Developments in Human Factors Critical Task Reviews (HFCTR)

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In the UK, sites governed by the Control of Major Accident Hazard (COMAH) regulations are required to identify COMAH-critical tasks, analyse them for vulnerability to human failures, and the factors that might make those failures more likely. This process, here called Human Factors Critical Task Review (HFCTR), is an important tool in the management of Human Factors (HF) at Major Accident Hazard (MAH) sites.

Most versions of HFCTR, also known as qualitative Human Reliability Analysis (HRA), Safety Critical Task Analysis (SCTA), and Human Error Analysis (HEA), have their roots in the Systematic Human Error Reduction and Prediction Approach (SHERPA) developed in the 1980s as an HF analogue to qualitative engineering risk analyses. Typically, the techniques include some form of task analysis, failure analysis, and Performance Influencing Factor (PIF) analysis.

This paper draws on over 10 years of practical experience, at a wide range of COMAH sites, to discuss developments in the practical application of HFCTR. The technique that Human Reliability uses, whilst being closely related to the original SHERPA technique, has been adapted to meet the requirements of increasingly specific regulatory guidance, and the demands of application at busy commercial sites.

1 Background and scope

In the UK, sites governed by the Control of Major Accident Hazard (COMAH) regulations are required to identify COMAH-critical tasks, analyse them to establish where they are vulnerable to human failure, and review the factors that might make those failures more likely (HSE, 2016). This process typically includes some form of task analysis, failure analysis, and Performance Influencing Factor (PIF) analysis. Ultimately, the aim is to optimise the performance of people undertaking COMAH-critical tasks, by ensuring, with reference to ALARP and Hierarchy of Control (HoC) principles, that control measures are appropriate and PIFs have been optimised (for more detail on this type of analysis, see, for example, Energy Institute, 2011).

This process is variously referred to as Human Reliability Analysis (HRA), Safety Critical Task Analysis (SCTA), Human-HAZOP, or Human Error Analysis (HEA). Our preferred term is Human Factors Critical Task Review (HFCTR), as this makes clear the discipline it relates to (Human Factors), and that it is to be applied only to the most important tasks (Critical). Task Review is used rather than Task Analysis, as task analysis is a sub-element of the process.

Most versions of HFCTR, have their roots in the Systematic Human Error Reduction and Prediction Approach (SHERPA) developed in the 1980s as an HF analogue to qualitative engineering risk analyses (Embrey, 1986, 2018).

This paper draws on over 10 years of practical experience, at a wide range of COMAH sites, to discuss developments in the practical application of HFCTR. The technique that Human Reliability uses, whilst being closely related to the original SHERPA technique, has been adapted in its application to meet the requirements of increasingly specific regulatory guidance, and the demands of application at busy commercial sites. This paper does not provide a full description of the HFCTR process, this can be found elsewhere (e.g. Energy Institute, 2011), instead we attempt to identify the parts of the process where we have found challenges in its implementation, and discuss both how we have addressed these, and how the process might be developed further in the future.

2 Issues with the HFCTR process

Identification of tasks for review

The first requirement is to identify the tasks that should be subject to HFCTR. HFCTR may be used on any task, but it can be a time-consuming process, therefore, ideally, the analysis effort should be directed where the risk is greatest. In the context of the UK COMAH regulations this is usually tasks that are related to Major Accident Hazards (MAH). The HSE's Inspectors' Guide describes the identification of tasks as a key success criterion (HSE, 2016), emphasising that this relies on a site having identified all relevant MAH-scenarios at the site, and that the identified tasks should be subsequently prioritised for review.

We have encountered some confusion around the terminology here, with some people using the term *task* to mean a whole activity (e.g. offloading a tanker), whereas others have used it to mean the important steps within the overall activity (e.g. connecting a loading hose). We prefer the former approach for two main reasons. Firstly, the use of whole activity descriptions usually ties in with existing procedure descriptions, which can make administration of the HFCTR process more straightforward. Secondly, success or failure in a task will often depend on actions taken prior to the obviously critical step. For example, in a task such as removing a pig from a pig trap, a critical step is the opening of the pig trap door to remove the pig. However, whether it is safe to do this (i.e. that the pig trap has been isolated and fully depressurised) will depend on the preceding steps (e.g. the isolation, the depressurisation, purging, proving the status of the pig trap). Therefore, we prefer to start in the task identification process with the broader definition of the task. Ultimately, during the HFCTR, it may become apparent which individual steps are the most critical, but we normally make this assessment at that stage, rather than during the task identification.

In addition, we refer to tasks rather than procedures, as there are often tasks which are not covered by existing written procedures. A common example of this is control room response tasks, where descriptions of required responses, if captured at all, are frequently described in documents other than procedures (e.g. training documents, alarm response manuals).

Different ways of identifying and prioritising MAH critical tasks for review have been tried (see, for a more detailed discussion, Henderson, 2014). In practice, these divide into two main types: scoring approaches, where lists of tasks are scored according to pre-determined dimensions (e.g. HSE, 1999), and a hazard-based approach, where tasks are identified according to their relationship to specific hazards. In general, for simplicity, we prefer the latter approach, primarily because it ensures a clear link to the MAHs at a site. We have found, with scoring approaches, that tasks unrelated to MAHs can score highly, and therefore appear to be high priorities, if they are complex, or related to other hazards such as production efficiency or personal safety. As the HSE require tasks to be prioritised for HFCTR (HSE, 2016), then a hybrid approach, where tasks are initially identified according to their relationship to MAHs, but then scored to prioritise them for review, is an approach we have found to be effective.

Ideally, the task identification process should be clearly integrated with other risk management activities. In the future, given the increasing prevalence of Bow-Tie representations (e.g. CIEHF, 2017), this may be one method for making a clear link between wider risk management and HFCTRs. For example, if a Bow-Tie has identified a top event such as overfilling a storage tank, and barriers such as operator response to high level alarm and a high-level trip have been specified, then related tasks will include the operator response to the high-level alarm and the testing and maintenance of the trip. If the Bow-Tie representations are a reasonable reflection of the primary site MAHs, then the resulting task list should include most of a site's critical tasks.

Often, similar task types, which are generic across a site, will be identified for different hazards. For example, for any given hazard, an obvious way for it to be released is by the incorrect performance of a maintenance preparation or reinstatement task, and these types of tasks can take place on any system. We have found that, once one or two analyses of these generic tasks have been completed, general improvements can be made, without the need to analyse every specific example of the task. For example, for maintenance preparation tasks, analysing one or two examples of this task type can lead to findings about the control of work processes (e.g. isolation management, permitry) that can be used to make general improvements (see Henderson et al, 2017, for an example).

Structure of HFCTR workshops

There is very little support available in the published guidance (e.g. Energy Institute, 2011) for the HFCTA facilitator in terms of how an HFCTR workshop should be structured. We have found the following to be useful.

Starting the workshop with a general discussion about the nature of the task being considered helps to set the context. This might include, for example, a discussion of who is involved in the task, how long it typically takes, and how often it is performed.

It is also important to be clear why the task has been identified for analysis. Typically, this is because of an identified relationship to one or more MAHs, but there may be other reasons. One useful time saving measure is to list, at the start of the analysis, the known task hazards, and the related control measures. For example, if a known hazard is overfilling a storage tank, the controls may include a high-level alarm (and operator response), a high-high trip and, in the event of the overfill, a bund. Listing these at the start of the analysis often saves time later, as, when an outcome is identified because of a failure (e.g. failure to monitor a tank level during loading), the hazards and lists of associated controls can be referred to rather than repeated (e.g. see controls for Hazard 1 – tank overfill). Should additional hazards be identified during the analysis these should be added to the list.

Finally, particularly in situations when the facilitator or other members of the workshop team are not familiar with the task, it is useful to outline the operating parameters of the system under consideration. This may be done with reference to P&IDs, but it is often also helpful to sketch out, if one does not already exist, a simple process diagram illustrating the key items. Photographs of areas which will be discussed in the workshop may also be beneficial.

Task analysis

We believe this is one of the most important parts of the HFCTR process. Where a reasonable procedure exists for a task, it can be tempting to skip this stage, and use the procedure as the basis for the subsequent failure identification and PIF analysis. However, in our experience, a proper task analysis, for example a Hierarchical Task Analysis (HTA), adds considerable value, not least in giving the workshop team the opportunity to consider why the task is performed in the way it is: this is often a rare opportunity. When sites review procedures, a typical practice is to distribute procedures to different individuals, and ask them to review them in their quiet time. Often, when doing this, the individual will cast their eye over the document and, after making one or two minor amendments, conclude that the task description is close enough to the method they would follow. On many occasions we have analysed tasks that have recently been through this type of review process and found fundamental issues with the approach to the task. This is not so much the fault of the individual reviewing the document, more an issue with the review process itself, which is passive in nature, includes only one individual, involves no discussion, and does not encourage detailed consideration of the task. Whilst this may be sufficient for most tasks, we believe that MAH-critical tasks should be subject to more thorough analysis.

If done properly, the HTA should be organised into sub-goals, which enables the workshop team to reflect, at every stage, on what is being done and to what end. Ideally, if the workshop team has more than one individual familiar with the task, then there can follow a discussion about the best way of approaching it. This exercise, which is particularly powerful when the existing procedure is not already organised in this way (e.g. it is a long list of actions, not organised into sub-goals), often leads the workshop team to question the purpose of sections of the task, which, otherwise, they might have just taken at face value. In many cases, in our experience, this has led to a rethink about the way tasks should be performed. We have even had some occasions where this process has led to a task being stopped, when the discussion has revealed that the task adds little or no value, or because it introduces other types of risk.

Participants are sometimes worried about what should happen when individuals have different ways of performing a task which both seem equally reasonable. If two methods really are equivalent, then this is not a significant issue. However, there may be sound technical reasons (which, if necessary, can be explored outside the workshop), as to why one method should be preferred (e.g. the two methods may achieve the required goal, but one has a potential long-term impact on equipment integrity). The identification, capture, and communication of these reasons is an important part of the process, as they are often not documented in existing procedures.

In terms of the efficiency of the HFCTR process, we tend to develop a draft task analysis in advance of the workshop based on available documents (e.g. procedures, vendors instructions, P&ID), and use this as a starting point for the workshop discussion. Ideally, the task analysis would be developed from scratch by the workshop team, however, in most cases, this would take a prohibitive amount of time.

Screening a task to identify the most critical steps

An important output from the HFCTR process is to identify the steps within a task that are MAH-critical. The HSE Inspectors' Guide (2016), in the context of procedure management, states:

> "The COMAH operator has…used on-plant task analysis to inform the step-by-step content of COMAH-critical procedures - they define the agreed way of carrying out relevant tasks in a safe manner. *Critical steps are clearly identified* and appropriate warning information is given, helping define a 'human basis of safety' for tasks where reliance is placed on people as part of the necessary measures."

The logic behind identifying MAH-critical actions in procedures is clear: they can be differentiated from other, less important steps, which means that an individual following a procedure, or being trained in a task, can see which steps are particularly important. A standard argument, that we often hear against this, is that all steps are important, and that people following procedures should be taking care to complete every action correctly, this viewpoint is often characterised in procedures by a requirement to sign for every action. However, even in MAH-critical tasks, there are steps which are objectively more important than others. For example, if one considers a ship-to-shore offloading task where an operator must remove a locking pin before moving the loading arm. Failure to remove the locking pin will simply result in a delay to the task, as it must be removed in order to move the arm. By comparison, failure in a step where the operator must ensure that a drain valve is closed in the loading line, may result in a loss of containment.

We believe, therefore, that identifying MAH-critical actions is important. However, the way that the identification is done requires some thought: if the threshold for determining whether a step is MAH-critical is set too low, then there is a risk of every step in a procedure appearing critical, making procedures look noisy, and reducing the benefit of differentiation. If it is set too high, then some steps that are critical might not appear so in the procedure, and receive less consideration in the risk analysis.

Therefore, whilst the simplest method for determining whether a step is MAH-critical is to consider whether it is related to a MAH, in practice, particularly for tasks where most of the steps are related to the MAHs, a subtler approach may be required.

One possibility is to consider the existing degree of protection (i.e. the control measures) related to a step. An example of a step for which there is little ambiguity about its criticality, is one where there are no control measures to prevent either the failure of the action, or to prevent the realisation of the consequences arising from the failure. This is sometimes referred to as a *single point of failure*. For example, in a storage tank with no high-level trip, a failure to respond to a high-level alarm is likely to result in an overfill. Where a trip does exist, the failure to respond to the high-level alarm, whilst important, does not feel as critical as the situation where it is absent. Therefore, one option, although we do not currently do this formally in our analyses, would be to score each step according to its relationship to MAHs, and to the existing degree of protection according to the Hierarchy of Control (HoC). This type of approach is illustrated in Table 1, below.

Figure 1 Example screening process for task steps

Step	Description	Hazard score	HoC score	Overall screening score (H x HoC) *Higher score = greater criticality*
Step 1a	Respond to high level alarm in storage tank (with high level trip)	1 (related to MAH outcome)	1 (with high level trip, so 1 for high up in HoC)	1
Step 1b	Respond to high level alarm in storage tank (with high level alarm, but no trip)	1 (related to MAH outcome)	2 (with high level alarm, requiring operator response so 2 for lower down in HoC)	2
Step 3	Return paperwork to tanker driver	0 (no relationship to MAH)	N/A	0

Such an approach would allow the analysis team to differentiate between steps which are related to MAHs, but which have control measures designed to prevent the release of the hazard, and steps where there is reliance on human action to prevent the release of the hazard. This type of process would enable analysis effort to be directed at the most important steps within a task. It has the additional advantage of aligning with HSE expectations regarding the consideration of HoC issues, and could potentially be used to demonstrate that these have been considered (see later discussion on presentation of outputs).

The scoring process could be extended if necessary to suit the requirements of a given site. For example, in Table 1, the hazard score is either 1 (related to MAH outcome) or 0 (not related to MAH outcome). For sites with a range of different MAH outcomes, this scoring process could be developed to differentiate between the scale of the hazard associated with each MAH (for example, 1 for loss of containment of chemical A, and 2 for uncontrolled reaction of chemicals A and B). Similarly, there are some subtleties in the consideration of control measures which could be reflected in the HoC scoring. For example, some measures prevent the failure itself (e.g. interlock systems which prevent valves being opened out of sequence), whereas others are designed to prevent the MAH consequences being realised following a failure (e.g. a trip which acts to prevent an overfill if an operator has missed a high-level alarm). However, our experience of these types of scoring systems is that it is better to keep them as simple as possible, as otherwise the screening process, the main purpose of which is to simplify the process, can end up becoming extended, and detract from the main goal of the analysis: to identify human factors vulnerabilities in MAH-critical tasks and make improvements.

Where reliance on a control measure is identified, it is important to consider the vulnerability of that system to human failure. If the control measure is part of a system that this tested and maintained (e.g. in this example, the high-level trip), then the related maintenance tasks, such as function tests, should be subject to their own HFCTRs. However, the facilitator and workshop team should also consider whether there are any conditions under which the control measures may fail to provide the intended protection. For example, an HFCTR may conclude that a failure such as inadvertently opening a drain valve on a pressurised reactor will not happen because of an interlock that prevents drain valves being open when the reactor is under pressure. In this case then there should be consideration of the possibility and desirability, from the operator's perspective, of bypassing the interlock.

Failure identification

Balancing thoroughness of analysis against available analysis time

Ideally, there would be sufficient time in an HFCTA to consider, in detail, every possible failure mode for every task action. In practice, this would be likely to take too long. It can also affect the quality of the analysis, as, for the workshop team, an involved consideration of steps that have no obvious relationship to a MAH, can result in a loss of focus. This in turn, can mean that by the time that important actions are discussed, the workshop team are too demoralised to give them proper consideration. This issue can be addressed by both good workshop facilitation and the use of more formal screening techniques.

In terms of facilitation, we have found that leading the discussion in a more engaging manner than simply by reading aloud the available failure modes is especially useful. For example, the facilitator, when considering part of a task, might start by asking the workshop team what the worst possible failures in this part of the task might be. This gives permission to the workshop team to do what our experience has shown that they may wish to do naturally, which is, as soon as possible in the discussion, to raise issues that their experience has led them to believe are important. The facilitator can capture and code the outputs of this discussion according to the HFCTR failure modes. Then, to ensure that all relevant failures are captured, the facilitator can subsequently prompt consideration of other failure types. For example, if the workshop team initially discussed a failure related to working on the incorrect piece of equipment (i.e. right action on wrong object), the facilitator can follow up the initial discussion by asking about failures of omission, timing, direction, etc.

Screening the task steps, particularly for larger tasks such as start-ups, is another possibility. The method discussed in the previous section on screening is one approach that might be used for this.

Failure modes and failure mechanisms

One area where we have found some confusion, is in the distinction between HFCTR failure modes and failure mechanisms. The guidewords in most variations of the HFCTR process, including the original SHERPA method (Embrey, 1986), are failure modes which are outcome-based (i.e. they describe the possible range of outcomes related to a task step). These failure modes are descriptive and do not directly support consideration of the possible reasons for failure. By contrast, failure mechanisms, such as slips, mistakes and violations (e.g. as described in HSE, Undated), do enable an analyst to consider why a failure might occur. For example, an HFCTR might identify a failure such as *action omitted* for the step *open valve* - this is the failure mode - the possible reasons for, or causes of, this failure mode, can then be described using the failure mechanisms. For example, it may be the result of *a slip of action* (where the operator intends to open the correct valve but inadvertently opens a different one), *a lapse* (where the operator forgets to open the valve), *a mistake* (where the operator incorrectly thinks that a different valve should be opened), or *a violation* (where the operator knows the valve should be opened, but decides to leave it closed). In other words, any given possible failure modes might be the result of one of a range of different failure mechanisms (or indeed, all of them).

In some of their guidance the HSE combine these together under the term *human-failure types*:

> "The COMAH operator should identify an appropriate range of human failure-types during the analysis process (e.g. potential decision-making errors and acts of non-compliance, in addition to the more obvious 'action errors')." (HSE, 2016b).

> "The COMAH operator can demonstrate that the HRA methodology is being implemented in a proportionate and effective manner. Key evidence could include…Risk reduction measures 'match' human failure-types identified." (HSE, 2016b).

Because identifying both failure modes and mechanisms for every step in a task can be prohibitively time consuming, and because, for many failure modes, all failure mechanisms might be credible, we focus initially on the failure modes (i.e. the undesired outcomes that are possible in the context of the step). Once an important failure mode has been identified (e.g. one where there is a potential impact on a MAH outcome), then we consider the potential reasons for the failure, which may include slips, mistake and violations.

The requirement to match risk reduction measures to failure mechanisms can also present difficulties. In some situations, if the proposed improvement acts directly on the failure mode, it can make consideration of failure mechanisms redundant. For example, if the identified failure mode is to open valves out of sequence, then an interlock, which prevents this failure mode, will prevent the failure regardless of the underpinning mechanism (i.e. slip, mistake, or violation). In other words, whatever the reason for the failure, the control measure will prevent it. Where considerations of the failure mechanisms may be more valuable, is in situations where any existing controls act on the outcome (e.g. a trip which prevent the consequences of the failure being realised) rather than the failure itself.

Treatment of Performance Influencing Factors (PIFs)

Understanding the PIFs that affect the probability of success or failure in a task is an important part of the HFCTR process. However, again, in practice, there is little guidance as to how this should be done. For a facilitator, relevant practical issues to consider include:

- Which PIFs should be considered?
- Should all PIFs be considered for every step in a task?
- What should be recorded? For example, should only PIFs with a negative impact on task performance be considered?
- How should evaluations be captured? Should there be some form of scoring to indicate the quality of the PIF, and/or should a narrative description be used?

The HSE Inspectors' Guide defines PIFs in the context of HFCTR in the following terms (HSE, 2016):

> "COMAH operators should use Human Reliability Analysis (*Critical Task Analysis*) …to gain a clear understanding of where and when they are vulnerable to human failure (COMAH-critical tasks), how those failures are likely to

occur (accounting for the different types of human failure), and *the factors that make those failures more likely (PIFs).*"

The first requirement is to determine which PIFs should be considered in an HFCTR. There are lists available (see for example, Energy Institute 2011) which we use for reference. However, in practice we find that there are often PIFs which are not covered in the checklists, or are specific to the task being analysed. In particular, PIFs that are more related to site management systems than the task in question. The HSE Inspectors' Guide again:

"Key elements of the HRA methodology include…a framework to identify, evaluate and optimise key PIFs at a job, individual and organisational level – this should be an integral part of the HRA process."

In terms of the latter statement ("…evaluate and optimise key PIFs at a job, individual and organisational level…"), we have found that some PIFs are difficult to evaluate in the context of an HFCTR. For example, whether or not a person is tired, a potentially important PIF in terms of its impact on task performance, is often the consequence of factors unrelated to the task being analysed. These might include the shift pattern they follow, the opportunities they have had to take breaks, and the amount of overtime they have completed. This means that, in an HFCTR, there is often little to gain by asking participants about PIFs such as fatigue, as they struggle to relate them to the task being considered (e.g. "Well I am tired, but it's nothing to do with this task"). By contrast, PIFs, such as equipment labelling, are easy to assess in the context of an HFCTR. This is not to say that these general PIFs will not have an impact on task performance, clearly if a person is fatigued they will be more prone to failure, more that they will have a generic impact across tasks, and that improvements may need to be made at an organisational level rather than a task level.

There is an argument, therefore, for addressing these different types of PIFs in different ways. One possible option is to separate out PIFs that make sense to evaluate in the context of a task (e.g. labelling, equipment layout, availability of information), we might call these *task specific PIFs*, and PIFs that have a more generic impact on task performance (e.g. fatigue, staffing levels, general workload, motivation), we might call these *generic PIFs*. Task specific PIFs can continue to be evaluated in the context of HFCTR, however the generic PIFs might also be evaluated independently of tasks (e.g. as a type of leading indicator)[1].

In practical terms, we consider PIF lists for both critical task steps and for the whole task (usually at the end of the analysis). To save time, we tend to only capture PIF information related to steps which have a clear link to the MAHs of concern. We tend to record only information for PIFs which have been identified as deficient, although there are occasions where we may choose to record PIFs which have a positive impact on task performance. This is so that, if the positive PIF has a significant impact on the likely success of the task step, the client can be made aware of it, so that they can ensure it is managed in the event of proposed changes to the way a task is performed. In most cases, the PIF information is captured in a narrative form. However, there are situations when numerically evaluating PIFs may be useful (e.g. if the analysis is to be used as an input to quantification).

Making the outputs of the analysis accessible

The latest version of the HSE's Human Factors roadmap (HSE, 2016) emphasises the importance of considering HoC improvements for critical task steps before improving PIFs. To support this, when writing up HFCTRs, we have chosen to supplement the detailed HFCTR outputs with a summary table, where the critical task steps are listed. The aim is to disentangle the key points from the detail of the analysis report, to enable the client to focus on the main issues.

For each critical step we discuss the primary failure modes of concern and, where appropriate, the possible contributory failure mechanisms. Secondly, we evaluate the status of control measures for the step with relation to the HoC. For example, if the step relies entirely on operator performance, then we will report that its current position is low down on the HoC, with scope for improvement. Whereas, if there is an effective control measure which is designed to prevent the failure, then we will report that it is high on the HoC, and that there is limited scope for improvement. Where a step currently has a lowly position on the HoC, then we may make suggestions for additional control measures. This can be difficult to do without detailed knowledge of the full range of possible practicable engineering solutions. However, these suggestions give a starting point for the client to make the case for a particular control measure, or for maintaining the status quo. Finally, we list PIFs we have identified as deficient with scope for improvement.

Whilst, understandably, the available descriptions of the HFCTR method focus on the elements of the process (i.e. task analysis, failure identification, PIF analysis), in practice the insights from any given analysis often come from an appreciation of the whole task rather than the analysis of any individual element. In some cases, the salient issues become apparent during the task analysis phase, before any formal failure analysis begins. This is difficult to capture in any HFCTR process description.

[1] In some cases, generic PIFs will have an impact on a specific task, and consequently, they may still need to be considered in the task context. For example, a task may have a specific requirement for the participation of two operators, which may be difficult to meet at times when performing the task (e.g. out of hours).

3 Summary and potential future developments

In general, we have found that the HFCTR process, when applied correctly, has the potential to identify significant issues associated with MAH-critical tasks. As with any process of this type, there is a danger of getting mired in the detail of the method, rather than focusing on the important issues associated with the task under consideration. We have tried in this paper to share some of the pragmatic approaches we have found useful in getting the most out of the technique.

Many of the weaknesses of the HFCTR approach are shared by the engineering analysis techniques that it emulates (e.g. HAZOP, Failure Modes and Effects Analysis). It is deterministic in nature, and requires confidence that the analysts can identify all different ways in which failures may arise. Consequently, in the longer term, as discussed in the section on PIFs, this type of technique may be supplemented by other analyses which look at the interaction of PIFs, which are known to have an impact on task performance, in real time. In these situations, personnel could be alerted to an elevated risk of failure arising from a conjunction of generic PIFs such as high workload, reduced staffing levels, and unfamiliar tasks. This might in turn lead to decisions such as delaying planned tasks, until such a time that the generic PIFs have improved.

References

Chartered Institute of Ergonomics and Human Factors (2017) Human Factors in Barrier Management Available at https://www.ergonomics.org.uk/Public/Resources/Publications/Barrier_Management.aspx

Embrey, D.E. (1986) SHERPA: A systematic human error reduction and prediction approach. Proceedings of the international topical meeting on advances in human factors in nuclear power systems; Knoxville, TN (USA); 21-24 Apr 1986.

Embrey, D.E. (2018) Addressing human reliability quantification issues in COMAH reports using the SHERPA and SLIM methodologies *Proceedings of Hazards 28 Conference, Edinburgh, Institute of Chemical Engineers*

Henderson, J. E. (2014) Task identification for COMAH. Proceedings of Hazards 24.

Henderson, J.E., Hunter, N, & Embrey, D. (2017) Human Factors Issues in Control of Work Systems. Proceedings of Hazards 27, Birmingham.

Energy Institute (2011) *Guidance on human factors safety critical task analysis*, 1st Edition. Web version available at: https://www.energyinst.org/technical/human-and-organisational-factors/scta (accessed January 2018).

Health & Safety Executive (Undated) *Human Failure Types*. (accessed January 2018). Available at: http://www.hse.gov.uk/humanfactors/topics/types.pdf

Health & Safety Executive (2016) *Inspecting Human factors at COMAH Establishments (Operational Delivery Guide)*. Web version. Available at: http://www.hse.gov.uk/comah/guidance/hf-delivery-guide.pdf (accessed January 2018).

Health & Safety Executive (2016b) *Inspection Guide – Managing Human Performance*. Not available online.