2014

Human Factors Analysis in Risk Assessment: A survey of methods and tools used in industry

Maria Chiara Leva
Technological University Dublin, maria.leva@tudublin.ie

Nora Balfe
Trinity College Dublin

Recommended Citation

Balfe, N. & M.C. Leva. (2014). Human factors analysis in risk assessment. In S. Sharples (ed.), Contemporary Ergonomics and Human Factors 2014 Proceedings of the international conference on Ergonomics & Human Factors 2014 (pp. 77-84). Contemporary Ergonomics and Human Factors 2014 Proceedings of the international conference on Ergonomics & Human Factors 2014, Southampton, UK, 7-10 April 2014 Edited by Sarah Sharples and Steven T. Shorrock Taylor & Francis 2014 Pages 77–84 Print ISBN: 978-1-138-02635-3 eBook ISBN: 978-1-315-76545-7 https://doi.org/10.1201/b16742-21

HUMAN FACTORS ANALYSIS IN RISK ASSESSMENT: A SURVEY OF METHODS AND TOOLS USED IN INDUSTRY

Nora Balfe & M. Chiara Leva

Centre for Innovative Human Systems, Trinity College Dublin, Ireland

This paper outlines the results of a series of 15 interviews undertaken to establish the methods and tools currently used to support risk assessment in industry. The interviews covered general risk assessment, but also looked specifically at human factors tools and methods in use, both in terms of the representation of the system under analysis and in terms of human reliability analysis or other tools to identify and analyse human error. The results show that, of the companies interviewed, only five use any form of structured technique to analyse human factors, and two of these companies had specific human factors teams to undertake the analysis. This points to a gap in risk assessment, as the lack of inclusion of human factors in risk assessment is in stark contrast to the high attribution of major accidents to human error. Possible reasons for this gap are discussed along with the need to better include guidance on human factors assessment in the applicable standards.

Introduction

The contribution of human performance, which has its roots in human and organisational factors (HOF), to major accidents is often cited as between 70% and 80% (e.g. Shappell & Wiegmann, 1997) and human and organisational factors are understood to have a dominant influence on safety in the offshore oil and gas industry with approximately 80% of accidents attributable to unanticipated actions of people during operations and maintenance activities (Bea, 1998). These statistics make clear the importance of accounting for human and organisational factors in risk assessments in order to manage safety. Major accidents, including Piper Alpha, Chernobyl and Three Mile Island have all had human factors described as a root cause (Gordon, 1998).

Direct human factors contributions to accidents and incidents tend to be described as human errors (Reason, 1990). Various factors including biological factors (e.g. age, gender, size, handicaps), physical condition, mental condition, competence, and personality may all contribute to human performance. All of these can be managed to some degree by the organisation, and the failure to do so can be regarded as an organisational contribution to an accident. Organisational factors may not be as readily identified during an accident investigation, as they tend to require a deeper level of analysis than is always performed following an accident/incident. Leveson (2011) suggests that organisational factors are frequently not identified because traditional accident investigation models stop once an immediate causal event has been identified. Therefore, the factors leading an operator towards an error are not analysed. Organisational factors can include management commitment to safety, training, communications, stability of the workforce, supervison and teamwork, among others (Gordon, 1998).

The primary approach to risk assessment uses established tools and methods developed to identify and quantify technical risks, such as HAZOP, risk matrices, FMEA, etc. These tools were originally developed to account for technical risks, and not for human performance, although some attempts have been made to incorporate human factors (e.g. human HAZOP; Kirwan, 2005). The limitations of traditional quantitative risk assessments methods are illustrated by Einarsson & Brynjarsson (2008) who describe an actual fire at a chemical storage facility; the facility was retrospectively analysed through a quantitative risk assessment (QRA) including a HAZOP for the entire plant. The results of the QRA indicated that the plant was safe by international standards. Einarsson & Brynjarsson suggest that this result could only have occurred if the significant human and organisational factors at work in the accident were not sufficiently captured by the risk assessment.

Human factors approaches to risk assessment tend to start with an analysis of the human activities, typically using a form of task analysis. Without a good representation of the human tasks and activities within the system it is difficult to identify with any confidence where human errors can occur. There are then a number of tools for identification of human errors, including SHERPA (Embrey, 1986), TRACEr (Shorrock & Kirwan, 2002), and human HAZOPs (Kirwan, 2005). Some analyses may base control measures and design changes on the results of the human error identification phase, but human reliability assessments (HRA) go on to quantify the probability of an error. The benefit of HRA is that human error mechanisms can be analysed and prioritised within a systems context, allowing human factors specialists to identify the critical areas for improvement (Kirwan, 2005). Again, there are a number of techniques available to conduct a HRA, including THERP (Swain & Guttman, 1983), HEART (Williams, 1985), CREAM (Hollnagel, 1998), and a wide range of nuclear specific tools (e.g. SPAR-H (Gertman et al, 2004), ATHEANA (USNRC, 2004), HFW (Embrey & Zaed, 2010) and MERMOS (Pesme et al., 2007).

Human factors specialists may also use a wide variety of methods relating to mental workload assessment, equipment and control room design, fatigue management, user interface design, etc. to design systems for optimal human performance, but these are not considered to be part of the risk assessment process here.

The approaches and tools briefly outlined above are known within the human factors domain, and HRA in particular is widely used in the nuclear industry, but the level of adoption of techniques to identify and mitigate human and organisational risks in wider industry (i.e. those who may not have internal human factors teams) is not known. These interviews sought to establish the risk assessment processes of the companies surveyed and the incorporation of human and organisational factors within that.

Study Methodology

The interviews were undertaken as a collaborative effort as part of the Innovation through Human Factors in Risk Analysis and Management (InnHF) project. The 15 semi-structured interviews were conducted across five different European countries using a standard interview template. The majority of the interviewees worked in the processing industry, but interviews were also undertaken in the transport, energy production, and manufacturing domains. Participants were primarily chosen from the partner companies in the project and other contacts. 11 of the interviewees held positions in risk analysis or safety management, two were human factors specialists, and two were production managers.

The interview questions were drafted based on the risk assessment process as described in ISO: 31000 and covered both design and operational/in-service risk assessments. The objectives were:

- To collect information about the risk assessment process used in the companies
- To collect information about the data and tools available to companies to perform the risk assessment
- To identify how human and organisational factors are accounted for in the process and tools

Only the data relevant to the third objective is presented in this paper.

The interview was divided in to three sections:

- The background to the risk assessment
- The risk assessment process
- Management of risk

Companies were approached to determine their willingness to take part, usually either the safety department or, where it existed, the human factors department were contacted. The interviews were undertaken face-to-face if possible, run by the researchers on the InnHF project, all of whom had previously been trained on interview techniques. If face-to-face interviews were not possible, the interviews were conducted over the telephone. All interviews were recorded. The countries in which the interviews were undertaken included Italy (eight interviews), Ireland (three interviews), Serbia (two interviews), UK (one interview) and France (one interview). Following the interviews, the recording was transcribed or detailed notes were drawn up. These documents were used for the analysis, which was a thematic-led qualitative analysis.

Results

The topics of relevance to human factors within the interviews were:

- Standards used to support risk assessment
- Representation of human tasks and activities within the system
- Human factors methods and tools used in risk assessment

The companies used a wide variety of standards to support risk assessment and safety management, including internal standards, industry standards, national standards (or regulations), and international standards. OHSAS 18001, ISO 9001, and ISO 14001 were the most common international standards used by the companies surveyed. However, none of the interviewed companies mentioned any human factors standards as supporting their risk assessment and, despite stating that human factors are important, there is a paucity of guidance in the standards on incorporating human factors within safety assessments. This shows a gap in the standards, which could either be filled by a specific human factors risk assessment standard, or perhaps more beneficially by providing more and better human factors guidance in the existing risk assessment standards which have already been adopted by companies. The key results for task representation and human factors (HF) risk assessment are shown in Figure 1:

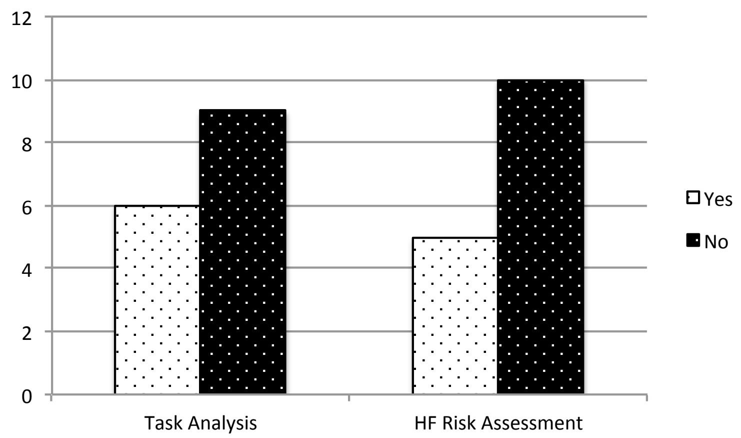

Figure 1: Numbers of companies undertaking HF assessments

Of the 15 companies surveyed, only six had some form of representation of human tasks and activities. All of these were based around Task Analysis. This illustrates that Task Analysis is a broadly accepted approach to representation of human tasks and activities within a system, but that the general idea of using this kind of information in a risk assessment is not as common as might be hoped. Without a formal representation of the human tasks, the risk assessment cannot have a firm structure on which to base its assessment of the risk associated with human factors. Although not using a structured technique, several organisations did include operations and maintenance staff in HAZOP or other risk assessment meetings in order to try to bring their expertise and knowledge to the assessment.

> *"The main tool is attendance of the people to the risk assessment meeting, they way they can provide their experience to the process"*

However, this method of including operational expertise to cover human factors is limited for several reasons, First, as mentioned by one of the interviewees, the input of the operators may be hit and miss:

> *"We encourage the supervisors to visit the site and they do risk assessment and discuss it with the people involved, but in practice we suspect that this is done in an office and is copied from the previous one"*

This may be because, as in the experience of this organisation, the operators are not always consulted as expected, or because the operational experiences of the operators themselves are not sufficient to identify all possible failure modes. The second reason that this approach is limited is the lack of structure involved. It relies entirely on the operators raising issues as they occur to them during the meeting without any attempt to ensure that the full range of potential human activities is accounted for.

All companies interviewed used a risk assessment method of some type, with risk matrices being the most common (used by eight companies). This is likely because risk matrices are relatively simple to understand and apply. More complex methods, such as FMEA and Fault Trees or Event Trees, were used by only four companies. In contrast to the wide (if varied) usage of risk assessment tools, only five companies reported using specific human factors tools for risk assessment. The analysis tools used in this sample included:

- A second generation HRA method
- TRACEr
- HEART
- Method Statements – modified to capture human factors risks
- Incident reporting/recording
- World Class Manufacturing approaches for human factors
- A company specific human performance modelling tool

Only the two companies with human factors specialists used known human factors tools; all the remaining companies used modified or general tools to address human factors risks. One company also stated that they were too focused on occupational health and safety risks related to manual handling:

> *"That's all we seem to do, and that's all every company seems to do, is concentrate on manual handling whereas there's a lot more going on. We miss an awful lot."*

In contrast to the representation methods, there was a wide variety of tools and methods used for human factors risk assessment (seven approaches across five organisations). This could be due to differing requirements of different industries or it could represent a level of dis-satisfaction with current available analysis methods, which means that no single approach has yet emerged as best practice in the area. Another possible reason is that risk assessment companies do not have specific expertise in human factors and therefore are not comfortable with its inclusion:

> *"If you are expert in natural or technological risks you often need the expertise from someone else to deal with human factors"*

This again points to a need for more guidance for risk professionals in how to incorporate human factors in their assessments. It is not realistic that all companies will have access to human factors expertise to conduct their risk assessment, although companies with a particularly high level of risk linked to human error should continue to use specialists. The high use of risk matrices as a risk assessment tool suggests that many companies are most comfortable with a simplistic approach to risk assessment. There is therefore a need for simple methods or approaches that can be easily described and applied as part of the risk assessment process.

Conclusions

In terms of human and organisational factors, there was very low usage of human factors tools and methodologies among the interviewed companies. Only five companies specifically included HOF in their risk assessment process, and since two of the interviewees were specialists in this area, only three companies without a specialist team included HOF in their analysis. Despite the small sample size, this points to a clear gap in risk assessment across all industry domains, particularly given the high prevalence of human and organisational factors in major accidents. This result reinforces the view that human factors are still not adequately addressed in risk assessment and safety management (e.g. Taylor, 2012). The recommendation on the basis of this research is to support better analysis of human and organisational factors risks by providing more, better, and simple guidance on the identification and analysis of human error in the most relevant standards, building on the existing guidance available (e.g.

Henderson & Embrey, 2012; Widdowson & Carr, 2002). The IEHF can assist in this by collecting together the current best practices, developing or identifying appropriate training, and promoting these in collaboration with other professional institutions.

Acknowledgements

This research was funded by Marie Curie Initial Training Networks under the FP7 Agreement, project ID 289837. The data was collected by a number of researchers on this project based in Ireland, Italy and Serbia as part of the Innovation through Human Factors in Risk Analysis and Management, Work Package 4 (InnHF, 2013). The data presented in this paper was partially analysed by Geng Jie and Evanthia Giagouglou.

References

Bea, R. 1998. Human and organisational factors: engineering operating safety into offshore structures. *Reliability Engineering & System Safety* 61(1): 109-126.

Einarsson, S. & Brynjarsson, B. 2008. Improving human factors, incident and accident reporting and safety management systems in the Seveso industry. *Journal of Loss Prevention in the Process Industries*, 21(5): 550-554.

Embrey, D. E. 1986. *SHERPA: A systematic human error reduction and prediction approach.* International Meeting on Advances in Nuclear Power Systems: Knoxville, Tennessee.

Embrey, D. E. and Zaed, S. 2010. *A set of computer-based tools for identifying and preventing human error in plant operations.* Proceedings of the 6th Global Conference on Process Safety: American Institute of Chemical Engineers, San Antonio USA.

Gertman, D., Blackman, H., Marble, J., Byers, and Smith, C. 2004. *The SPAR-H human reliability analysis method.* NUREG/CR-6883. Idaho National Laboratory, prepared for U. S. Nuclear Regulatory Commission Office of Nuclear Regulatory Research Washington, DC 205555-0001.

Gordon, R. P. E. 1998. The contribution of human factors to accidents in the offshore oil industry. *Reliability Engineering and System Safety*, 61(1): 95-108.

Henderson, J. & Embrey, D. 2012. Guidance on quantified human reliability analysis. (Energy Institute, London).

Hollnagel, E. 1998. Cognitive Reliability and Error Analysis Method. (Elsevier, Oxford).

InnHF. 2013. Categorisation of current issues – Human and organizational factors. Internal project report. www.innhf.eu.

Kirwan, B. 2005. Human reliability assessment. In J.R. Wilson & N. Corlett (Eds.) *Evaluation of Human Work*, 3rd edition, (CRC Press, Boca Raton): 833-876.

Leveson, N. 2011. Engineering a safer world: Systems thinking applied to safety. (MIT Press, Cambridge MA).

Pesme, H., Le Bot, P., & Meyer, P. 2007. *Little stories to explain Human Reliability Assessment: A practical approach of the MERMOS method.* In Proceeding of the Human Factors and Power Plants and HPRCT 13th Annual Meeting, Monterey, CA, USA.

Reason, J. 1990. Human Error. (Cambridge University Press, New York).

Shappell, S. A., & Wiegmann, D. A. 1997. A human error approach to accident investigation: The taxonomy of unsafe operations. *The International Journal of Aviation Psychology*, 7(4): 269-291.

Shorrock, S. T., & Kirwan, B. 2002. Development and application of a human error identification tool for air traffic control. *Applied Ergonomics* 33(4): 319-336.

Swain A. D. and Guttmann H. E. 1983. *Handbook of human reliability analysis with emphasis on nuclear power plant applications*. US Nuclear Regulatory Commission), Washington, DC. NUREG/CR-1278.

Taylor, J. R. 2012. Lessons learned from forty years of HAZOP. *Loss Prevention Bulletin,* 227: 20-27.

US Nuclear Regulatory Commission (USNRC). 2000. *Technical Basis and Implementation Guidelines for A Technique for Human Event Analysis (ATHEANA).* NUREG- 1624. Division of Risk Analysis and Applications. Office of Nuclear Regulatory Research, Washington DC.

Widdowson, A. & Carr, D. 2002. Human factors integration: Implementation in the onshore and offshore industries. (HSE, Norwich, UK).

Williams, J.C. 1985. *HEART – A Proposed Method for Achieving High Reliability in Process Operation by means of Human Factors Engineering Technology*. In Proceedings of a Symposium on the Achievement of Reliability in Operating Plant, Safety and Reliability Society, Southport, UK.