HUMAN FAILURE IN THE ASSESSMENT OF MAJOR HAZARD RISK: A CASE STUDY FOR THE HUMAN FACTORS SAFETY CRITICAL TASK ANALYSIS (HFSCTA) METHODOLOGY

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The industry faces many challenges in meeting the goals of health, safety and environmental management, regulatory compliance and business improvement. There is an increasing need for operators to demonstrate that they have identified and controlled the risks associated with human failure as a cause of major accident hazards (MAHs). In particular, human factors requirements relating to MAH are becoming more explicit in legislation such as COMAH, as well as in company standards and guidance.

In response to this requirement, Human Engineering has developed the Human Factors Safety Critical Task Analysis (HFSCTA) methodology. This methodology, based on the HSE's 7 step approach to human factors risk assessment, provides a pragmatic approach to the identification of human failures that could contribute to MAHs, thereby enabling appropriate mitigations to be developed.

This paper describes how the HFSCTA methodology was adapted for use within a semi-batch chemical processing plant at a top tier COMAH site. The HFSCTA methodology was modified to take account of the specific MAHs relevant to Syngenta's Huddersfield Manufacturing Centre, and to ensure its outputs could be integrated with the site's existing site risk assessment processes. The paper also describes how the revised methodology was evaluated.

INTRODUCTION

The industry faces many challenges in meeting the goals of health, safety and environmental management, regulatory compliance and business improvement. There is an increasing need for operators to demonstrate that they have identified and controlled the risks associated with human failure as a cause of major accident hazards (MAHs). In particular, human factors requirements relating to MAH are becoming more explicit in legislation such as COMAH, as well as in company standards and guidance.

In response to this, Syngenta approached Human Engineering, an independent human factors consultancy, for support in developing a systematic process for identifying the human contribution to the MAH risks at their Huddersfield Site which manufactures herbicides and insecticides.

Syngenta specifically required a process that:

- Is based on the HSE's guidelines for human factors risk assessment.
- Facilitates compliance with COMAH legislation relating to human factors in MAH risk assessment.
- Is easily integrated with Syngenta's existing risk assessment tools and Probabilistic Risk Assessment (PRA) process.
- Is resource efficient, pragmatic, and proportionate to risk.

Human Engineering had already developed a methodology for human factors risk assessment – the Human Factors Safety Critical Task Analysis (HFSCTA) methodology, which identifies and assesses, human failures that have the potential to contribute to MAHs, and derives appropriate measures to manage these. The methodology fulfilled many of Syngenta's requirements in that it is a pragmatic, resource-efficient process which is based on the HSE's 7 step approach to human factors risk assessment. The methodology has successfully been applied within the oil and gas industry, both on- and off-shore, to identify measures for managing MAH risk and to demonstrate compliance with COMAH and offshore safety case regulations. Upon reviewing the HFSCTA methodology, however, a number of changes to the method were identified that would enhance its suitability to Syngenta and the Huddersfield site.

Syngenta and Human Engineering worked collaboratively to adapt the HFSCTA methodology for Syngenta's requirements. The result was a highly resource efficient methodology that is easily integrated with Syngenta's existing PRA process.

This paper describes:

- The original HFSCTA methodology.
- Adaptation of the original HFSCTA methodology for application to Syngenta's Huddersfield Manufacturing Centre.
- Evaluation of the revised methodology.
- Application of the methodology since its development.

THE ORIGINAL HFSCTA METHODOLOGY

The original HFSCTA methodology was developed to identify potential failures that could cause or contribute to a MAH, and in doing so, to enable appropriate measures to be proposed for managing these failures. The methodology is based on standard human factors techniques, and is in line with the UK HSE's 7-step approach:

i. Consider main site hazards.
ii. Identify human activities.

iii. Outline key steps in these activities.
iv. Identify potential human failures for key steps.
v. Identify Performance Influencing Factors (PIFs) that make failure more likely.
vi. Use hierarchy of control measures for identified failures.
vii. Manage recovery.

The HFSCTA methodology has been designed to be practical and simple to use. Emphasis has also been placed on making the methodology as resource-efficient as possible. This is achieved through the application of two screening activities, ensuring that the detailed analysis required to assess the potential human contribution to MAHs is only conducted when necessary.

The methodology comprises three steps, as described below:

STEP 1: SITE PROCEDURE SCREENING
The aim of the first step is to identify those procedures that are safety critical, and therefore require further assessment. This is achieved by reviewing each site procedure in turn and deciding whether a human failure during performance of that procedure could contribute to any of the site-specific MAHs. Where such human errors are identified, the related procedures are considered to be safety critical and are subjected to steps 2 and 3 of the methodology.

STEP 2: SAFETY CRITICAL TASK IDENTIFICATION
This step identifies the specific tasks within a procedure where the consequences of a human failure could contribute to a MAH. This involves breaking down the procedure into its constituent steps to form a high-level task analysis. This is necessary for the assessor to understand all of the human interactions in the task, and therefore all of the stages where human failures could occur.

Next, each task is reviewed in turn to identify those that are safety critical, i.e. those where the consequences of a human failure could cause or contribute to a MAH. Tasks that are identified as safety critical are then subjected to step 3.

STEP 3: HUMAN FAILURE ANALYSIS
The final step involves a detailed analysis of the human failures that could contribute to a MAH. This is achieved using a standard human failure analysis, which comprises a number of its own steps.

Identify Possible Human Failures
First, the specific human failures that could occur during each safety critical task should be identified. This process is facilitated through reference to a list of human failure types. Examples of human failure types include omitting to perform a step, performing a step too soon or too late, performing the correct operation on the wrong object, or performing an incorrect operation on the right object.

Identify Likelihood of Failure
Second, a judgment should be made regarding the likelihood of human failure. The methodology includes a definition of 'high' 'medium' and 'low' probability. The rating selected should reflect the worst case, i.e. the failure that is considered the most likely to occur during the task.

Identify Performance Influencing Factors
Performance Influencing Factors (PIFs) are the characteristics of people, organizations, tasks, and working environments which influence human behaviour, and therefore the likelihood of failure. For each safety critical task, the PIFs that could influence task performance should be identified. A checklist of PIFs is included with the methodology to assist in this process.

Manage Failures and Recovery
Next, the existing measures for managing the failures should be identified, including those which:

- Improve the potential for recovery of the failure before the consequences occur.
- Reduce the probability of the failure occurring.
- Reduce the severity of the consequence if the failure occurs.

The final step is to identify any additional measures to reduce the risk associated with human failures. This is particularly important where the likelihood of a failure is deemed to be high and the existing mitigation measures are minimal.

All of the information collated through Step 3 is recorded within a Human Failure Analysis Form. The headings used in the form are shown in Figure 1.

A summary of the methodology's steps are shown in Table 1 below, and an overview of the HFSCTA process is shown in Figure 2.

ADAPTATION OF THE HFSCTA METHOD

The installations at Syngenta's Huddersfield site manufacture herbicides such as 'Gramoxone' and 'Fusilade', as well as insecticides such as 'Karate' and 'Force'. Owing to the substances and operations involved, some installations, such as the Karate Intermediates Plant, are associated with a range of MAH risks. Syngenta recognised the importance of utilising a systematic process for considering the human role in contributing to MAH risk, and requested that Human Engineering Limited support them in developing a suitable methodology.

Syngenta and Human Engineering worked collaboratively to tailor the original HFSCTA methodology to the specific needs of Syngenta and the Huddersfield site. The result was a highly resource efficient methodology whose outputs can be easily integrated with Syngenta's existing risk assessment processes. This section describes how this was achieved.

1. Site procedure screening	1.1 Identification of site hazards 1.2 Safety critical procedure screening
2. Safety critical task identification	2.1 Task analysis 2.2 Safety critical task step screening
3. Human failure analysis	3.1 Identify possible failures 3.2 Identify likelihood of failure occurring 3.3 Identify performance shaping factors 3.4 Identify existing mitigations 3.5 Develop additional risk reduction measures

Table 1. HFSCTA process steps
Figure 1. Human failure analysis form

REVIEW OF ORIGINAL METHODOLOGY

First, the original methodology was reviewed against Syngenta's requirements. This review identified two aspects of the methodology that could be improved to enhance its suitability for application to the Huddersfield site. These aspects were:

- The efficiency of Step 1 – 'Site procedure screening'
- The integration of the methodology into Syngenta's existing PRA process.

Syngenta and Human Engineering worked together to identify ways of modifying the methodology in order to improve these aspects of the HFSTCA method.

IMPROVING EFFICIENCY – DEVELOPMENT OF AN OPERATION SCREENING TOOL

It was identified that if the existing approach to site procedure screening (Step 1 of the original methodology) was applied to the Huddersfield site, it was likely to be the case that virtually all operations conducted on site would be classified as safety-critical. It was therefore decided that the screening method should be adapted to enable operations to be prioritised according to their level of risk. This was achieved through the development of an Operation Screening Tool, developed in Excel to facilitate quick and easy screening.

The tool comprises a number of questions which the user has to work through, selecting the appropriate answer for the operation being assessed. Based upon the answers selected, the tool calculates a risk score and provides a priority rating for that operation.

Development of the screening tool involved 2 steps: Question Development, and Assignment of Scores and Priority ratings.

Question Development

It was recognised that under the following two conditions, there would be no need to consider an operation further:

- When there are no circumstances under which a failure during the operation could lead to a MAH.
- When humans are not involved in the operation (during normal working conditions).

These reflect items (i) and (ii) of the HSE's 7 step approach.

These conditions were used to form two 'Preliminary Screening' questions. If the user's responses indicate that either of the above conditions is true, the user is informed that there is no requirement to answer further questions in relation to that operation.

Next it was necessary to identify those factors that have the most impact on the likelihood and/or severity of a MAH. The factors identified were:

- How hazardous the substances involved in the operation are.
- The probability/severity of any loss of containment.
- The probability of ignition sources being present.
- Possible changes to operating configurations.
- Availability of, and compliance with, procedures.

Questions were developed in relation to these five key factors that would enable the MAH risk associated with the operation to be assessed. These were named the 'Risk Assessment' questions. For each question, a set of possible responses was developed.

Assignment of Scores & Priority Ratings

Developing the tool as an Excel Spreadsheet enabled automated scoring of questions, allowed the user to work through the questions as efficiently as possible, and provided a consistent approach to screening.

Human Engineering and Syngenta worked together to assign a score to each alternative response in relation to each question, for each type of MAH. Scores were selected to reflect the impact of that condition on the risk of each type of MAH. An example is shown in Table 2.

Formulae were developed to allow a total risk score to be calculated for each MAH. The total risk score is a simple sum of the scores assigned to each question response.

The final step was to consider priority ratings, i.e. what score is required in order to recommend that a human failure analysis be conducted. It was decided that the following 3 priority levels should be used:

- *Low:* Human Failure Analysis is not required.
- *Medium:* Human Failure Analysis is recommended.
- *High:* Human Failure Analysis is required.

After discussion and initial testing, it was decided that scores should be assigned to priority ratings as follows:

- *Low:* Scores representing 0–33% of the maximum possible score.
- *Medium:* Scores representing 34–66% of the maximum possible score.
- *High:* Scores representing 67–100% of the maximum possible score.

Question	Response	Scores				
		External fire	Internal fire/ explosion	Over-pressure	MATTE	Acute human toxicity
How flammable are the substances involved?	Not flammable	0	0	0	0	0
	Flammable	2	2	0	0	0
	Highly flammable	4	4	0	0	0
	Extremely flammable	6	6	0	0	0

Table 2. Examples of risk assessment question scores
Figure 2. Overview of HFSCTA tool process

The appropriateness of the scores and priority ratings was assessed during application to two case studies, described later.

IMPROVING INTEGRATION WITH SYNGENTA'S PRA PROCESS

Actions were also taken to enable the methodology to become integrated into Syngenta's existing processes. These actions included not only modifying the HFSCTA methodology, but also updating the existing PRA process.

Step 3 of the HFSCTA methodology was modified to ensure that the outputs of the human failure analysis were compatible and consistent with those produced by the PRA process. This involved:

- Incorporating an additional sub-step for rating the severity of the potential MAH.
- Applying existing PRA probability ratings to human failure probabilities.
- Adapting the human failure analysis form to be consistent with the PRA form.

As part of this work, Syngenta also adapted the PRA process to ensure that the outputs of the human failure analysis are captured within the existing system. The PRA process now includes taking the outputs of the HFSCTA methodology and entering them into Syngenta's PRA spreadsheet. By doing this, Syngenta ensures that that the information recorded on the human failure analysis forms is retained, and not lost. It also enables recommendations arising from the HFSTCA methodology to be assessed and prioritised alongside other mitigation measures that have been identified through the PRA process.

Syngenta has also modified the PRA process to include some human factors related questions that act as prompts for the assessor to use to judge whether application of the HFSTCA methodology is required.

CASE STUDY EVALUATION

The adapted HFSCTA methodology was evaluated through application to two case study operations: (a) Tanker Off-loading of Toluene, and (b) Reactive Solid Charging to Reactors. These operations were selected because it is recognised on site that these are high risk activities which rely on human performance and which could lead to a MAH. The case studies involved application of each step of the methodology as described below.

STEP 1 – SITE OPERATION SCREENING

Syngenta personnel used the Operation Screening Tool to assess the case study operations. Feedback on the tool design was very positive. The appropriateness of the scoring and associated priority levels was also assessed by examining the tool's outputs for the two case study operations. The two operations are considered to be associated with a high risk level, and consistent with this, the tool's outputs revealed high scores for both case studies, and a 'high' priority rating. The tool was also applied to a number of operations that were considered to be associated with low risk of contributing to a MAH. Again, the tool's outputs were in keeping with subject matter expert (SME) opinion and expectations.

STEP 2 –TASK ANALYSIS

A task analysis was developed for each of the case study operations, based upon information collected through discussions with an operator and examination of the related work areas and equipment. Syngenta personnel observed these discussions in order to gain an understanding of how to collect the data required to build a task analysis. A section of the output from the task analysis is shown in Table 3. This relates to the task step "Charge Solid" as part of the process of charging a reactive solid to a reactor.

STEP 3 – HUMAN FAILURE ANALYSIS

Human Engineering and Syngenta personnel worked together in a workshop-style format to perform a human failure analysis for the two case studies. For each operation, the analysis identified potential human failures and associated risk management measures, where required.

A section of the output from the human failure analysis is shown in Table 4. This relates to the task step "Charge

Solid" presented in the task analysis in Table 3. The analysis identified a range of potential failures that could occur when undertaking this task step. For example, if an operator failed to close the door to the charging booth, the consequence could potentially be a fire if a flammable atmosphere existed outside the booth. This is classed as high severity in terms of MAH risk, and the failure (though not necessarily the consequence) was judged to be a high likelihood event based on the inadequacies in existing procedures. In order to reduce the risk of this occurring, it was agreed that the procedure and associated training would be updated.

Any measures identified through the case study evaluation process were incorporated by Syngenta into their existing safety management strategies.

The results of the case study application illustrated the effectiveness and value of the approach.

APPLICATION AND FEEDBACK

Since the development of the revised HFSCTA methodology, Syngenta has applied the Operational Screening Tool to assess all of the insecticide plants' operations. This has resulted in the identification of a number of high risk operations, which are currently being subjected to Steps 2 and 3 of the approach. Feedback from Syngenta personnel indicates that the Operational Screening Tool is quick and easy to use, and effective in identifying high risk activities.

Syngenta has also updated the site's COMAH Safety Report to reflect the work that has been undertaken to address human factors in MAH risk assessment. Further details of the work and the HFSCTA methodology were provided to a human factors expert from the HSE during a visit to the Huddersfield site. Syngenta has received positive feedback from the HSE in relation to the work.

CONCLUSIONS

This work has illustrated the value of a joint development approach to these type of projects. In this case, collaboration between Human Engineering and Syngenta proved particularly useful for:

a. Ensuring that the methodology is compatible with Syngenta's existing Process Risk Assessment (PRA) process.
b. Facilitating skill transfer to Syngenta personnel responsible for rolling out and/or using the approach.

The outcomes of this work have demonstrates that the HFSCTA methodology can be easily adapted to provide a context-specific assessment of the potential contribution of human failures to MAH risk. In addition, use of a site-specific screening tool enables operations to be screened quickly and accurately. In conclusion, human factors risk assessment can fit alongside existing processes and is effective in identifying additional measures to manage MAH risk.

Table 3. Section of task analysis for reactive solid charging to reactor

Level 1		Level 2		Level 3		Level 4		
No	Task	No	Task	No	Task	No	Task	Plan
4	Charge soli	4.1	Ensure solid booth is safe to work in	4.1.1	Operate extractor fan	4.1.1.1	Switch extractor fan on	
				4.1.2	Close solid booth door	4.1.1.2	Position hand under fan	
		4.2	Set up reactor to receive solid	4.2.1	Undo canon port clamping bolts	4.1.1.3	Verify suction is working	
				4.2.2	Open canon port lid			
				4.2.3	Position letterbox assembly inside the canon port opening			
				4.2.4	Secure the letterbox in position using clamping bolts			
		4.3	Ensure net weight of solid charged can be calculated	4.3.1	Read weight of full pallet on the scales			
				4.3.2	Record weight on Charging PI Sheet (KIPI004WP)			
				4.3.3	Record make/source of solid on Charging PI Sheet (KIPI004WP)			
		4.4	Monitor indicator light throughout charging process	4.4.1	Observe red indicator above canon port			
				4.4.2	Judge charging can proceed			Plan 4.4.2: Perform if red indication is off
				4.4.3	Judge charging must stop			Plan 4.4.3: Perform if red indication illuminates
		4.5	Place solid sticks into reactor	4.5.1	Open lid of the solid drum that is on the scales			Plan 4.5: Perform 4.5.1–4.5.5 until all solid sticks have been placed in the reactor
				4.5.2	Stand to one side of the pallet on the scales			
				4.5.3	Remove a solid stick			Plan 4: Perform 4.5–4.8 until all 12 drums of solid are empty.
				4.5.4	Place stick carefully through letterbox			
				4.5.5	Wait until operator 2 places a stick through the letterbox			

(*continued*)

Table 3. Continued

Level 1		Level 2		Level 3		Level 4		
No	Task	No	Task	No	Task	No	Task	Plan
				4.5.6	Observe all solid sticks have been placed in the reactor			
				4.5.7	Reseal lids of empty solid drums			
		4.6	Ensure net weight of solid charged can be calculated	4.6.1	Observe weight of the empty pallet on the scales			
				4.6.2	Record weight			
				4.6.3	Calculate the net weight of solid charged for that pallet			
		4.7	Remove pallet of empty drums from scales					
		4.8	Position next pallet of drums on the scales					
		4.9	Calculate net weight of solid charged	4.9.1	Sum the net weight of solid charged for the 3 pallets			
				4.9.2	Record net weight charged on Charging PI Sheet (KIPI004WP)			
				4.9.3	Check net weight is within required range			
		4.10	Set up booth to charge catalyst	4.10.1	Unscrew letterbox clamping bolts			
				4.10.2	Remove letterbox from canon port			
				4.10.3	Place letterbox in support bracket			
		4.11	Inform computer that solid charging is complete	4.11.1	Exit solid booth			
				4.11.2	Press 'charge complete' button on local panel			

Table 4. Section of human failure analysis for reactive solid charging to reactor (for task step 4)

Human failure analysis of current situation								Additional measures to deal with human factors issues	
Task step	Potential consequences of task failure	Severity of MAH	Possible human failures	Likelihood of a failure occurring	Performance influencing factors	Existing risk management measures	Potential to recover from the failure before the consequences occur	Risk management measures	Measures to improve recovery potential
4.1.1. Operate extractor fan	Ext fire	Med	• Operation omitted	Med	• Noise • Roles and responsibilities unclear	• MAH training • Procedures	• Ability to notice lack of suction • Ability to communicate with colleague • Magnahelc gauge		Autostart fan based on cannon port open signal
4.1.2 Close solid booth door	Ext fire	High	• Operation omitted • Violation	High	• Procedure inappropriate/ incorrect	• Unofficial procedure followed.	• Lack of flammable atmosphere outside booth	Procedure and training to be updated	
4.2.3 Position letterbox assembly inside the canon port opening	Int fire	High	• Operation omitted	Low	• Tools inappropriate	• MAH training • Procedures			
4.3.2 Record weight on Charging PI Sheet (KIPI004WP)	Overpressure	High	• Operation omitted • Wrong information obtained	Med	• Tools inappropriate • Roles and responsibilities unclear	• MAH training • Procedures	• Software requirement for weight to be inputted • Software hi/low weight limit • Communication • 12 drums will equal approx correct charge	Consider procedure update for checking the weight	
4.4.1 Observe red indicator above canon port	Int fire/ explosion	High	• Check omitted • Violation	Med	• Lack of consequences of failure to follow procedures	• Two sets of lights plus flashing light • MAH training & validation • Procedures	• Nitrogen blanket reduces probability of flammable atmosphere • Safety margin on oxygen detection • Low probability of ignition source in vessel	Provide an audible alarm	
4.6.3 Calculate the net weight of solid charged for that pallet	Overpressure	High	• Information incorrectly interpreted	Med	• Task difficulty	• Procedure directs calculation • Experience	• Ability to double check sums • Software hi/low weight limit	Alter procedure to carry out calculation in ctrl room	
4.9.1 Sum the net weight of solid charged for the 3 pallets	Overpressure	High	• Information incorrectly interpreted	High	• Task difficulty	• Procedure directs calculation • Experience	• Ability to double check sums • Software hi/low weight limit • 12 drums will equal approx correct charge	Alter procedure to carry out calculation in ctrl room	
4.9.2 Record net weight charged on charging PI sheet (KIPI004WP)	Overpressure	High	• Operation omitted • Wrong information obtained	Med	• Tools inappropriate • Roles and responsibilities unclear	• MAH training • Procedures	• Software requirement for weight to be inputted • Software hi/low weight limit • Communication • 12 drums will equal approx correct charge	Consider procedure update for checking the weight	