Breaking with Tradition: Business-Wide Human Factors Integration on a Global Scale

Peter Webb, HSE Director, Europe Asia International, LyondellBasell, Manchester, UK

Richard Scaife, Director, The Keil Centre Limited, Edinburgh, UK

Human Factors Integration (HFI) is not new, stemming from the US Army's MANPRINT programme of the 1980's, to ensure that relevant human factors topics were included in military engineering projects. Since then, research and guidance has been developed for applying HFI to engineering projects in the process industries. This paper describes a significant undertaking to expand the traditional application of HFI beyond engineering projects into the wider operating practices of a business on a global scale.

LyondellBasell is a global chemicals, plastics and refining company formed when a Netherlands based company, Basell, acquired the U.S. based company Lyondell. Both companies shared an underlying assumption that petrochemicals manufacturing should be accompanied by a social responsibility commitment to stakeholders including employees and communities, and that incident free operation was correlated with reliability. In 2016 a strategic decision was made to integrate human factors into key processes across the business. This was driven by the company's GoalZERO programme which aspires to a workplace free from incidents. Whilst significant progress had been made towards this aspiration, new approaches had to be found to make larger steps towards the goal. It was agreed that one such new approach should be addressing human performance and behaviours, but there was a lack of understanding of how human performance could be measured and influenced. This presented a significant organisational challenge to be overcome before progress could be made.

Human factors was perceived as a nebulous topic, difficult to tangibly relate to day-to-day operations. The company embarked on a "learning-by-doing" approach to help people grasp the key concepts, develop a common human factors language, and develop buy-in from key personnel at site level to champion human factors and facilitate the success of the programme. The first step of helping people to grasp the key concepts of human factors was achieved by providing high-level awareness training with the aim of making the topic more tangible and helping to establish a common language.

Next, it was necessary to understand the main needs and opportunities for HFI; many existing processes already addressed human factors, if not strategically. An opportunities assessment was performed which looked at how risk assessment, human resources & work management, organisational change, training & competence, equipment design & engineering, maintenance & reliability, operating practices & operating discipline and incident investigation were being done.

A modular training programme was developed to provide awareness-level training for managers covering all of the topics identified during the opportunities assessment. Practitioner level training was also developed for those who would be applying tools and methods in their roles, and for those who would become champions and who would provide further education to personnel at local level.

A framework was developed which organised existing and missing human factors processes into a single road map. This was used to provide a structure for developing detailed preferred practices and tools for specific HSE management system processes. Two practices which had been defined as high priority, risk assessment and incident investigation, were addressed first.

The company already had a risk assessment programme in place to identify Critical Administrative Controls (CACs), Independent Protection Layers (IPLs) where technical IPLs are not practicable, which define the human interventions required to provide the required level of risk mitigation. What was missing was a way to systematically identify how human interventions might fail, and how to mitigate such failures. This paper will describe the development of the company's own methodology for assessing CACs.

The company already had two well developed processes and tools for incident investigation but no systematic way to analyse the human contribution. They developed tools and training for investigators and managers which could be used alongside the existing investigation methodologies. These covered interviewing skills, analysis of the root causes of behaviours, and writing corrective actions.

The forward plan is to develop preferred practices and associated guidance for the further integration of human factors into the business, and this paper will provide further details of this plan.

Keywords: Human Factors Integration, Incident Investigation, Human Reliability Assessment, Training, Safety Culture.

Growing a Culture

Organisational cultures can be described as being built up in three onion layers: underlying assumptions are at the centre, then espoused values with artefacts being the skin at the surface (Schein 1992). In 2007 Netherlands based Basell acquired U.S. based Lyondell to form the new company LyondellBasell. The asset and business footprints were such that synergies were expected and were found. But cultural integration was less straightforward. Regarding safety culture, the two companies shared the underlying assumption that petrochemicals manufacturing should be accomplished with injury and incident free performance. Associated with this assumption was a belief that manufacturing activities should be accompanied by a social responsibility commitment to stakeholders including employees and communities, and that incident free operation was correlated with reliability. Despite being based on the same underlying assumptions, the safety cultures differed in their values and consequently also their artefacts. Lyondell followed a path guided by a value that injury free performance could best be achieved by rigorous and prescriptive corporate standards. Basell values, on the other hand, were influenced by the European goal setting model of safety regulation. The artefacts of the Basell system comprised a smaller set of company guidelines, which left sites significant latitude regarding implementation. The Basell corporate resources were commensurately smaller than the Lyondell ones.

Around 2005, two years prior to the formation of the new company, both companies had recognised that improvements in safety performance had hitherto followed a trajectory starting with technical measures, followed by systems approaches and that the next field of attention should be the human contribution. But guided by their different cultures, they followed different paths. Lyondell's human factors activities were inspired by practices which had been developed for military and civil aviation and was guided by a centrally coordinated steering team. Basell's activities found their origins in programmes which originated in the manufacturing sites in different countries and which diffused to other sites along pathways which included central functions as well as directly site to site. There was some overlap in the human factors topics which the two companies had addressed. For example, both had addressed alarm management; the existence of an internationally recognised standard (EEMUA 1999) meant that the fundamentals were similar. Both had also identified incident investigation as a cornerstone for their human factors strategies but had selected different tools. Lyondell implemented the Human Factors Analysis and Classification System, HFACS (Wiegman & Shappell 2003). Influenced by its Shell legacy, Basell used Tripod Beta.

For the first nine years, the new company did not address human factors explicitly. That is not to say that nothing was happening. Even if they were not recognised as such, human factors topics like alarm management continued to receive attention. But the priority in the early years was to create a new HSE management system and to establish a new zero harm safety culture, GoalZERO. The legacy human factors programmes freewheeled on, but they no longer benefitted from coordinated corporate support. But in 2016, looking for a way to drive further performance improvements, the company made a strategic decision to address human factors explicitly, and started to build a framework with prioritised goals. A global steering team was established to coordinate activities across the company.

Why Human Factors

It is axiomatic that any system, regardless of its level of automation or sophistication comprises engineered equipment (which includes hardware and software components) and a human component (the person who will operate or maintain the engineered equipment). Generally speaking, when an input is made to an engineered system, the output that the engineered system will produce can be predicted with a given level of certainty. The human component of the system is a little more difficult to model in this way as humans can be classed as non-deterministic systems: if an input is made it is difficult to predict how the human element of the system will react and therefore what the output will be.

The engineered and the human components need to work together seamlessly in order for the entire system to work effectively, efficiently and safely. Consideration of how the human component will operate in the design of the engineered equipment has long been known to be essential. If consideration of the human component of a system is not included throughout the design and development of the system, the end result can be an increase in accidents, increased costs of training and procedure writing, poor performance, and increased total lifecycle costs of the system due to the need for design modifications to accommodate the human operator and/or maintainer.

In the 1980's the US Military developed a programme known as MANPRINT, which was a guide to the integration of human factors into the procurement and design of military systems at all stages of development to optimise performance and efficiency of the system when introduced to service. The UK Ministry of Defence followed suit in the 1990's with a programme based on MANPRINT called Human Factors Integration (HFI). This, term is now widely used within many industry sectors to refer the integration of the people and equipment components of a work system from concept through to decommissioning.

HFI uses a series of domains to ensure that all aspects of human behaviour, capability and limitations are addressed when procuring or developing a new system, as delineated below:

- Manpower;
- Personnel;
- Training;
- Human Factors Engineering;
- System Safety;
- Health Hazards;
- Social and Organisational.

The benefits of HFI have been recognised within other industry sectors beyond military systems in more recent times (see for example Edmonds, 2016, Widdowson & Carr, 2002). The traditional focus of HFI has been on design and procurement of equipment, which is not surprising given its roots. However, the domain areas of HFI lend themselves to a much broader application, for example in the processes that are used to run a successful business.

This paper describes how LyondellBasell, a global chemicals, plastics and refining company, undertook a project to integrate human factors practices into a wide range of business processes. Figure 1, below, shows how these processes broadly align to the HFI Domains described above.

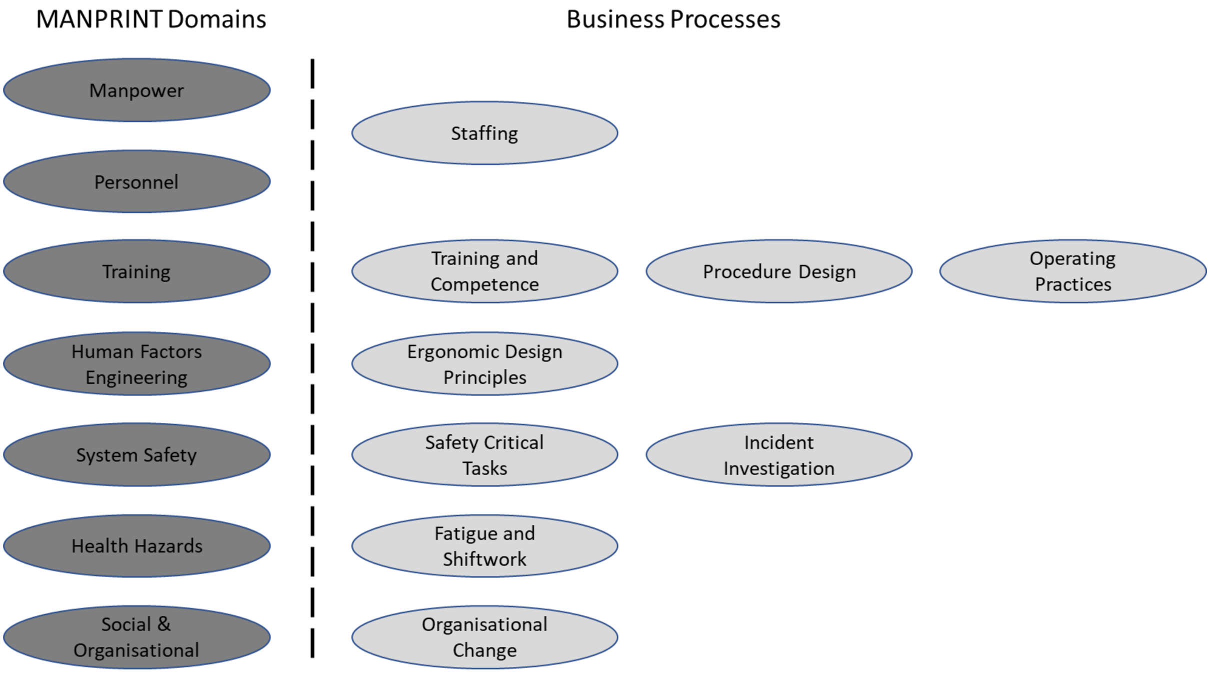


Figure 1: Relationship Between HFI Domains and Key Business Processes

The Challenge

In its first six years, LyondellBasell made significant progress towards its GoalZERO vision. Injury rates were halved and there were reductions in process safety incidents. This performance put it amongst the leaders in its peer group of petrochemical manufacturers. But performance levelled off. Some might argue that consistently delivering industry leading performance was good enough, but the company's leadership was committed to the GoalZERO culture which means that they had expectations of continual improvement.

The company recognised that making further steps to improve performance would require an approach that was focused on addressing the behavioural and human factors aspects of performance. However, the company felt that the understanding of human factors, and how it could be used to influence human behaviour and human performance was not widely understood within the organisation. It was concluded that to initiate any programme aimed at integrating human factors into key business processes, without increasing the level of knowledge about human factors within the company, would be futile. It was felt that developing knowledge of the field of human factors at an appropriate level for the target audience would have a positive impact on buy-in from people at all levels of the organisation, Therefore, an early step in this project was to gain an understanding of the existing level of knowledge and to work on increasing this across the business.

Many people at various levels of the organisation had addressed human factors issues before but had not necessarily realised that this was what they were doing. Part of the issue was that there was no common language of human factors concepts within the organisation. For example, whilst developing procedures, some people will have conducted a walkthrough of the task with subject-matter experts and developed the procedure based upon a description of the task. If they had been asked if they had ever conducted task analysis, however, they would almost certainly have said that they had not done so.

The first step in overcoming the potential challenges of making the project a success was therefore to establish a basic level of understanding of human factors, and a common language that identified certain activities as being related to the strategy of integrating human factors across the business.

Speaking the Language

The field of human factors is replete with technical terms used to describe concepts such as human error, procedural violation, procedure design and the design of equipment. Some such terms tend to be used interchangeably depending on the reference material used. When this project was initiated, it was recognised that different terms were being used in different parts of the business to refer to the same basic concepts. It was therefore necessary to begin establishing a common language that could be applied at all levels of the business.

At an early stage of this project, an opportunities assessment was planned to identify where the company was already using human factors effectively within the business, and where opportunities existed for the introduction of human factors methods and techniques. However, it was felt that performing such an assessment without a common language and understanding of the topic would result in inaccurate results, hence the need to build understanding and establish the common language.

As a starting point for addressing this issue, those involved in identifying the ways in which human factors would be integrated into the business were provided with a high-level human factors awareness introductory training course to help to establish a common set of terms for the human factors concepts used within the company. This included a definition of what human factors is, and how it applies to health and safety within industry to ensure that the understanding of the scope of human factors was understood. It included a discussion of why human factors was important within industry in general and within LyondellBasell in particular. An important point in communicating this across the company was that LyondellBasell had independently identified that a greater focus on human factors was one of the keys to improving business and safety performance, rather than being asked to focus on this topic by international regulators. It also covered the fact that human errors and intentional violations of procedures are very different and need to be considered different phenomena that are tackled in different ways, using case studies to illustrate this point. The topic of safety culture was also discussed to help those involved understand how differences in safety culture can have an impact on how human error and procedural violations are handled within an organisation. The topic of safety culture was extended into the topic of intervention, and consideration was given to how the culture of the organisation has an impact on the willingness of personnel to intervene when they spot behaviours that may increase risk, and on the attitudes of those on the receiving end of safety conversations.

This initial education was used to formulate expectations for personnel within the company for how they manage different aspects of human factors within the business. This was an iterative process, added to throughout the project, with the ultimate goals of issuing a "preferred practice" for the use of human factors tools and techniques within the business.

A glossary of key human factors terms was produced at the end of this process, to be developed and extended as practices within the company evolve, but to ensure that there are definitions in place for the key topics, which can be applied during the development of the "preferred practice".

Assessing Opportunities

Having established a base level of understanding of human factors for key personnel within the business, it was felt that personnel in the USA and Europe would have sufficient understanding of the subject matter to make judgements on the opportunities for the company.

A series of facilitated workshops were held in both USA and Europe during which participants were asked to:

1. Review an incident where numerous human factors failures had been contributing or causal factors in the occurrence of the event.
2. Identify these causal and contributory factors and classify them according to a breakdown of the topics that are included in human factors (e.g. human factors design, organisational change, etc.)
3. Determine whether similar situations could arise at their sites, and if so identify any opportunities to do more work on human factors in this area.
4. Assign each proposed opportunity with a priority between high and low.
5. Writing an outline action plan for addressing the opportunities that were identified.

The opportunities assessment identified five areas that were considered high priority for further work and four areas that required improvement but were not considered an immediate priority.

This process resulted in the identification of further measures to help ensure that the integration of human factors across the business was successful. The first of these was to ensure that senior management within the business understood human factors in order that they could support the integration project going forwards.

The high priority opportunities included how to identify safety critical tasks and analyse them to identify what potential errors could occur and how to mitigate them. This was an area that LyondellBasell had identified as an area for improvement prior to the opportunities assessment. It was determined that this action should include maintenance activities as well as operational activities.

A further opportunity identified was the review of existing and new equipment against established ergonomic design standards to identify practical risk reduction measures through design.

Incident investigation practice was another area identified as requiring improvement but had also been identified by LyondellBasell as an area requiring additional focus. The results of the opportunities assessment identified a need to determine when human factors analysis should be applied, using a just and fair approach to the investigation, distinguishing between human error and procedural violation and determining the root cause of these behaviours, developing investigation skills of incident investigators, selecting and developing investigators in accordance with a competence matrix, monitoring the quality of investigations and ensuring that feedback on the results of investigations is provided to all personnel.

Procedure design and content was a further high priority recommendation, involving the development of guidance on the design of procedures, and how they should be used.

Operating practices were also identified as a high priority opportunity, predominantly involving considering the company standards and expectations for handovers and permit to work systems.

Further opportunities identified during this process included the following topics:

- Implementation of a formal process for the assessment of organisational change, including a formal organisational change management procedure;
- Training and competence assessment, with a particular focus on succession management and ensuring the competence standards of new, less experienced personnel are sufficient to replace the competence of more experienced personnel expected to leave the organisation in years to come;
- Formal systems for the formal assessment of staffing levels required to maintain safety performance, for example when staffing changes or planned or when modifications to plant are introduced;
- Setting firm expectations for the management of fatigue in all parts of the organisation.

Creating a Road Map

Having identified a number of opportunities for integrating human factors into key business processes it was necessary to have a strategy for doing this, to ensure that the project was completed as planned and that proportionate and timely effort was applied to achieving the integration.

The strategy became known as the road map for the integration of human factors, and took the opportunities identified earlier in the project along with their priority to define the order in which integration would take place. In engineering projects, this would have been known as a Human Factors Integration Plan (HFIP) defining how human factors would integrate with the various project stages and associated activities.

In this case, the road map defined the order for the development of human factors tools to integrate with existing processes and set out design criteria for the human factors tools.

The intention of the road map was to feed into a more formal "preferred practice" for the organisation on the integration of human factors. As tools were developed for the application of human factors in the various aspects of managing the business these were written into a preferred practice for human factors. This formal document continues to develop as new methods and tools for addressing human factors are rolled out into the business and will remain a living document until the process of defining specific tools has been completed.

At this point, the preferred practice will become a manual for conducting human factors activities, specifying what is required and providing detailed guidance in the appendices for conducting specific analyses and using specific tools.

Training

During the development of the road map and preferred practice, a need was identified to develop multi-level training for personnel in the organisation. Some personnel would need to understand the key concepts surrounding the application of human factors within the business. Others would become responsible to conducting analyses using the appropriate tools and feeding the results into the relevant business processes.

There was therefore a need to train some people to an awareness level so that they could understand the outputs from human factors analyses and tools. This training would need to be more targeted than the earlier training provided to help personnel to understand what human factors was, to help establish a common language. This training would need to provide awareness level training on each of the topic areas identified during the opportunities assessment, providing more depth than the initial awareness training.

There was also a need for practitioner level training for those that would perform the analyses and use the tools as part of their existing role, and who would become the "champions" for the process that they were associated with. For example, incident investigators would learn how to apply human factors techniques during an investigation and would also provide others with education on the techniques and tools that they were trained to apply.

Before training any of the practitioner level personnel, it was decided to roll out the awareness level training to site management level, to encourage buy-in and support for the activities of the practitioners at the local management level.

Eight awareness training modules were developed and rolled out in North America and Europe. The material covered in these modules was as follows:

- Introduction to human factors;
- Human factors in risk assessment;
- Human factors in organisational change;
- Human factors in operating practices;
- Human factors in maintenance and reliability;
- Human factors in incident investigation;
- Human factors in human resources and work management;
- Human factors in equipment design and engineering.

Each of these modules was relatively short and designed to make delegates aware of the key principles only, and for managers to provide information on the human factors processes they were likely to be asked to support for their site.

Practitioner level training was developed in accordance with the priorities identified during the opportunities assessment and is ongoing in accordance with the road map for the project.

The first two training packages developed were for the analysis of safety critical tasks and for the integration of human factors techniques into incident investigation. Within LyondellBasell safety critical tasks are known as "critical administrative controls" and this language will be used henceforth. The training for those at practitioner level included training in how to deliver the awareness level materials (with appropriate ongoing support) to ensure that practitioners would be in a position to provide awareness level training and become champions for the areas that they were trained in.

Support in the use of tools and methods to integrate human factors into the assessment of Critical Administrative Controls and incident investigation is provided for personnel within the organisation in the form of a preferred practice for human factors. The two areas of focus were chosen because of a clear link between them: they both focus on the failure of the human element to perform in the way that was expected. Investigations deal with the ways in which people failed retrospectively, and the aim is to understand why this was the case. Critical Administrative Controls deals with how people may fail and is a proactive form of analysis of human failure. The distinction is made in the preferred practice, and is shown in the following diagram:

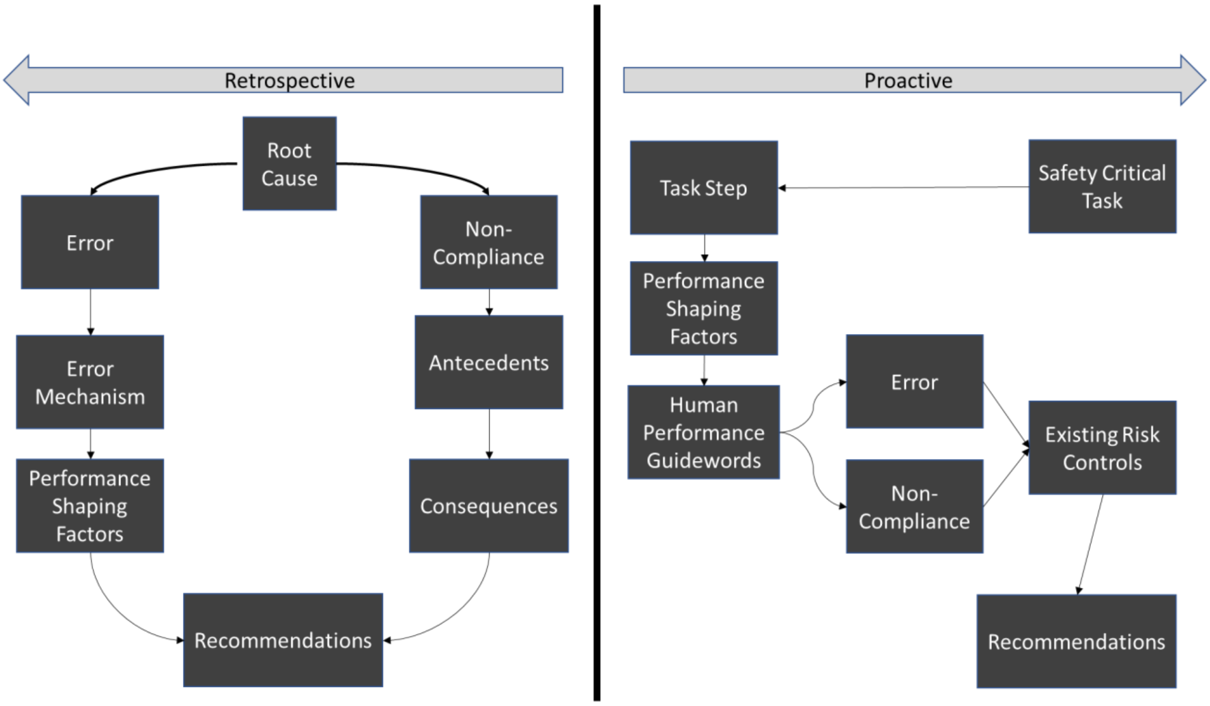


Figure 2: The relationship between retrospective and prospective analysis of human failure

Over time, the company plans to develop a competency matrix which defines human factors competency requirements for roles within the organisation, indicating which roles are expected to have awareness level training, and which roles require practitioner level training.

Incident Investigation

Incident investigation is one of the most important elements of an HSE management system. There is a "depressing sameness" about major accidents (Hopkins 2008), and it is not uncommon for investigations to reveal that unlearned lessons preceded the incident under investigation. Such was the case for the NASA space shuttles Challenger and Columbia and the BP Texas City Refinery incident in 2005. Hopkins describes BP Texas City prior to 2005 as having a "learning disability". Given their shared underlying assumptions about the need for incident free operation, it is therefore no surprise that both Lyondell and Basell had applied themselves to learning more about the human contribution to incidents. But they had followed different paths.

Starting in 2005, Lyondell had implemented HFACS. It is an incident analysis tool, which is based on an adaptation of the version of the Reason Swiss Cheese Model (SCM) which was published in Reason 1990, known as the Mark 1 SCM (Figure 3). It suffers from three weaknesses. Firstly, it tends to place the causes of incidents at organisational locations. The "logic" behind the model is that accidents are the result of a sequence of events or a serial development which has a trajectory through the organisation. Events in the sequence are described as failures at different organisational levels, going from senior management to unsafe acts or active failures by front line staff. This version of the SCM can therefore also be seen as representing the kind of thinking that became known as the *sharp end, blunt end* descriptions of accidents (Reason, Hollnagel and Paries 2006). In a two-year period, out of a total of 7,042 human failures which had been classified, the distribution was as follows:

Organisational Influences – 0.2%
Inadequate Leadership – 5.9%
Preconditions for Active Failures – 79.3%
Active Failures – 14.6%

Thus 93.9% of the human failures were assessed to be at the *sharp end*. The most commonly occurring failure type was *Inadequate Degree of Attention Applied to Task Details*.

Secondly HFACS required the investigator to classify the human failure according to a list of over 200 failure types. The intention was that a big picture would emerge from all the classifications, to inform management about which part of the organisation needed attention. However, it proved an unrealistic objective in a petrochemical company to make the classification calls in a way which was sufficiently consistent for a useful big picture to emerge.

Thirdly, HFACS gave little or insufficient guidance on how to analyse the human failures and define effective corrective actions. For example, it gave no guidance on what to do about a systematic *inadequate degree of attention applied to task details*.

HFACS is a tool which is used alongside a root cause investigation methodology. A further challenge for the legacy Lyondell organisation was that the preferred root cause methodology for higher severity incidents was Apollo. Apollo is not well suited to identifying human contributions.

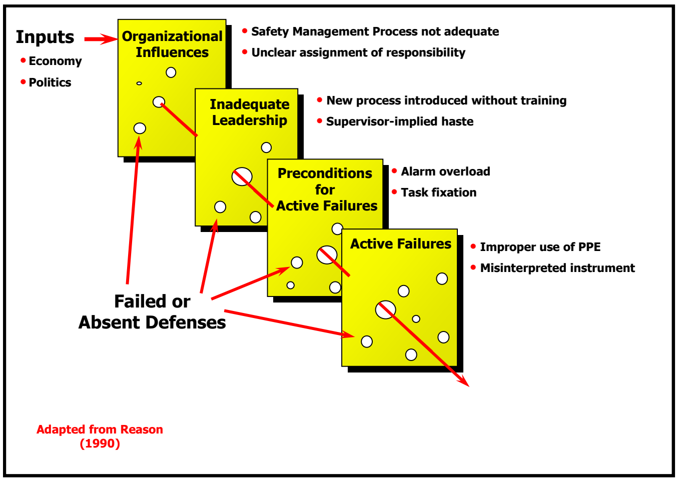


Figure 3; Swiss Cheese Model used in HFACS

Nevertheless, Lyondell's systematic implementation of HFACS across several sites, meant that many incident investigators had a working knowledge of a taxonomy of human failures (Figure 4). This taxonomy was an adaptation from Reason (1990) which included the Rasmussen (1982) skill based, rule based, knowledge-based error taxonomy. It encouraged investigators to get an understanding of what type of unsafe act was associated with the incident, which was a useful step in the direction of defining appropriate corrective actions.

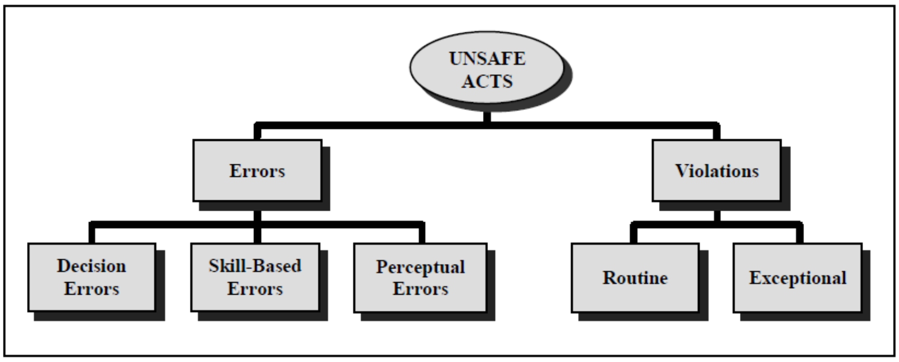
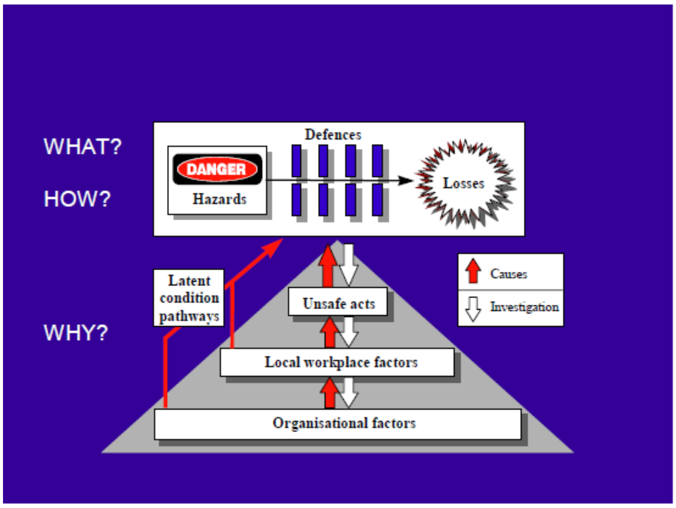


Figure 4; Taxonomy of human failure used in HFACS.

Basell's preferred methodology for all kinds of higher severity or higher risk incidents, regardless of human involvement, had been Tripod Beta for more than ten years prior to the formation of the new company. The incident causation logic behind Tripod Beta is adapted from the Mark 3 Reason SCM (Reason 1997), see Figure 5. The Mark 3 model separates the *why* of an incident (the causes), from the *what* and the *how* (the barriers or arrangements which should have been in place to prevent the incident). The Mark 1 model did not make that separation. This important distinction assisted investigators in finding causes within the management system, without the need to place the causes at the feet of specific roles or people.



The Mark 5 Reason Swiss Cheese Model (Reason 1997)

Regarding the human contribution, Tripod Beta is based on the assumption that incidents are to a large extent caused by human error and that human error is mainly caused by the working environment; risk management focused directly on human behaviours is not the most effective way to control them (Tripod Solutions 2007). The methodology guides the investigator towards working environment causes, and analysis of the human behaviour is just a step along the way. Knowing the form of human error helps the identification of Preconditions. Preconditions are the environmental, situational or psychological "system states" or "states of mind" that promote immediate causes (Stichting Tripod 2006). Tripod Beta uses a similar taxonomy of human failure to HFACS, i.e. the Reason/Rasmussen one (Figure 4).

Its tendency to put the focus on the working environment, not only risked missing important learnings about behaviour, it put it at odds with LyondellBasell's GoalZERO culture, for which balanced consideration of individual accountability was central. Tripod Beta is suitable for identifying where there has been a human contribution and what was the relevant behaviour, but the tool itself is not sufficient for analysing the human failure and deriving suitable corrective actions directed at the behaviour.

So as the two companies came together, foundations were in place for an improved approach to analysing human failures in incidents.

In integrating human factors tools and methods into the investigation process, it was first necessary to provide guidance on when in the investigation process human factors should play a part. In the first instance, a root cause analysis would need to have been performed so that the causes of the incident had been identified. A decision is then required on whether the root causes of the incident indicate that there is a human behaviour associated with either an immediate or underlying cause of the incident. If a behaviour was involved, then more detailed human factors analysis is justified.

Many organisations find making this decision difficult because they do not spend enough time honing investigative interviewing skills. Often, personnel who have become investigators have been trained in such techniques by previous employers, but this may have been some time ago. Others are selected on the basis that they have strong analytical skills and the assumption is made that they can conduct a good interview. It was decided that for this project, detailed training in witness interviewing should be included in the practitioner level training. This included some of the difficulties associated with helping witnesses remember the events that they witnessed accurately, bearing in mind the fact that people often create false memories for the parts of the incident sequence that they didn't directly witness. It also covered strategies to combat the loss of information during communications between the investigator and the witness, advanced interviewing techniques to help stimulate genuine memories of the event, and strategies for controlling for social threats to the witness that may impede their recollection of information or their willingness to co-operate in the investigation. It was also important to highlight the potential impact of cognitive bias on investigations, and to help investigators spot situations where they may be more likely to be influenced by bias and appropriate strategies to combat this.

In practice, a very large proportion of incidents have human behaviours as an underlying or immediate cause when the timeline of the event is examined in detail. Active failures of those directly involved in the incident for example, or latent failures further back on the timeline that have created the conditions under which an active failure could occur.

If more detailed human factors analysis is required, then the first step is to determine the focus of the human factors analysis of the incident. In most events there are several people involved at various points on the timeline, and therefore specifying where in the timeline the analysis will focus is important to avoid confusion.

The next stage in the analysis is to determine whether the behaviour(s) involved in the incident were intentional behaviours (i.e. non-compliance with procedures) or unintentional behaviours (i.e. human errors). It is important for investigators to be able to examine the evidence and determine the type of behaviour involved, as treating them the same way could lead to an unjust culture developing that would not be healthy for the organisation. Training in the use of human factors techniques during the investigation process was developed to assist those involved with telling the difference between an intentional an unintentional act so that they can be investigated in the most appropriate way. It was also necessary to ensure that managers who may be the recipients of investigation reports have sufficient education in the distinction so that their actions do not undermine the culture that the organisation is attempting to develop and maintain.

The education in the process being followed to investigate the behavioural causes of incidents needs to be delivered at the awareness level across the organisation, so that anyone becoming involved as a member of an investigation team, or as a witness, can understand the process and the objectives of the process.

Those who will lead investigations require a practitioner level training course to provide them with detailed tools and methods to support all aspects of the investigation. Such training was developed to cover interviewing and data collection, data analysis, and reporting of the investigation findings, thus covering the entire investigation process.

In understanding the underlying causes of behaviours, appropriate techniques for analysing error and non-compliance need to be used, and guidance on techniques was provided to those trained as practitioners. Human errors need to be investigated to identify the underlying psychological mechanisms that led to the error and the associated PSF's that had the negative impacts on human performance.

The analysis of non-compliance requires identifying the conditions which first prompted the person (or people) to believe that working outside the rules or procedures was a possibility, but also the expected consequences of doing so from the point of view of the person involved. This involves "getting inside the tunnel" with the operator to understand the sequence of events from their point of view. Often looking at an intentional behaviour from an investigator's point of view makes it difficult to understand why a person would have behaved in such a way. It is only by understanding how the conditions and motivations from the point of view of the person that is being investigated that the investigator can see that the non-compliance happened for reasons that the individual felt were logical.

The objective of integrating human factors into incident investigation is to be able to make recommendations that will address the underlying reasons why the behaviour that caused or contributed to the incident occurred in the first place. Not getting to this understanding is one of the reasons why investigations that do not incorporate human factors analyses result in recommendations that are not effective at addressing the underlying causes, with the result that repeat incidents occur.

In defining the human factors tools and techniques for use in investigations, reference was made to the Energy Institute guidance on investigating human and organisation factors of incidents and accidents (Energy Institute, 2008). This guidance suggested that to be successful, the tools used need to have the following characteristics:

- Be able to identify the immediate and root causes of human performance – why did the person do what they did?
- Be able to integrate with an existing root cause analysis tool rather than replace it
- Provide a standardized way of performing human factors investigations using a common language
- Be able to identify the conditions that influenced human performance leading to either errors or violations.
- Be scaleable to allow use of tools on a near-miss or a serious accident, and in formal and informal investigations.
- Be solution-focused to identify learning opportunities from one incident that can applied to other situations
- Be able to collect the data on the human factors causes and export the results of the analysis to allow recording of data.
- Be based upon a simple model of human behaviour and should be able to produce results within a short period of time.
- Clearly differentiate between unintentional human error and intentional violation and not encourage the use of the term "human error" to describe any type of human failure.

In order to successfully integrate human factors into the investigation process, it was also necessary to consider the skills and abilities of the investigators themselves. Guidance from the Institution of Occupational Safety and Health was used to identify the analytical, interpersonal, technical and administrative skills required of an investigator (IOSH, 2008).

Finally, the training of investigators covered the application of just culture models. It was stressed that such models should only be used based upon the evidence gathered about the causes of human failure, and as such need to be applied once the investigation and analysis process is complete.

Critical Administrative Controls

Critical administrative controls (CACs) are one example of the application of human factors in risk assessment. According to the LyondellBasell definition, they are a subset of human interventions for which credit has been taken as Independent Protection Layers (IPLs) in process safety Layer of Protection Analysis (LOPA) risk assessment. The human intervention, if it performs as expected, will prevent an initiating event from materialising into an incident. CACs are a subset of human intervention IPLs, in that they are only designated CAC if they are required to mitigate defined higher risk scenarios. They are only applied when technical measures are not practicable. The human intervention is initiated by an alarm or procedural requirement. They are naturally considered to be highly safety-critical activities due to the fact that administrative controls are crucial to success yet known to be fallible under certain conditions.

The preferred practice for human factors in risk assessment was initially focused on CACs but the guidance also states that this is not the intended limit of the application of this approach; the methodology is also suitable for the wider category of safety critical tasks. For example, it is expected that the same approach would be used across the business to identify potential errors during fired heater start-up, maintenance tasks, design of new procedures, modification of existing procedures, and the design and modification of plant equipment.

For activities that have not already been assessed as safety critical, the guidance provides details of the methodology developed by the UK Health and Safety Executive for assessing task criticality (Health and Safety Executive, 1999). This methodology uses a series of screening questions to establish how critical human performance is in completion of the activity and provides criticality bands depending on how the questions have been scored for the task to determine the level of criticality of the activity being assessed.

The screening questions cover:

1. How intrinsically hazardous is the system involved?
2. To what extent are ignition sources introduced during the activity?
3. To what extent does the task involve changes to the configuration of the system?
4. To what extent could incorrect performance of the task cause damage?
5. To what extent does the task involve defeating protection devices?

Screening takes place in a workshop setting with subject matter experts in the activity being assessed and the assessment methodology (i.e. those who have been trained to practitioner level). At the end of the screening process, all tasks assessed as high criticality are automatically put forward for more in-depth analysis, along with any that are medium/high criticality or tasks that are part of the emergency response.

For those activities identified for further analysis, the first step is to conduct a task analysis of the activity to accurately understand the steps that the human operator or maintainer goes through to complete the activity. This requires the team completing the analysis to use a range of sources of information on what the task entails, the procedure alone is insufficient as experienced operators use tacit knowledge that is usually not documented to complete the task.

It is stipulated that a task analysis can begin by reviewing the procedure and using this to identify some of the key steps involved, but that it should be supplemented by a walkthrough of the task onsite to identify details not included in the written procedure. Talking the task through with those that complete the task can be done as well, or in some cases if the task is too hazardous to legitimately involve someone in a walkthrough. The resulting task analysis should describe how the task is actually performed and is validated by a group of subject matter experts on completion to ensure its accuracy.

Following the task analysis, the next step in the process is assessing the presence of conditions that could have a negative impact on human performance during the task. In the LyondellBasell language these are known as Performance Shaping Factors (PSF's). These are assessed continually throughout the analysis, but it is useful identify at an early stage which conditions are likely to be present and affecting personnel working on the plant and in the control room when the task is being completed. A standardised list of PSF's is used at this stage, and the analysts identify potential risk control measures to either remove the PSF or mitigate its impact during task performance.

The next stage in the preferred practice covers the conduct of Human Reliability Analysis (HRA). An analyst with a suitable advanced level of training and experience of conducting such analyses is required to perform this part of the process.

This stage of the process uses a series of human factors guidewords to identify credible errors for each step in the task analysis. Additional specific PSF's that may influence performance on the subject step of the task analysis are also identified. The consequences of the error and the potential existing recovery mechanisms are then identified, along with the current control measures which are in place in the event that the error is not detected and recovered.

The existing control measures are then assessed against the severity of the potential consequences of the error. For example, if the potential consequences are an explosion and the existing control measures are procedures and operator competence, the assessment should be that the existing control measures are not sufficient. On the other hand, the existing control measures may be robust involving multiple alarms and trips, in which case the existing control measures may be considered sufficient.

If the existing control measures need to be improved, the workshop moves on to discuss what the additional control measures could be, using the hierarchy of control as a guide. This way engineering solutions are considered first, and if they no feasible controls can be identified, the analysis turns its attention to other ways to control the hazard such as administrative controls. The aim is also to consider what might be done to better detect the error, mitigate its impact, or aid the recovery from the error in a timely manner.

A small number of personnel within LyondellBasell have currently been trained to the advanced level required to conduct the full scope of this technique within the company. A larger number have received the awareness level training to help them to understand the approach, so that when they are approached to take part in such an analysis they are aware of it, although they still require some introduction from their facilitator on the details.

Experience with the methodology indicates that a small multi-disciplinary team, including workforce participation, is necessary to complete the analysis of an alarm-initiated CAC or procedural CAC.

The Next Steps

The work done so far at LyondellBasell to systematically account for potential human failures, has put important foundations in place: the definition of a road map; alignment on terminology; defining a tool for analysing human failures in incident investigation; creating methodologies for critical administrative controls and safety critical tasks.

For incident investigation, they will monitor activities in the sites to identify if additional coaching or focused support is required to embed usage of the tools. A key success factor by which the activity will be measured will be the extent to which the investigations are identifying corrective actions which will make the tasks of front line staff less vulnerable to human failure. For human reliability analysis of Critical Administrative Controls and Safety Critical Tasks, given that this new methodology might require significant resources in the sites to implement, the focus of attention in the near term will be how to prioritise and coordinate that work to complete it efficiently.

They are now focusing on operating practices, including developing a global approach to writing procedures.

Directly addressing behaviours and recognising that the safety choices people make are influenced by context, LyondellBasell are piloting an innovative approach applying Behavioural Insights and nudges using techniques which have found increasing application in public policy (Halpern 2016).

References

Dekker, S. (2014) The field guide to understanding “human error”; CRC Press

Edmonds, J (2016) Human Factors Integration within Design / Engineering Programmes; in Edmonds (Ed.) 2016 Human Factors in the Chemical and Process Industries – making it work in practice, Elesvier

EEMUA (1999); Alarm systems - a guide to design, management and procurement, Publication 191. EEMUA

Energy Institute (2008); Guidance on Investigating and Analysing Human and Organisational Factors Aspects of Incidents and Accidents

Halpern. D (2016). Inside the Nudge Unit; how small changes can make a big difference. WH Allen

Health & Safety Executive (HSE) (1999), Offshore Technology Report, Human Factors Assessment of Safety Critical Tasks, OTO 1999 092.

Hopkins A. (2008), Failure to Learn; the BP Texas City disaster. CCH, Australia

IOSH (2008) Learning the Lessons – How to respond to deaths at work and other serious incidents

Rasmussen, J. (1982) Human errors. A taxonomy for describing human malfunction in industrial installations; Journal of Occupational Accidents Vol 4 Issues 2-4 pp311-333, Elsevier

Reason J. (1990) Human Error. Cambridge University Press

Reason J. (1997) Managing the Risks of Organisational Accidents. Ashgate

Reason J. , Hollnagel E. , Paries J. (2006) Revisiting the Swiss Cheese Model of Accidents; Eurocontrol

Schein E.H. (1992) Organizational Culture and Leadership (2nd Edn.) Jossey-Bass, San Francisco

Stichting Tripod Foundation (2006) Tripod Beta Incident Analysis Primer

Tripod Solutions (2007) Tripod Beta – Overview Downloaded 2007 01 18

Widdowson, A. & Carr, D. (2002) Human Factors Integration : Implementation in the Onshore and Offshore Industries. HSE Research Report 001, 2002

Wiegmann D. and Shappell S. (2003) A Human Error Approach to Aviation Accident Analysis: The Human Factors Analysis and Classification System. Routledge