session.
- Incorporate a SCTA into a wider risk assessment as part of a safety report/case.
- Commission a SCTA and need help with preparing a specification.
- Need to read, understand and act upon a SCTA.

Thus, the target audience includes designers, operations, assessors and managers. For people who will actually conduct a HF SCTA they will need probably to consult some of the reference documents listed in the guidance document and obtain prior experience through training and participation in SCTA projects. For relatively simple SCTAs someone with experience in traditional safety studies such as HAZOPs may have most of the relevant competences. However, for more complicated SCTAs, specialised HF support may be required.

Table 2. Summary of case studies with respect to SCTA process

Steps	Chemical offloading operation	Power plant control room operation
Step 1 – Identify main site hazards	Identified from COMAH report 2000, updated 2005.	From Probabilistic Safety Assessment supporting Pre-Construction Safety Report (PCSR).
Step 2 – Identify safety critical tasks	Identified from COMAH and SIL studies. Focussed on task where human factors known to be significant.	From Probabilistic Safety Assessment supporting PCSR – over 50 operator actions to ensure that plant could be safely operated or could be safely shutdown following a fault.
Step 3 – Understand the tasks	Written procedure was reviewed. Observation of drum unloading activity.	Description of operator actions derived from PCSR and supplemented with control panel drawings, drawings of proposed Video Display Units (VDU) formats, system diagrams, etc. Informal discussions with technical experts.
Step 4 – Represent the safety critical tasks	Procedure broken down into key steps using HTA. Key steps are ones that could either prevent or mitigate the effects of a drum explosion or fire. Steps of no relevance to the hazardous event were discarded.	Draft set of main steps identified by analyst. "Talk through" of these proposed steps was then undertaken by operations expert using control panel drawings to check for completeness and correct sequences. Each of the steps then re-described to appropriate level of detail which indicated how each step would be carried out and what equipment was necessary. These task descriptions were then checked by the analyst in an accurate control room mock up.
Step 5 – Identify human errors and performance influencing factors	Team based HAZOP approach. Nodes of HAZOP formed by key task steps. Guidewords and standard PIF lists used.	Tasks decomposed by analyst into initiating cues; control actions; decisions; communications; sustaining cues (feedback), and termination cues. Mismatches identified between the information/control which was currently available in the design and that which was required to successfully undertake each step.
Step 6 – Determine safety measures to control risk of human failures	Recovery mechanisms considered. Risk reduction measures assessed – engineering controls and HF improvements. Human-HAZOP recorded.	Mismatches which were highly likely to result in a failure to fulfil a safety action were given highest priority. Behavioural mechanisms were identified and potential remedies recommended. Reports produced clearly identifying systems affected so that relevant system owners could understand and act on outputs.
Step 7 – Review the effectiveness of the process	Trial appeared effective. Suitable for wider application to other tasks on site.	Because analysis was undertaken early on in the project, the recommendations could be implemented at little cost. The reports were sent to the licensing authorities so that they had confidence that each of the operator actions had been adequately safety assessed.

It should be stressed that application of SCTA does not mean that all Human and Organisational Factors (HOF) have been addressed in an organisation. While it can be valid to extend SCTA to cover a wider range of tasks than traditionally considered (see examples under step 2 above) SCTA does need to be complemented by other tools and techniques to ensure systematic evaluation of HOF and a balanced continuous improvement programme. SMS surveys and audits can be used to identify where SCTA should be enhanced as well as related and broader HOF safety issues. Workforce involvement programmes are another key tool in raising awareness of and improvements in HOF. If violations are an issue at a site, specific initiatives to identify and remove the drivers for these violations may be needed. Safety culture surveys, detailed ergonomic studies, fatigue assessments, behaviour observation and modification are all further examples of addressing HOF issues. SCTA should be seen as one valuable technique within a wider HOF safety toolbox.

CONCLUSIONS

The "Guidance on human factors critical task analysis" is an easily accessible document for all non-HF specialists. It is written in a straightforward way by hands-on experts with practical illustrative examples. It has been thoroughly reviewed by industry representatives and the EI's HOFCOM to ensure it is suitable for practitioners in the energy sector. The full guidance document will be available on the EI's human factors website (http://www.energyinst.org/technical/human-and-organisational-factors).

As with all its other guidance documents, the EI would appreciate feedback from the target audience to learn of the guidance document's successful use in day to day safety and risk assessment work, or to note any changes that may be required for future revisions. Any comments are very welcome by the EI, and can be submitted via email to technical@energyinst.org.

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