Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio
 Published by Research Publishing, Singapore.
doi: 10.3850/978-981-18-8071-1_P354-cd

Which human reliability analysis methods are most used in industrial practice? – A preliminary systematic review

Caroline Pinheiro Maurieli de Morais

Operational Safety and Environment Division, Agency for Petroleum, Natural Gas and Biofuels (ANP), Brazil. E-mail: cmorais@anp.gov.br

Raphael Neves Moura

Research and Development, Agency for Petroleum, Natural Gas and Biofuels (ANP), Brazil. E-mail: rmoura@anp.gov.br

Marília Ramos

B. John Garrick Institute for the Risk Sciences, University of California Los Angeles (UCLA), USA. E-mail: marilia.ramos@ucla.edu

Human reliability analysis (HRA) is the most acknowledged methodology to assess the probability of human errors depending on the tasks and its contextual factors. There are many methods available, but some exploratory research show that only a few of them are frequently cited in research papers, or even accepted by safety regulators.
This paper describes the methodology used to do the systematic review approach to understand which HRA techniques are the most cited by country and by industry sector along the years. The research methodology has considered only research papers. The results per country focus only on the oil & gas industry sector, more specifically on the countries with safety regulators which are part of the International Offshore Forum (IRF): Australia, Brazil, Canada, Denmark, Ireland, Mexico, The Netherlands, New Zealand, Norway, United Kingdom, and United States of America.
Future development of this review is to also review regulations and consultancy companies' portfolios. The aim is to understand in which level the industrial practice follows the pattern observed in academia and if they are influenced by regulations.

Keywords: human reliability analysis, safety regulations, industrial practice, systematic literature review.

1. Introduction

Good industry practice in risk management, such as ISO IEC 31010, recommend the human reliability analysis (HRA) as the risk assessment technique to evaluate the human contribution to system reliability and safety by analysing their potential for an incorrect action (International Organization for Standardization, 2019). While other proposed techniques assess human error alone, the scope of HRA is more complete as it has the purpose of analysing each potential human error after the influence of some contextual factors (the so-called *performance shaping factors*, such as human-machine interfaces, time to perform a task, task complexity, training, existence/quality of procedure, etc). By using this HRA feature, risk assessors have a reproducible tool to analyse systems and recommend improvements that reinforce Reason's idea that "we cannot change the human condition, but we can change the conditions under which people work" (Reason, 2000).

However, the task to choose the best HRA technique for a system can be hard for beginners, as there are more than 70 techniques available (Bell and Holroyd, 2009). One can filter out some techniques by considering the type of industry sector. For example, some techniques are allegedly fit for nuclear industry only. However, there are evidence in other fields that

market perceives regulator's preferences and tend to follow them to decrease regulatory risk (OECD, 2000). The aim of this paper is to conduct a preliminary analysis review (Wohlin, 2012) to understand if this is also the case of HRA, or if the most used techniques are governed by other features.

2. Methodology

The systematic literature review has focused primarily on methods considered valid in the Research Report RR679 – Review of human reliability assessment methods prepared by the Health and Safety Laboratory which was part of the safety regulator of United Kingdom, known as HSE-UK (Bell and Holroyd, 2009). However, as the guide has been published in 2009, three newer techniques were included which that have been extensively cited: Petro-HRA, FRAM and Phoenix. This report has filtered out 17 methods from nearly 70. Then, have classified these 17 techniques into three domains: 'nuclear', 'nuclear with wider application', and 'generic'. Following this criterion, from the 17 related techniques in HSE's report, only eight were considered for this search: the ones classified as 'nuclear with wider application' and 'generic'. This choice was made to better compare the use of each technique within different industry sectors.

Table 1. Techniques chosen for this systematic review.

Techniques classified as *nuclear with wider application domain (from HSE report)*	Techniques classified as generic domain (from HSE report)	Not considered in HSE report, but considered in this study (after 2009)
THERP	HEART	FRAM
SPAR-H	APJ	Petro-HRA
ATHEANA	PC (Paired Comparisons)	Phoenix and Phoenix-PRO
CREAM	CAHR	
SLIM-MAUD		

To enable other researchers to check and reproduce results, the search criteria used for this systematic review is here described.

The review was split on three separate phases: phase 1 conducted a review on research and review articles on reliable academic journals; phase 2 is being conducted in consultancy portfolios websites (i.e. companies and individuals who provide assistance in risk assessments); phase 3 is being conducted within safety regulations of different industry sectors, starting by the oil & gas sector.

2.1. *Phase 1 - Academic review*

The journals were reviewed within three databases: Science Direct, Springer list and ASME (American Society of Mechanical Engineers). At this point the only search was on 'human reliability analysis'. Results are shown in Table 2. As the Reliability Engineering and System Safety Journal has far more papers published regarding HRA than other journals, the next filters have been applied for its articles only. Next phases of research will extend this review to all the journals.

The next filter applied, only to Reliability Eng and System Safety Journal, was 'human reliability analysis" AND 'THERP'. Then this process was repeated to every HRA technique of Table 1. The number of papers published were registered also per year, for every year except 2023. Results are shown in Figure 1.

The next filters included in the search were the following industry sectors: nuclear, chemical, oil, aviation, railway, maritime, healthcare, mining. Results are shown in Figure 2.

Finally, the next filter was applied in order to understand if there are trends by country, as some publications have shown a possible trend of higher use of SPAR-H in USA (Growth and Swiler, 2013) and HEART in the United Kingdom (Kirwan et al. 2004). To speed up the process it has been used the advanced search engine option of "Author affiliation" – however it must be stated that the engine searches all the authors' affiliations, so further filtering must be done if the intention is to better segregate countries' tendencies, by filtering only the first author for example. The review presented in this paper is only for oil sector, and only for the Countries of the IRF - International regulator forum, which include: Australia, Brazil, Canada, Denmark, Ireland, Mexico, The Netherlands, New Zealand, Norway, United Kingdom, United States of America. Results are presented in Figure 3 (IRF, 2023). This

is a group that share good safety practices to regulate offshore exploration and production of oil & gas since 1993.

In this phase of research only the title, keywords and abstract were checked. The results presented in the next section are based solely in search engine numbers, without deeper interpretation of content. A second phase of this review will comprise understanding the text. That will correct the data in the case that HRA techniques cited just for reference are included, or words such 'aviation' or 'oil' are cited due to other context rather than describing the industry sectors.

4. Results and discussion

The journals which present research and review articles about HRA are presented in Table 2, which depicts the quantity of articles per journal results for the search on 'human reliability analysis' only.

Table 2. Techniques chosen for this systematic review.

Journals in Science Direct database:	Search: "human reliability analysis"
Reliability Engineering and System Safety	228
Safety Science	123
Journal of Loss Prevention in the Process Industries	49
International Journal of Industrial Ergonomics	22
Ocean Engineering	19
Applied Ergonomics	18
Expert Systems with Application	7
Petroleum	0
Journals in Springer list database:	
Cognition, Technology and Work	27
Journals in ASME database:	
ASCE-ASME J Risk and Uncert in Engrg Sys Part B Mech Engrg	16
Journal of Offshore Mechanics and Arctic Engineering	5
Journal of Manufacturing Science and Engineering	2

The numbers in Table 2 shows that the Reliability Engineering and System Safety Journal is up to date the journal with the higher quantity of HRA research.
Figure 1 shows that the articles relating to HRA have increased more than 4 times from 2019 to 2020, while the trend has been keeping steady for almost ten years.

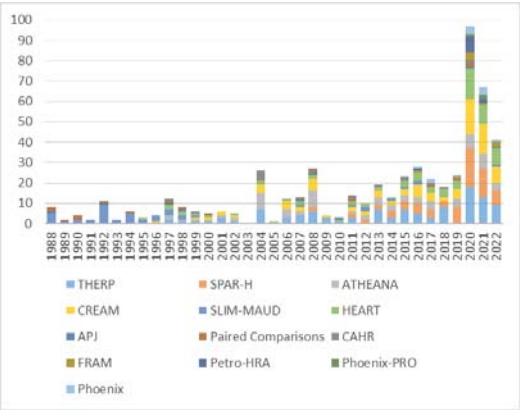

Fig. 1. HRA techniques x year in Reliability Engineering and System Safety Journal

Figure 2 shows that nuclear maintains the ranking as the industrial sector leading the HRA studies, however chemical and oil & gas are following closely and more than aviation, possibly because the process industry has more diversity of operations to be analysed than aviation.

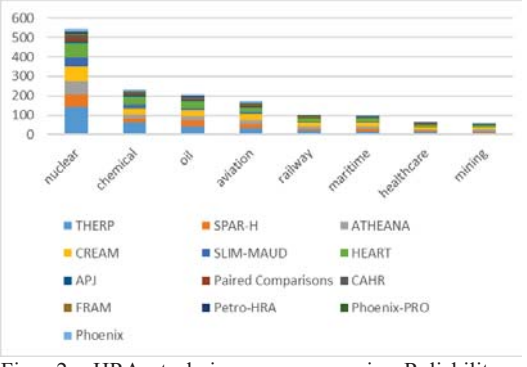

Fig. 2. HRA techniques x year in Reliability Engineering and System Safety Journal x industry sector

Figure 3 shows that the reported trend in use of SPAR-H in United States of America and HEART in United Kingdom is somehow reflected in the results. However, both countries also had THERP at the top citation. In the United Kingdom the number of papers citing HEART was the same as the number of papers citing THERP, and in the US SPAR-H was only one paper behind THERP. Norway also has shown a high number of citations

to SPAR-H, but it is fair to state that at least three of those citations are due to an adaptation of this technique to Petro-HRA, which was primarily conducted at this the country.

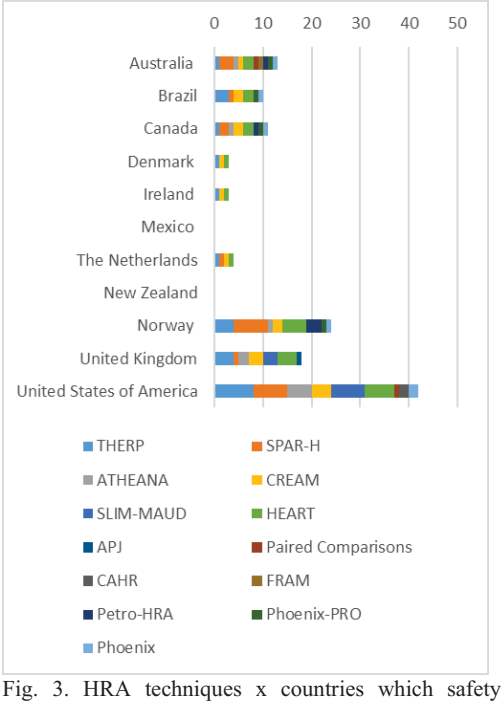

Fig. 3. HRA techniques x countries which safety regulators are part of the international regulators forum x in papers that cite the oil industry in the Reliability Engineering and System Safety Journal

5. Conclusion

While the aim of this research project is to understand what are the most used HRA techniques in industry practice and what leads than to this position – ease-of-use, precise results, or regulatory compliance – this preliminary systematic review shows that a systematic search within academic engines might not reflect the industry practice.

Thus, future research might compare these numbers in this review to risk consultancy portfolios and country's safety regulations. Besides this second phase, further studies might consider reading the full research papers to check, for example, if the HRA techniques are used only as a reference or really aggregating new information and being used in case studies.

A second and third phase of studies might also: (i) investigate if the authors used HRA within a PRA (probabilistic risk analysis) or stand-alone HRA, as suggested by Boring et al that this might differ from different industry sector (Boring et al., 2018); (ii) include conference proceedings, as industry practitioners tend to publish more on conferences than journal papers; (iii) Investigate if the amount of research follows any trend on regulators enforcement or preference of technique in licensing processes.

References

Bell, J. & Holroyd, J. (2009). Review of human reliability assessment methods RR679. Health & Safety Laboratory, 78. Available at: https://www.hse.gov.uk/research/rrhtm/rr679.htm

Boring, Ronald L., Martin Rasmussen, Thomas A. Ulrich, and Nancy J. Lybeck. "Aggregation of Autocalculated Human Error Probabilities from Tasks to Human Failure Events in a Dynamic Human Reliability Analysis Implementation." In Proceedings of Probabilistic Safety Assessment and Management. 2018.

International Organization for Standardization (ISO), IEC 31010:2019, Risk management – Risk assessment techniques.

Katrina M. Groth, Laura P. Swiler, (2013) Bridging the gap between HRA research and HRA practice: A Bayesian network version of SPAR-H, Reliability Engineering & System Safety, Volume 115, Pages 33-42, ISSN 0951-8320, https://doi.org/10.1016/j.ress.2013.02.015.

Kirwan, B., Gibson, H., Kennedy, R., Edmunds, J., Cooksley, G., Umbers, I. (2004). Nuclear Action Reliability Assessment (NARA): A Data-Based HRA Tool. In: Spitzer, C., Schmocker, U., Dang, V.N. (eds) Probabilistic Safety Assessment and Management. Springer, London. https://doi.org/10.1007/978-0-85729-410-4_195

International Regulators Forum (2023), About IRF, Accessed on 2023 and available at: https://irfoffshoresafety.com/about-irf/

Organisation for Economic Co-operation and Development (OECD), (2000) Reducing the risk of policy failure: challenges for regulatory compliance. Available at: https://www.oecd.org/gov/regulatory-policy/46466287.pdf

Reason, J. (2000), Human error: models and management, doi: 10.1136/bmj.320.7237.768

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C. , Regnell, B. and Wesslén, A. (2012) Experimentation in Software Engineering, Springer, ISBN 978-3-642-29043-5.