The CIEHF White Paper on Human Factors in Barrier Management: Recommendations for good practice

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Barrier management – implementing and assuring a range of controls to protect against the risk of major losses - is widely used across many industries, particularly the traditional "high hazard industries" (nuclear, oil & gas, rail, etc.). However, the concept applies to virtually every industry with the potential for significant losses.

Risk management strategies that aspire to a degree of formality and rigour in the way they identify, assure and manage controls (including barriers and safeguards) need to be able to deal with the many human and organisational (HOF) factors issues that inevitably arise. This needs to be done in a way that is both rigorous and technically sound whilst being realistic and pragmatic, and adequately grounded in what is known of the psychology of human behaviour and performance.

This paper introduces and summarises a white paper setting out a position developed by the Chartered Institute of Ergonomics and Human Factors (CIEHF) on the treatment of Human Factors in barrier management in general, and Bowtie Analysis in particular. The white paper summarises CIEHF members' concerns with current practice, including concerns about the way Human and Organisational Factors are often addressed in Bowtie Analysis. It also contains recommendations covering Human Factors in the selection, verification, implementation and assurance of controls (including both barriers and safeguards).

Where there is a need for a detailed examination of the potential for human error to defeat barriers, the white paper proposes that a layered approach should be adopted with lower levels examining in progressively more detail how barriers can be defeated, and what safeguards need to be in place to mitigate against it.

Introduction and Background

With a membership drawn from 43 countries, the Chartered Institute of Ergonomics and Human Factors (CIEHF) seeks to promote best practice in ergonomics and human factors. For over 65 years, CIEHF members and associates have been prominent in the research, development and implementation of many of the techniques and regulatory approaches that are now considered global best-practices in implementing Human Factors in safety-critical industries. Examples include: safety management systems; safety-critical task analysis; safety culture assessment; Human Factors in incident investigation; integration of Human Factors Engineering into capital projects; and Human Reliability Analysis (quantitative and qualitative approaches to demonstrating that risk of human error has been reduced to a level that can be shown to be as low as reasonably-practicable (ALARP).

Through their professional activities, CIEHF members are aware of the cross-sector importance of barrier management. In particular, the technique of Bowtie Analysis is increasingly prominent in supporting the development and operational management of barrier models. This rapid growth in Bowtie Analysis has been driven largely by the conceptual simplicity of the approach and the visual representation of the analysis together with access to easy-to-use software tools.

CIEHF members have however become concerned at how human performance is being addressed in some current approaches to barrier management, and Bowtie Analysis in particular. There is, as yet, little standardization or agreed statements of best practice about how to implement Bowtie Analysis either within or across sectors. The guidance that is available says little or nothing about what represents good practice in dealing with Human Factors aspects of barriers. Consequently, practices have developed and been shared across businesses and industries that are inconsistent with good practice in Human Factors and Ergonomics.

A white paper is defined in Wikipedia as "..*an authoritative report or guide that informs readers concisely about a complex issue and presents the issuing body's philosophy on the matter. It is meant to help readers understand an issue, solve a problem, or make a decision".* Adopting that definition, and in line with its remit to promote best practice and raise competence in the application of ergonomics and human factors in applied settings, the CIEHF has developed a white paper on Human Factors in Barrier Management (CIEHF, 2016). Development of the white paper had two principal objectives: i) to try to explain in a simple a way some of the complexity that needs to be taken into account when trying to properly reflect the role of human performance in barrier models, and ii) to set out some basic recommendations that, if they were followed, would lead to a step improvement in the treatment of human factors in those models.

Development of the White Paper

Development of the white paper began with a half-day workshop held immediately prior to the 2016 CIEHF annual conference. The workshop aimed to discuss and review concerns held by Human Factors professionals about current practice and to try to determine what the CIEHF might consider as the basis of good practice.

Around 30 delegates, drawn from a wide range of industries including oil and gas, nuclear, maritime, rail, healthcare and defence attended the workshop. Invited speakers known to have particular experience in the operational use of barrier management strategies gave a series of short briefings. Delegates were then organised into working groups and asked to work through four discussion questions, each with a dedicated facilitator and scribe (i.e. each group discussed all four questions). The discussion questions were;

1. What criteria should a proposed barrier in a layers of defences strategy that relied on human performance be expected to satisfy to be considered acceptable?
2. What action can organizations that propose to rely on human performance as a barrier take to demonstrate that those human barriers are as robust as they reasonably can be?
3. Is it realistic to identify a best-practice approach that can apply across all industries? What are the key differences and challenges that need to be customised to suit the needs of different industries or regulatory situations?
4. Can the role of people as a barrier preventing the release of a hazard (i.e. the left-hand side of a bow-tie) and as a mitigating barrier (the right-hand side of a bow-tie) be treated in the same way? Or do different factors need to be considered in each case?

At the end of the workshop, a working group was organized comprising CIEHF members prepared to contribute to development of the white paper. Over the subsequent six months, and drawing on the conclusions reached in the four discussion groups, three draft versions of the white paper were prepared and reviewed by the working group. Following the third round of reviews, the document was sent to a further four experienced individuals who had not previously seen the content for their review. A copy was also sent, on request, to the UK's Health and Safety Laboratory. Comments and suggestions from these reviewers were incorporated at the discretion of the lead author, in consultation with working group members as appropriate.

Following completion of the fourth and final draft, the document was sent to a professional publisher who carried out an editorial review and formatted the document ready for external release. The document was released for public use on the CIEHF web-site in January 2017.

As well as the experience of CIEHF members, development of the white paper drew on a variety of sources, including incident investigation reports and guidance from regulators, published literature about human performance in complex systems, and literature specific to barrier management systems. Development of the white paper also coincided with work being carried out by the Centre for Chemical Process Safety (CCPS) to produce guidance on good practice in bowtie risk management (CCPS, 2017). Two members of the CIEHF working group were also involved in the CCPS project and were active members of its Human Factors sub-committee. This has led to an overlap of some of the material in the CIEHF and CCPS publications. Due to differences in the target audiences, stakeholder communities and the purpose of the guidance for the two documents, there are differences in emphasis and in detail in the way the same material is presented in the two publications.

The theoretical basis of Bowtie Analysis

There is confusion in the technical literature about the theoretical basis of Bowtie Analysis. Assumptions are frequently held, based largely on the visual structure of the representation, that the method assumes a linear, event-driven model of accident causation. A type of model that leading thinkers such as Nancy Leveson, Erik Hollnagel, David Woods and others have long argued is inadequate as a means of understanding the dynamics of complex socio-technical systems or the ways they can lead to incidents. Such an assumption however is neither true nor necessary.

The reality is that Bowtie Analysis, and the understanding of barriers and safeguards that it can generate, is neutral in terms of any underlying model of accident causation. (Though it is true that many users of Bowtie Analysis do still subscribe to a traditional linear, event-driven model of technical systems and how they fail). Bowtie Analysis itself makes no assumption about the mechanisms that might lie on the path between threats and the top events and consequences they can lead to. It simply recognises that some structures, systems, processes or activities (i.e. controls) can be effective in blocking that path, whatever the mechanisms involved.

It is true that Bowtie Analysis are often based on risks identified through HAZOP or related studies. Though there is no reason why a Bowtie model should not be based, for example, on a STAMP (Leveson, 2012) or FRAM (Hollnagel, 2014) analysis. For example, if a FRAM analysis raised concern about resonance between functions in the financial services system (Sundström and Hollnagel, 2011), a Bowtie analysis would seek to identify controls capable of detecting the developing resonance and intervening to dampen it. It would also evaluate those controls to ensure they were capable of providing the protection expected, and explore how they might fail.

CIEHF Concerns with current practice

Discussions both at the workshop and within the working group, as well as comments from a wider group of interested stakeholders, identified a range of issues and concerns that directly impact on the treatment of human and organisational factors in barrier models. Some of these concerns were generic to the use of Bowtie Analysis, while others were specific to the treatment of the role of people in bowtie models. Generic concerns included;

- Over-emphasis on the analysis method with a focus only on controls against specific threats at the expense of a richer understanding of the complex ways in which threats develop and manifest themselves, and the full range of issues that need to be managed for controls to be effective. This includes constraints on thinking about the nature and characteristics of hazards and risks and their management arising from the practical and physical constraints inherent in the use of computer software to visualise bowtie models on 2-D computer displays.
- Getting the right balance between having adequate controls in place to mitigate against specific identified threats, and having the resilience and flexibility to be able to respond adaptively and effectively to the unexpected. In a

bowtie model, the location of the top event, and the relative balance between reliance on left-hand side and right-hand side barriers, can be associated with many human and organisational issues. An organisational culture that has a high degree of confidence and trust in its systems and practices will tend to rely on left-hand side barriers. By contrast, a culture that has significant doubts about the robustness of the left-hand side barriers, but values its ability to solve problems and get out of trouble will tend to place a lot of emphasis on the right-hand side.

- Differences in the respective ownership of left and right-hand side barriers. Ownership of left-hand side barriers is often seen as lying with engineering and management; how the system is designed, and how operations are managed and controlled. By contrast, right-hand side barriers tend to rely on the skill, experience, adaptability and problem-solving capability of front line operators: ownership of right-hand side barriers is therefore often seen as lying with operations.

In addition to these generic issues, the working group identified eight concerns specifically to do with how human and organisational factors are addressed in Bowtie Analysis. In brief;

1. Human error is commonly modelled as a threat, and barriers are put in place that try to block the error from leading to a top event. This focuses effort and attention on trying to minimize the risk of human error rather than recognizing the real barriers and ensuring they are as robust as they can be against any degradation factors – of which human error is usually only one.
2. Too many "barriers" being identified, most of which are not able to meet the generally accepted criteria for robust barriers.
3. Equipment that is identified as performing a barrier function will typically have an Equipment Performance Specification associated with it. Although bowties frequently identify a reliance on human performance to achieve barrier functions, they rarely (if ever) specify the level of human performance that needs to be achieved for the barrier to function.
4. Top Events being located too far to the right: that is, the events that barrier systems seek to avoid by means of prevention barriers are too close in time to the consequences (fatalities, losses, etc.) that those events can lead to.
5. Barrier models rarely take a systems view of the human and organisational factors associated with the threats they are trying to control. They rarely recognize the influence that a wide range of organisational factors at different levels of an organisation's hierarchical structure can have on the performance of people at the front-line.
6. Organisations frequently hold unrealistic expectations about what people will be able to do, and how they will actually perform, in the circumstances that exist when barriers need to function.
7. Related to this is a lack of awareness of the difference between "work-as-imagined" (i.e. an idealised, office-based view of how tasks and processes are performed) and "work-as-done" (i.e. the reality of how work is actually done, including the compromises and adaptations made when carrying out tasks under real-world constraints and pressures). (See Hollnagel, 2014 for a discussion of the difference between work-as-imagined and work-as-done).
8. Barrier models are often prepared, implemented and distributed to the workforce in a manner that does not support their operational use.

The white paper sets out to address these concerns and to offer practical recommendations for organisations seeking to ensure the human elements of their bowtie models are consistent with good practice in the professional practice of Human Factors. It seeks to achieve this in a number of ways, including;

- Clarifying the terminology used, the nature of controls, and the relationship between key components of a barrier system. This includes distinguishing between the role played by full barriers – i.e. controls that can be assured to meet minimum requirements to be considered as barriers - and safeguards. Safeguards are important in supporting and underpinning the availability and performance of barriers but cannot meet the standards to be relied on as a primary control measure.
- Setting out recommendations to improve the development, implementation and management of those aspects of Bowtie Analysis that rely on human performance or are intended to protect against loss of human reliability.
- Recommending an approach that can be followed when an organisation has an interest in developing a detailed understanding of barriers that rely on human performance, how they can be degraded or defeated, and the safeguards that need to be in place to prevent such degradation.
- Demonstrating how a Human Performance Standard for barriers that rely on human performance can be documented.

The following sections will briefly consider each of these.

The characteristics of controls

Figure one summarises the terminology and key characteristics of controls used in the CIEHF white paper and indicates key relationships between the various components. As well as illustrating the difference between barriers and safeguards, figure one identifies six criteria that controls "must" have;

- All controls, whether barriers or safeguards, must;
  - Have an identified owner. The barrier owner will rarely be the same individuals as those tasked with performing the barrier function (i.e. typically identified as the Safety Critical Role associated with a barrier). The owner of a control must have a position in the organisation where they can be responsible for the ongoing support and maintenance to ensure the control is in place and capable of functioning as intended when needed.
  - Be auditable. Each control should have characteristics that indicate its state in order that its existence and ability to perform can be assured. Assurance can take various forms, from simple inspection, to testing or review of records.
  - Be treaceable to some requirement, process or activity in the organisations management system.
- Barriers must be effective (sometimes referred to as "fully functional"). Every barrier, on its own, should be capable of preventing an event from leading to an undesirable consequence in the circumstances likely to exist when the barrier function is needed. As long as the barrier performs as expected when needed, it will be successful in preventing the identified threat from leading to either the top event or to one of the consequences.
- Individual Elements that collectively provide the functionality needed of a barrier must be both specific to the threat, and independent of any other element protecting against the same threat.

Note that while Safeguards are not expected to meet the criteria of being effective, independent or specific, they must still, if they are to be considered as a control, have clear ownership, be auditable, and be traceable to the organisations management system.

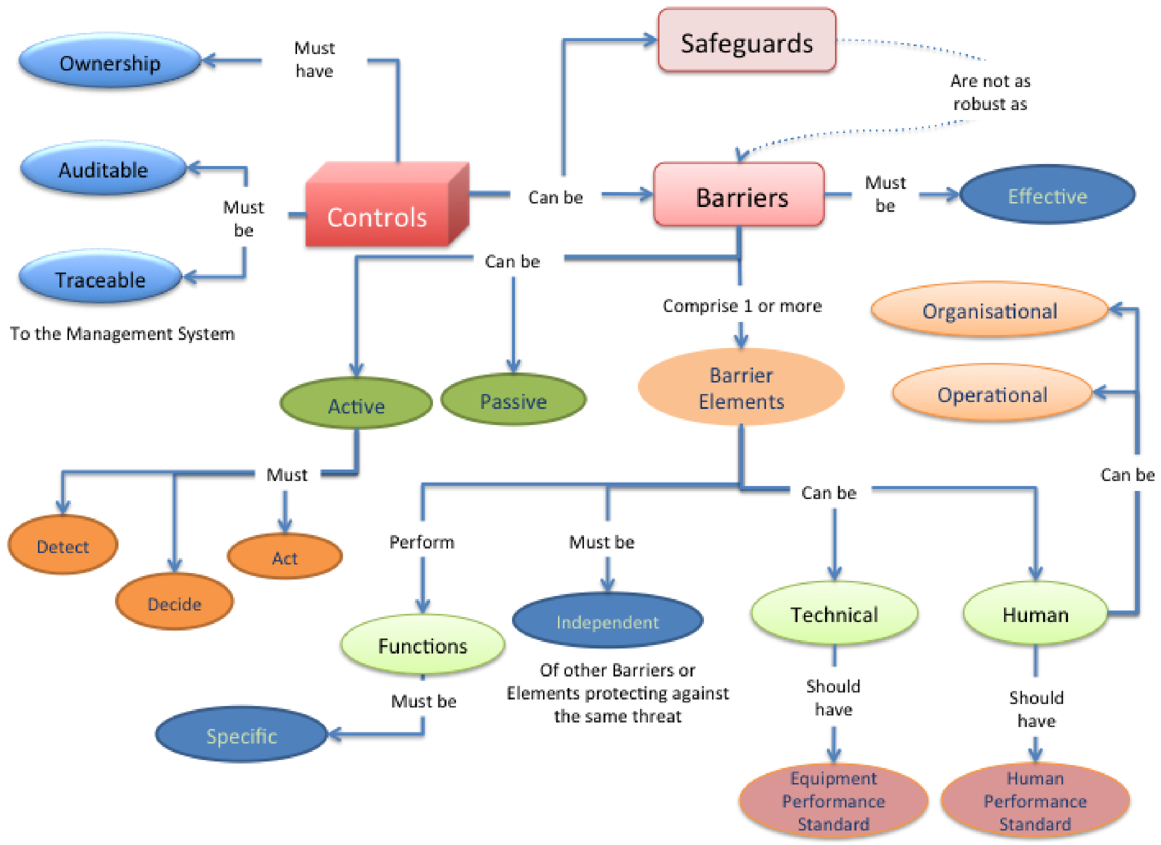

Figure 1: Summary of the relationships between components of a Barrier system (from McLeod et al, 2017).

To illustrate the difference between barriers and safeguards, figure two shows the left hand side of a bowtie for a crane operation. The hazard is the overhead object during the lift, and the top event is loss of control of the object during the lift. The threat is the lift exceeding the crane's capacity. In this treatment, an error on the part of the crane driver is seen as one of many factors that could defeat or degrade the barrier "Planning and Lifting Procedure". Five safeguards (driver competence, communications, etc.) are shown that are expected to reduce the likelihood of crane driver error from leading to failure of this organisational barrier.

Recommendations for good practice

The white paper makes thirty-three recommendations intended to improve the development, implementation and management of those aspects of barrier management systems, and particularly those based on Bowtie Analysis, that either rely on human performance or are intended to protect against loss of human reliability. While the recommendations do not provide comprehensive coverage of all of the issues that need to be considered, they provide the basis for a step improvement in current approaches to managing the Human Factors aspects of barrier models.

In addition to recommendations about the use of terminology and quality criteria for controls, recommendations are organised into three topics:

1. General policy around the treatment of and attitude to barriers. For example, the first general recommendation is that *"All barriers should be considered to be critical: they must be capable of being demonstrated to meet the minimum criteria necessary to be recognised as a barrier"*. While this may seem obvious, perhaps even trivial, many organisations have spent a great deal of effort in recent years trying to determine which of the "barriers" they have included in their bowtie models are critical. This is a fundamental misunderstanding of the role of barriers. It confuses the concept of barriers with the very real and practical issue of having to decide where to allocate what are always limited time and resources in maintaining and assuring barriers. Every barrier on a bowtie model must be treated and managed as being critical (and of equal criticality). Organisations should make decisions about their ability to maintain and assure barriers before bowtie models are issued for operational use, not after. If an organisation is not able or willing to commit the necessary time and resources to assure a particular barrier, then it must recognise that it is a safeguard, not a barrier. It is important, but cannot be relied on in the way that full barriers can. (Note that it follows that failure of any barrier should be considered and investigated as a high-potential incident).

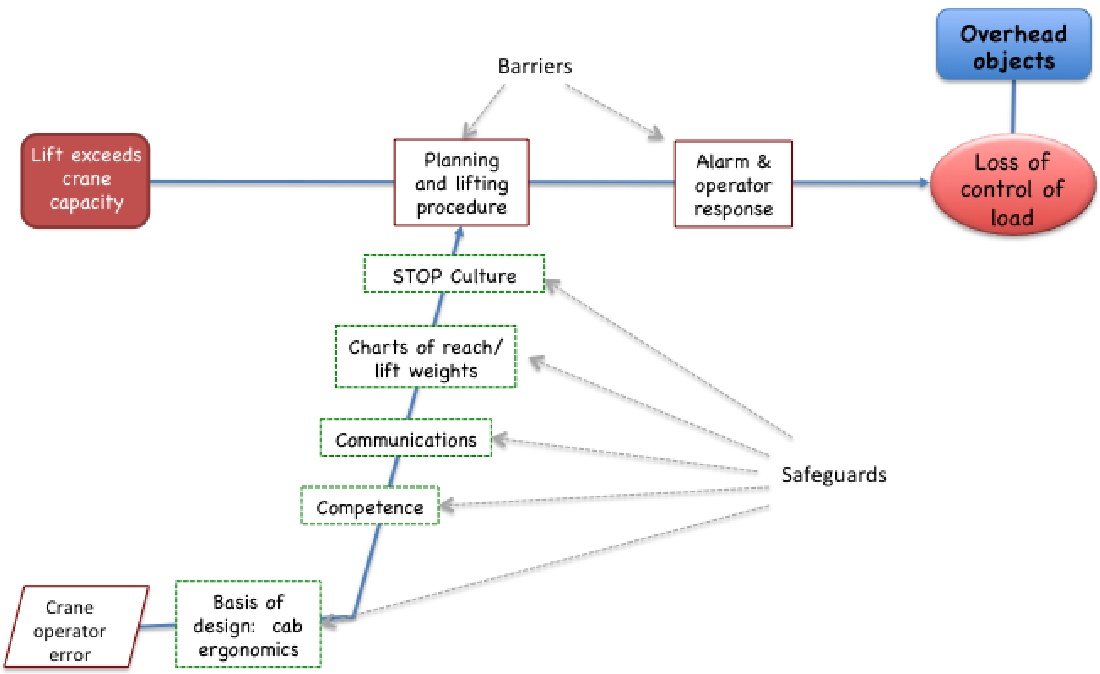

Figure 2: Example bowtie analysis of loss of control of the load during a crane lift where driver error is treated as a degradation factor leading to loss of effectiveness of the lifting procedure as a barrier (left-hand-side only). (From CIEHF, 2016).

2. The lifecycle of the development and use of barriers, including selection, verification, implementation and assurance.

    - Selection refers to the first pass at identifying potential human performance requirements to perform or support barrier functions. The key Human Factors decision to be made is whether the human performance required for the barrier element to perform its function is worth considering as a barrier element (whether Organisational or an Operational). Three recommendations concern the selection of barriers, for example; *"The performance needed to deliver the required functionality should be capable of being described clearly: i) what state or events would initiate the performance, ii) what task(s) are involved in carrying out the function, and iii) when the function has been achieved."*

    - Verification refers to the review of suggested Organisational or Operational barrier elements to ensure they are suitable – assuming they are correctly implemented and assured - to be relied on as human barrier elements. The decision to be made is whether the proposed human performance is considered to be sufficiently robust to be included as a barrier/ element. Seven recommendations concern the verification of barriers, for example; *"Expectations about what it is reasonable to expect of people involved in performance of the barrier function should be subject to review by experienced operational personnel."*

- Implementation refers to the process of implementing barriers in the operational environment in such a way that the likely performance of the barrier is not degraded by the environment, work systems or organisational or commercial arrangements. The key Human Factors decision to be made is whether the human barriers have been implemented in such a way that they are likely to perform as expected when needed. Seven recommendations concern the verification of barriers, for example; *"Performance incentives – both personal to the operators and commercial agreements of the organisation - should be consistent with and supportive of performance of the barrier. There should be no personal or commercial incentive that would lead to the required barrier performance being given a low priority."*
- Assurance refers to the process of confirming that the working environment, work systems and operational and commercial arrangements are managed and maintained in such a way that the assumptions made about the ability of operators to carry out barrier functions successfully and for safeguards to perform as expected continue to be valid: that is, that "work as done" has not deviated significantly from the way it was understood when the barrier was implemented. The key Human Factors decision is whether the conditions necessary for effective performance of Organisational and Operational barriers are being maintained and assured in the workplace. Six recommendations concern the Assurance of barriers, for example; *"Individuals assigned responsibility for barrier performance need to have adequate opportunity to perform the task and to practice the skills needed under realistic conditions."*

3. The contents of a Human Performance standard for human barrier elements. The white paper makes recommendations, and contains two examples showing how a Human Performance Standard for human barrier elements can be specified in terms of six characteristics:
   - What makes the human performance specific to the threat and situation?
   - Who is expected to be involved in delivering the required performance?
   - What competence do the individuals involved need to have?
   - What is the expected timing of the performance of the barrier?
   - What are the criteria for successful performance of the barrier?
   - Key expectations about how operations around the barrier will be conducted that are especially critical to performance of the barrier function.

Table one shows an example of how a Human Performance Standard could be documented, based on the top event of loss of control of a load during a lift by a crane shown on figure two. The table is concerned with the element "operator response" of the barrier "Overload alarm and operator response".

The use of layering to model risk from human error in bowties

One of the key concerns raised by CIEHF members discussed earlier was around what is a widespread practice of modelling human error as a threat in a Bowtie Analysis. Barriers are then put in place that try to block the error from leading to a top event. The white paper sets out a number of reasons for this concern, though perhaps the most significant is that it focuses effort away from the real barriers that should be in place – the ones that the human error is capable of defeating – and concentrates solely on the potential for human error. CIEHF proposes in the white paper that human error should not be treated as a threat in the main (also referred to as the "top level") bowtie. In its forthcoming book on Bowtie risk management, the Centre for Chemical process Safety (CCPS), makes the same recommendation.

CIEHF recognises however that there are often situations where an organisation does want to focus specifically on the risk of human error, understanding what controls need to be in place and how they themselves can be defeated or degraded. To support such situations without violating the principle that human error should not be treated as a threat on a main bowtie, the white paper (in common with the CCPS book) suggests using a layered approach: while human error should not be modelled as a threat in the main (top level) bowtie, it can be considered as a threat at lower levels of analysis. Figure two illustrates the concept of such layered bowties. The figure shows a main bowtie ("Level 0") where human error has been identified as a degradation factor for Barrier 2. Two progressively more detailed levels are shown (Levels -1 and -2) developing progressively more detailed understanding of the risk from human error and the safeguards that are relied on to mitigate that risk. The white paper uses an example, taken from a healthcare incident, to illustrate how the layered approach can be applied in practice.

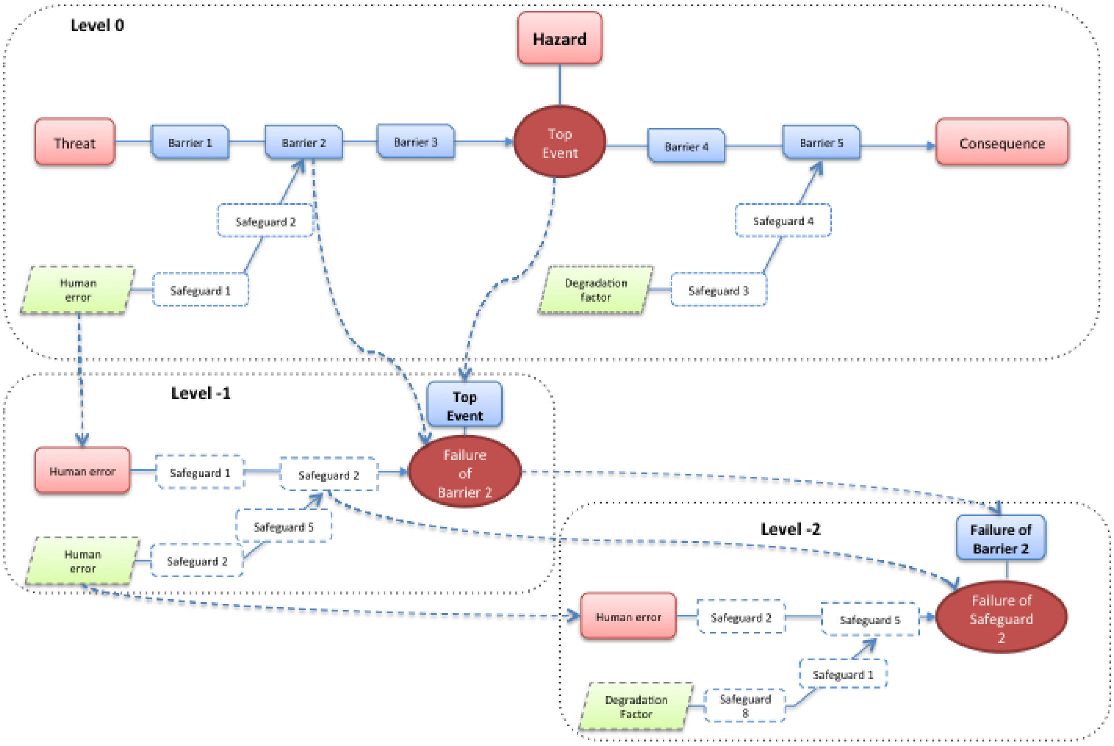

Figure 3: Illustration of the concept of layered Bowties (from CIEHF, 2016)

Concern has been expressed in some quarters that it is unrealistic and impractical to expect organisations to routinely develop bowties in such multiple layers. Doing so would require a level of time and effort that is simply not available to organisations with limited resources that have to be financially responsible and profitable. This concern however misses the key point that choosing to conduct such a layered analysis to explore the implications of and controls against human error is entirely at the discretion of the organisation with responsibility for managing its major risks. If the organisation sees no value in exploring risks associated with human error, there would be no need to develop any layered bowties. The white paper states that *"The number of levels of analysis is at the discretion of the organisation".*

But if there was such a concern, the white paper recommends an approach, consistent both with good practice in Human Factors and with the principle that human error should not be treated as a threat on a main bowtie, that allows as detailed an exploration as the organisation wishes to conduct of the risks from human error that it is particularly concerned about.

Barrier Reliability

Bowtie analysis is a qualitative approach to risk management. Unlike techniques such as Layers of Protection Analysis (LOPA, see CCPS, 2015) Bowtie Analysis does not attempt to quantify the reliability of barriers by estimating the likelihood of their failing to deliver the required functionality when it is needed.

Clearly, the expected reliability and availability of barriers has got to be taken into account when making decisions about whether a proposed control is likely to meet the criteria of being effective. For example, it might be proposed that strong winds from the south east would be a barrier against a fire spreading to flammable material stored to the south east of a fire hazard. While that might be true if the wind occurred at the right time (i.e. it would act as a barrier as long as the wind blew with sufficient strength), the likelihood of it existing when needed might be considered to be low: the likelihood of the barrier failing to perform when it was needed would be unacceptably high. Relying on the wind as a barrier would clearly not be a sensible policy.

In situations where there is a requirement to produce a formal demonstration that risk has been reduced to a level that can be shown to be ALARP, some means of estimating the reliability of human elements of barriers will be needed. The CIEHF white paper however has not made any specific recommendations about how to evaluate the reliability of the human element of proposed controls or the likelihood of human error defeating controls. Rather, it is considered as one of the issues where informed judgement will need to be used when making a decision about barrier effectiveness and the relative risk of human error acting as a degradation factor. Among the reasons the assessment of human reliability is beyond the remit of the white paper, the most important was awareness of the purpose and value of Bowtie Analysis, bearing in mind the scope and intended target audience.

Although development of the white paper drew heavily on experience of CIEHF members in high-hazard industries (oil and gas, chemicals, rail, maritime, nuclear power, etc.) the target audience is seen as being significantly wider than those industries. Industries such as banking, insurance, healthcare, policing and the social services, among others, have all experienced major incidents in recent years which were traced to the failure of the controls those in positions of responsibility expected to be in place. Many CIEHF members believe that Bowtie Analysis has as much to contribute to the identification and management of risk through in those industries as it has in the traditional high-hazard industries. And while the oil and gas, rail and nuclear industries can be very sophisticated in how they estimate and attempt to quantify risk and the likelihood of controls failing, other industries within the target audience for the white paper have little experience in those areas. Assessment of reliability is frequently carried out informally drawing on professional judgement and experience rather than the use of formal risk assessment techniques.

In many complex socio-technical systems with the potential for significant unwanted events, there is simply a lack of awareness or any real degree of rigour attached to identifying, assessing and managing the controls that are relied on to protect against incidents. This can be seen in the many investigation reports into major incidents which discuss the controls that should have been in place, and the way those controls failed in the circumstances at the time. CIEHF has taken the view that the real value of bowtie analysis lies in the awareness and visibility of the controls an organisation relies on to protect against major losses that Bowtie Analysis produces. In very many situations, it is the recognition and evaluation of barriers, and the discrimination between barriers and safeguards that should result from the analysis that, in its own right, has the potential to provide a significant step forward in managing risk.

To give an example, a workshop was recently run (facilitated by the lead author of this paper) to examine the value of applying Bowtie Analysis to evaluate the controls against what are sometimes known in healthcare as "Never Events" (i.e. adverse events that should never occur). An example "Never Event" was examined involving a patient attending her GP for hormone replacement therapy. Among a number of controls that met the criteria to be considered as barriers one element was an alarm included in the electronic patient management system used by GPs in making diagnoses and deciding on a treatment plan. Having realised the importance of this barrier element, the analysis identified many factors that could – and, in reality, frequently did - defeat it. Attempting to quantify the likelihood of this alarm failing to alert the GP to the risk would be futile due to the numerous factors, each with complex organisational chains, that could contribute to the failure. It would also almost certainly be impossible to achieve with any degree of objective validity. However such quantitative analysis is unnecessary and misses the real value of the analysis. That value lay in the awareness of the controls that were being relied on and the recognition of which are barriers and which are safeguards, as well as recognition of how those barriers can be defeated and the range of stakeholders and activities that need to be managed to ensure they are both in place and assured to be effective.

Table one: Example Human Performance Standard for human barrier element "Operator response" (from CIEHF, 2016)

Barrier	Overload alarm and Operator response		
Barrier Element	Operator Response	Type	Operational
Barrier function(s)	1: Stop the lift. 2: Ensure all personnel are in a safe place. 3: Prepare a plan to safely lower the load. 4. Safely lower load		
Limits	Determined by alarm limits		
Active or Passive?	Active		
What makes the barrier specific to the threat?	Actor: Crane driver Object: Conduct of the lift. Goal: Detect an unsafe condition and bring lift to a safe state.		
Performance Criteria	The driver should: 1.Detect and correctly understand the meaning of the alarm within 1 second of it sounding 1. Be capable of stopping crane movement within 3 seconds of the alarm sounding 2. Be capable of identifying that the alarm is not working before taking a load.		
Timing	As Performance.		
Who is involved?	1. Crane driver; 2. Supervisor or Banksmen.		
Competence Standards	Lifting Supervisor: Crane Driver: Banksmen:		
Who Detects?	Crane driver		
Who Decides?	Crane driver		
Who Acts?	Crane driver, in communication with Supervisor and/or Banskmen.		
Information needed	• Alarm status (working/not working) • Alarm function (active/not active)		
Key judgements or decisions involved?	• The element should not require any decision or judgement about the need to stop the lift immediately. There should be no doubt or ambiguity. • Decision/judgement will be needed about how to bring the load to a safe state.		
Actions	• Stop the lift • Plan how to proceed • Bring the load to a safe state.		
Feedback	Feedback available to the crane driver shall include: • Visual sightline of load • Visual confirmation from cab displays that movement of crane arm ha stopped • Visual confirmation from in cab display that weight has been taken off. • Visual confirmation from Banksmen that weight is on the ground.		

Engineering Standards	• The overweight alarm shall be designed and tested to comply with Human Factors Engineering standard xyz. • The location, layout and operation of controls associated with response to the alarm shall comply with Human Factors Engineering standard xxx. • Sightlines from the crane cab to be in accordance with ISO xyz.
Critical Expectations associated with human performance for the barrier to be effective.	
If the alarm fails to function to the expected standard, this will be clearly brought to the drivers attention.	
The driver will not initiate a lift if the alarm is not functioning to the expected standard.	
The barrier is dependent on; 1) The alarm functioning reliably, 2) The alarm being designed and implemented so it is effective in capturing operator attention in any situation.	

Reliability clearly has to be taken into account when estimating barrier effectiveness. But it is not the main purpose of a Bowtie Analysis, and over-emphasis on it can detract from that value. When there is a need to formally estimate the reliability of barriers, there are many established approaches and techniques that can be applied. In very many situations however such formality will not be necessary and its lack will not detract from the value that can be gained through Bowtie Analysis.

Conclusions

The Chartered Institute of Ergonomics and Human Factors is the largest professional body representing Human Factors professionals outside the USA. Its membership has a long history at the leading edge of research and application of knowledge and thinking as well as the development of tools and techniques to support understanding and optimisation of the role of people in complex socio-technical systems.

The white paper 'Human Factors in Barrier Thinking" is the first time the Institute has published guidance and recommendations seeking to improve good practice in the application of Ergonomics and Human Factors in applied settings. The need for the white paper was driven by awareness of a gap between, on the one hand, a rapid growth in the application of Bowtie Analysis to an increasingly diverse range of industries, and, on the other hand, a lack of standardisation or recognised good practice about how to carry out Bowtie Analysis in general, and how to take account of the role of people in bowtie models in particular. The content of the white paper provides background to the role of people in barrier management systems as well as recommendations covering Human Factors across the lifecycle of barrier models, from selection, verification and implementation to assurance.

Developing the white paper drew on experience from safety-critical industries including oil and gas, mining, nuclear, rail, healthcare and air traffic management. The target audience however is seen as being significantly wider than those industries, and may, among others, include banking, insurance, healthcare, policing and the social services. Bowtie Analysis has as much to contribute to the identification and management of risk in those industries as it has in the traditional high-hazard industries. While recognising the need for care in cross-industry applications, the material contained in the white paper should be of value in many sectors.

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