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Technical Paper

Safety-II Approach in the O&G Industry: Human Factors and Non-Technical Skills Building Safety

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Abstract

The Evolution of Technology in the workplace in the O&G industry carry this segment to a present dilemma, where in given situations, there is so much complexity that the system operability became quite complex too. In this context, the traditional ways to promote safety – regulations and procedures – can't deal with the demands from these complex system – like an offshore oil rig. Understand the evolution of these activities, and the increase of its complexity, can develop an adequate manner of perceive the interaction between the equipment, environment, organization and workers, especially with regard risks and safety issues to prevent losses. Thus, the natural step to keep up with this is to understand the Human Factors and related Non-Technical Skills that are integrated with these systems, forming the modern sociotechnical complex system. In this evolved Safety-II approach, the FRAM (Functional Resonance Analysis Method) appears as an adequate methodology to recognize and analyse, seeking to promote safety and productivity.

Keywords: Human Factors. Non-Technical Skills. Safety-II. FRAM. Drilling

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1. Introdução

Since the beginning of the O&G industry, its activities involve high risks and heavy investments. In this sense, it is necessary to take efforts to understand how those risks are presented and how can be assessed and managed. For instance, the construction of an oil and gas well, from the geological studies till the production of hydrocarbons, includes different phases, starting with drilling, then completion, operation and intervention, and finally WCT (Wet Christmas Tree) installation for production. All the well life phases are subject to high well leakage risk, and a main rule to ensure well safety is necessary to understanding the risks involved and have adequate well barriers towards a reservoir. Thus, understand the evolution of this activity, and the increase of its complexity, can develop an adequate manner of perceive the interaction between the equipment, environment, organization and workers, especially with regard risks and safety issues to prevent losses. The O&G industry plays an essential role for Society, bringing not only gasoline and diesel, but also polymers, special fabrics, medicines and food for countries. To promote safety in their activities is not only good for business or workers, but also a way to keep the World running.

2. Safety-I and Safety-II concepts – Human Factors Evolution

The concepts of human reliability and the definition and early measurements of human error had started with the empirical theories of Heinrich, being more scientifically developed by other authors, and marked the risk assessment theories and industrial accidents in much of the 20th century, especially the accidents of Three Mile Island – TMI (1979), Bhopal (1984) and Piper Alpha (1988) (Turner and Pidgeon, 1997). This human error perspective is a classic feature of Safety-I approach. This concept placed a understanding of human error is considered a part of everyday functioning and it is expected that people will make errors (Noroozi et al., 2013). Also, this concept became part of safety lore when Heinrich noted that as improved equipment and methods were introduced, accidents from purely mechanical or physical causes decreased and (hu)man failure became the predominant cause of injury (Hollnagel, 2014).

The traditional human reliability analysis covers few stages in the so-called human error identification, such as identifying human act, modelling of significant human action and evaluating human action probabilities. However, these methods have fundamental limitations to introduce all the significant aspects of human performance due to insufficient data, subjectivity of analysis and uncertainty, which shows a need of a clear understanding of how human performance happens, in a daily basis routine (Akyuz and Celik, 2015). In this sense, few studies postulate that human errors are practically always involved in accidents and continuous efforts to reduce human errors have placed increased emphasis on training, motivation, hardware design, and management systems, in a pursuit for eliminate, or at least reduce, the so-called human error (Skalle, Aamodt and Laumann, 2014). From the core of these studies, a new perspective regarding human error and accident analyses revealed factors that were related to the human performing the task, but was not directly related to individual issues, so the focus shifted to organizational factors, such as management and safety culture, which form many of the conditions in how the work is done in the sharp end, like training, staffing and high work pressure. This new perspective understand that Human Factors are directly linked to human performance, with positive or negative outcomes, depending on how the variability, and results, of the human outputs are interpreted.

Human performance is part of the human reliability studies, although from a different perspective from the current human performance studies, where the concepts of Human Factors are sedimented. Aiming for a balance perspective, Bellamy, Geyer and Wilkinson (2008) postulates that Human Factors is about the understanding of the relationships between demands and capacities in

considering human and system performance (i.e., understanding human capabilities and fallibilities). The term is used much more in the safety context than ergonomics even though they mean the same thing very much. Like Human Factors, ergonomics deals with the interaction of technological and work situations with the human being. Anatomical, physiological and psychological knowledge/data are applied to achieve the most productive use of human capabilities and the maintenance of human health and well-being. The job must ‘fit the person’ in all respects and the work demands should not exceed human capabilities and limitations. Its meaning is hard to distinguish from Human Factors, however, is often associated more with the physical design issues as opposed to cognitive or social issues, and with health, wellbeing and occupational safety, rather than with the design of major hazard systems.

Seeking to integrate and comprehend technology and behavior, Human Factors engineering (HFE) came as a discipline that work in the interaction between humans and technology, as well as system and process, especially for the Nuclear Industry. The aim of that was to seek, discover and apply knowledge about human capabilities and limitations to system and equipment design, ensuring that the system design, human tasks and work environment are compatible with the sensory, perceptual, cognitive and physical attributes of the personnel who operates systems and equipment (Hollnagel, 2014). After the accident at TMI, a critical review of plant design in several countries, with respect to the control room, was conducted by the International Atomic Energy Agency (IAEA). Human Factors was considered in a much broader sense and a chapter 18 was included in the Final Safety Analysis Report (FSAR) of the nuclear power plants, addressing Human Factors engineering (HFE) issues (Luquetti dos Santos et al., 2009). However, the Human Factors by this time of TMI accident was mistaken understood just as the individual factors, it means, the individual issues of the workers. Few years later, in the 1986, the Chernobyl accident, Human Factors issues was complemented by the concepts of the organizational factors, especially connected to the safety – and operational – culture of the Soviet Union industries (Labib, 2015). After this disaster, a solid path for the understanding started to be built, fetching the systemic understanding that the individual, organizational, environmental and technological factors, as well as their interactions, form an inseparable set that forms the so-called Human Factors.

Bringing a balance and more consolidated perspective, Luquetti dos Santos et al. (2013) presents that Human Factors deal with issues related to humans, their behavior and the physical aspect of the environment in which they work. And in this context, ergonomics is an inter-disciplinary research field that focuses on improving the functioning of the human-technology interaction about safety, specially showing the difference between WAI (Work-As-Imagined) and WAD (Work-As-Done). This is accomplished by considering the strengths and weaknesses of human performance, which in the FRAM methodology can be properly addressed in the resonance of the function’s couplings. The goal of the ergonomics is to achieve the best possible match between products and users, in the context of the task to be performed. The ergonomics incorporation in the system design, interfaces and equipment offers a lot of opportunities for improvements regarding system effectiveness, efficiency, reliability and safety (NUREG, 2002). And, in fact, analyzing all the discussed concepts of Human Factors, ergonomics and human performance, under a more comprehensive systemic view of the modern complex socio-technical systems, such as a drilling unit of an offshore oil rig, Human Factors emerges as the main issue of scientific factors about human characteristics, covering biomedical, psychological and psychosocial considerations, including principles and applications in the personnel selection areas, training, aid tools for job performance and human performance evaluation.

Based in all of that evolution and principles, the current understanding of Human Factors is a comprehensive and widely understanding of all the factors that can have influence in the human performance during their work, and can be originated from inside, outside or even is part of the

individual characteristic of a person. This comprehensive and widely understanding is one of the main characteristic of Safety-II approach. For IOGP (2018), Human Factors are simply those things that can influence what people do. They may include factors relating to the job people do (e.g., time available or control panel design) personnel factors (e.g., fatigue, capability) and organizational factors (roles, manning levels). The idea that during the events leading up to accidents, people are acting in a way that makes sense to them at the time. All their knowledge, training, experience, organizational culture, and input from the environment combine to influence the decisions made and the actions taken. In this way, Human Factors is not simply "what the human being does", or "the mistakes made by the worker"; it is much more than that and requires a much greater understanding than simply blaming the human being for doing something wrong. Human Factors, in fact, is a philosophy of comprehension, from human perspective, where it is necessary to understand the interactions that happen in a sociotechnical system, involving all the technological, environmental, organizational and individual elements of these. Thus, in a labor context, Human Factors are the set of all factors that can influence human performance in their work activities, being technological, environmental, organizational and individual, as well as the interaction between these and other factors that may arise. In the Figure 1 is presented a representation of this set, representing the current understanding of Human Factors.

Figure 1: Human Factors scheme.

Source: Authors, 2020.

As presented by this set, Human Factors are not a singular issue; it is a set of other factors that are present in the real work scenarios and have influence over the performance of the workers. The light grey doubled arrows show that all factors interact which each other, continuously. In this principle, Human Factors cannot be addressed or interpreted as only the individual factors, which is a quite common – and mistaken – understanding. Human Factors is far beyond that and is in fact all things that, one way or another, alter the workers performance in a labor context. And in most cases, the alteration in the performance, the variability of workers' performance, is something positive, which actually gets the job done. Thus, comprehend Human Factors is not a way (or "the way") to avoid accidents, but a way to improve performance, which consequently reduces accidents and

enhance production. And together and integrated with the evolution of Human Factors approach, there was also an integrated and inseparable evolution of workplaces, especially due to the technological evolution of machines, devices and systems. As a result, and also part of this evolution, the modern complex sociotechnical systems emerge, where through technology, workplaces are locals where there is intense interaction between workers, machines, environments, systems and processes. In the Safety-II perspective, the systemic understand of Human Factors is the main line for develop safety operations.

The sociotechnical systems behaving (interaction between social and technical elements with organizational and environmental issues) is heavily dependent on interactions within and between system components (Wooldridge et al., 2019), independently of the occupation area, being able to characterize operating room (OR), pediatric intensive-care unit (PICU), as well as refineries or offshore oil platforms . There are different elements, different characteristics between them, but they certainly characterize complex sociotechnical systems with his own particularities. In this context, De Vries (2017) postulates that safety may be seen as an emerging property of sociotechnical work, based on the natural interaction between Human Factors and the complex sociotechnical systems, and it is necessary an appropriate methodology to evidence these specific characteristics of this interaction. Seeking for un adequate answer for this, the FRAM (Functional Resonance Analysis Method) was found to be a valuable methodology for describing sociotechnical system and Human Factors interactions, based on a strong grounding in empirical studies and themes of “making work visible,” symmetry between human and nonhuman, and work as activity. Indeed, FRAM supports describing the dynamic interactions in sociotechnical systems from the perspective of normal performance variability that is necessary to understand how the real work is performed (Zheng, Tian and Zhao, 2016).

Also, emerging and making part from this Human Factors concepts, there is some individual skills and organizational characteristics that enhance the safety in the complex sociotechnical systems, and these are known as Non-Technical Skills, being the most relevant Situation Awareness, Decision-Making, Communication, Team Working and Leadership (Flin, O’ Connor and Crichton, 2016). According to ARPANSA (2017), the Non-Technical Skills do not include the technical skills required to get the job done e.g. the technical skill or know-how to operate a machine or conduct a certain operation, which is provided by proper training and work profile, however non-technical skills complement these technical skill & know-how making them more efficient and effective. In this context, and seeking to understand complex sociotechnical systems, FRAM arises as a suitable methodology that can, at the same time, recognize and analyze Human Factors and their related Non-Technical Skills. And specifically in the O&G industry, where high complexity, high risks and high skills are present in refineries, terminal and platforms systems (França and Hollnagel, 2019), FRAM methodology seems reasonable and adequate for comprehend operations and promote safety.

3. The FRAM Methodology

The Functional Resonance Analysis Method (FRAM) is a methodology to analyze and describe the nature of workaday activities. Because of this methodological structure, it can analyze past events of complex system, such as an accident investigation, as well as possible future events, as the Human Factors recognition and analysis in a drilling unit of an offshore drilling rig. For a professional who has never seen the graphical representation of a FRAM model, this methodology may seem relatively complex, which it is not. In fact, the analysis promoted by this methodology is not an algorithmic process, but rather the gradual development of a mutual understanding among a team of professionals working as a team. It's a kind of complex discussion about the complex relationships of complex socio-technical systems but done in a simple way. This methodology is based on four principles (Hollnagel, 2012):

- Equivalence of failures and successes. Failures and successes come from the same origin, i.e. everyday work variability. This latter allows both things go right, working as they should, and things go wrong.
- Principle of approximate adjustments. People as individuals or as a group and organizations adjust their everyday performance to match the partly intractable and underspecified working conditions of the large-scale socio-technical systems.
- Principle of emergence. It is not possible to identify the causes of every specific safety event. Many events appear to be emergent rather than resultant from a specific combination of fixed conditions. Some events emerge due to combination of time and space conditions, which could be transient, not leaving any traces.
- Functional resonance. The function resonance represents the detectable signal emerging from the unintended interaction of the everyday variability of multiple signals. This resonance is not completely stochastic, because the signals variability is not completely random, but it is subject to certain regularities, i.e. recognizable short-cuts or heuristic, that characterizes different types of functions.

To build a FRAM model, it is necessary to follow four steps, which is the structure of the FRAM and begin with the identification of the functions. It means, the first step is the identification and the description of the functions, which can be human, technological or organizational, depends on its natures in the system, seeking to describe in detail how a task is done as a real everyday activity, rather than to describe it as an overall task or procedure. Analyzing this functions and its coupling with other functions, it is possible to see that is a valid representation of the real scenario where the work happens, which is an adequate way of Human Factors recognition, once those functions match with the n factors of the Human Factors characterization: organizational, individual, technological and environmental. The similarities are clear, although the words may appear different, which is the case of the individual factors, which corresponds to the human functions on the FRAM, and the technological and environmental factors, which merge into technological functions of the FRAM.

The graphic representation of a function is a hexagon, where there is, basically, one output and five inputs for each potential function. Each vertex of this hexagon is, in fact, the determination of one of the six aspects of the FRAM methodology function: Time, Control, Output, Resource,

Precondition and Input. It is important to notice that the capital letters, begging each aspect observed, marks its difference from an ordinary input or output of a simple flow chart; they are the aspects that form the FRAM model and determined by its methodology as the connections between functions. In the Figure 2 is presented a representation of one organizational function, which also represents the organizational factors of the activities being analyzed, once the Output and inputs of this functions are, in fact, the Human Factors that can be recognized.

Figure 2: FRAM representation of an organizational function.

Source: Authors, 2020.

Once the functions description is done, a second step for modelling is the recognition of the Output variability of each function of the model, characterizing each function with its potential and actual performance variability. For time, the possible Output variability are too early, on time, too late or not at all. For precision, the possible Output variability are precise, acceptable or imprecise, for each of the three FRAM functions types: Technological, Human and Organizational (Hollnagel, 2012). It is important to notice that the variability is something live, dynamic, and in certain cases, can be seen and a concatenation of the internal variability of the function, the external variability of the function coming from its aspects and/or the upstream-downstream coupling variabilities that resonates in the entire model. In this research, the focusing will be in the first two variabilities - internal variability and external variability, in terms of time and precision of these Output. This is the way that FMV® software (FRAM Model Visualizer) set its Output functions options and it is a solution for characterizing performance variability.

Since the recognition of the Output variability is completed, a third step is needed, which is the examination of the instantiations of the model to understand how the potential variability of each function can become resonant, leading to unexpected results, as stated by the premises of the method. The variability of a function is the result of a combination of the function variability itself (internal

variability) and the variability deriving from the outputs of the upstream functions, depending on the type of the function (human, technological or organizational) and their own aspects (Time, Control, Resource, Precondition and Input). Analyzing these instantiations, it is possible to identify critical scenarios, Human Factors, risks and variabilities that have which have a direct and intrinsic relationship with safety.

And talking about safety, the fourth and last step is the monitoring and managing of the performance variability of each proposed instantiations, identified by the functional resonance that characterizes the performance variability of the method and can result in positive and negative outcomes. In this sense, Hollnagel (2012) proposes that the most fruitful strategy consists of amplifying the positive effects, i.e. facilitating their happening without losing control of the activities, and damping the negative effects, eliminating and preventing their happening. The dampening process may require substantial changes, even in a permanent way, involving people, organization or equipment preventing things from going wrong as well as contributing to things going right. In a more traditional way, it helps creating barriers and defenses to prevent from harmful situations. In this case, the recognition and analysis of the relevant Human Factors.

4. Analysing the Drilling Unit (Doghouse) operations using FRAM – a Safety-II approach

The drilling unit, also called doghouse, is the workstation where the driller performs a series of activities to effectively drill the well hole, which is divided in four phases: 1st phase (conductor), 2nd phase (surface), intermediate phases (as many as needed) and production phase, which ends the construction phases of the well. Inside of the doghouse, the driller is responsible for monitor, control, drill, exchange, replace, observe, communicate and stop safely the operations during emergency situations. This series of activities are crucial for the construction of the offshore oil well and fall under one person inside of the doghouse, who performs this whole framework of activities by dividing his attention and managing the necessary priorities, developing skills that are not exactly measurable, and are often called Non-Technical Skills (Sneddon, Mearns and Flin, 2006). An example of doghouse is presented in Figure 3, from an oil rig operating in the offshore oil production area of Brazil known as Pre-Salt. From inside, only one worker (a driller) operates the entire drilling, sharing his attention and interacting with systems, controls, other workers and responding for non-planned situations and occurrences.

Figure 3: Doghouse & drill floor of an oil rig, Brazil offshore area.

Source: Authors, 2020.

Based on a series of interviews, on-board observations and expert's support, a FRAM model of the doghouse operations, from the driller perspective, was developed to understand how the real work is done, analysing the Human Factors and Non-Technical Skills in this work. It's important to note that by adopting a Safety-II perspective, is not as a full replacement of Safety-I initiatives, but a complement of it, developing and resulting in a systemic understand of the driller's work. A Safety-II approach assumes that everyday performance variability provides the adaptations that are needed to respond to varying conditions, and hence is the reason why things go right. Workers are seen as a resource necessary for system flexibility and resilience, developing dynamic and productive ways to have the work done. Immersed in this perspective, the development of a comprehensive analysis of Human Factors requires a methodology capable of modeling the complex socio-technical system under study. Thus, in the activity of the driller, the most suitable was the FRAM, where it is possible to verify not only the Human Factors involved, but also the Non-technical skills that promote the performance of productive work and adequate to the specific conditions of offshore drilling in deep waters. In the Figure 4 is the FRAM modeling of the driller's work inside of a doghouse.

Figure 4: FRAM modeling of the driller's work inside of a doghouse.

Source: Authors, 2020.

This FRAM model has 26 functions in total, being of these 7 background functions and 19 foreground functions, as the functions are defined by the methodology. While many of the existing methods and techniques can't delineate how a complex socio-technical system works, FRAM properly deals with that in a Safety-II perspective. This also shows what goes right, to focus on frequent events, to maintain a sensitivity to the possibility of failure, to wisely balance thoroughness and efficiency, and to view an investment in safety as an investment in productivity (Hollnagel, Wears & Braithwaite, 2015). In this sense, the Functions "Cognize and manage relevant external noises", "Cognize and manage relevant equipment vibration" and "Cognize and manage relevant smell of hydrocarbons" shows that the individual perception and awareness of the work environment are part of how the job is done. These skills are not addressed in the formal training that drillers participate in. Thus, situation awareness, communication, among others, are considered non-technical skills and are living, complex and inseparable elements of the work of the driller. Non-technical skills, according to ARPANSA (2017), are interpersonal skills which refers to communication skills, leadership skills, team-work skills, decision-making skills and situation-awareness skills. They do

not include the technical skills required to get the job done e.g. the technical skill or know-how to operate a machine or conduct a certain operation, which is provided by proper training and work profile, however non-technical skills complement these technical skill & know-how making them more efficient and effective.

Analysing this FRAM model, it's possible to notice an integrality between Human Factors and non-technical skills, once the individual variability, senses and skills of the driller produces an integrated and safety understand of the work, having intense verbal and non-verbal communication among workers and supervision. In this context, another important function from FRAM model shows the importance of leadership: "Have pressure from supervision", which reflects the importance of the non-technical skills, such as communication, leadership and teamwork to deal with situations where there is hierarchical pressure to get the job done on time. In fact, for Shroder & Konrad (2011), the pressure from BP's supervisors on Deepwater Horizon drilling crew was one of the determinative factors that contributed to this tragic accident. Analyzing these ponderations, it's possible to noticed that the non-technical skills, associated with the individual experience and perception, are the way the work takes place in a real, productive and safe way. And in fact, for offshore workers, according to O' Connor & Flin (2003), non-technical skills and safety attitudes, when understood and applied, can prevent or mitigate the effects of fails whether instigated by technology, organization, workers, system, or the interaction between them. From this, the driller's work inside of a doghouse, under a Safety-II perspective, and analysed by FRAM, is based on the principle that performance adjustments are ubiquitous and that performance not only always is variable but that it must be so. The variability should, however, not be interpreted negatively, as in performance deviations or violations (Hollnagel, Wears & Braithwaite, 2015). On the contrary, the ability to make performance adjustments, taking experience, perception and senses into account, is an essential human contribution to work, without which only the most trivial activity would be possible.

5. Considerações finais

The onboard offshore drilling activities experienced and observed are, definitely, one of the most dangerous work activities in modern industry. The isolation, the rigors of the weather, and the handling of heavy machinery during long runs are both physically and cognitively exhausting. Also, the constant presence of hydrocarbons emissions – crude oil or natural gas, machinery lubricants, sea water and drilling fluid maintain an oily, dirty and hazardous work environment, that can not only affect worker's health, but also cause fire principles or large explosions. This activities take place in a complex socio-technical system - offshore oil platforms - where methodologies such as FRAM assist not only in understanding the functioning of the system, but also in the systemic comprehension of the Human Factors involved, reaching the non-technical skills that assist in the productivity of activities. This comprehension allows to understand how failures may occur, causing accidents, but also what happens productively, what really works in the work-as-done, which is one of the elements of the Safety-II perspective. In this study, it is possible to observe how adequate communication, extended risk perception and situation awareness are allies in the productivity of work relationships,

but also key elements in the construction of a safe work environment. In this scenario, perspectives focused on the positive elements of work, such as Safety-II, show that there is an integrated path for production and safety, where the organizational culture of a company is also consolidated, which, ultimately, is also the safety culture. Therefore, understand the work, as well as comprehend the Human Factors relates to, is an objective and complex way of promoting safety, sustainability and business. And in this interspersed and complex scenario, only the complexity of the human being can understand and give the appropriate answers, in moments of normal operation, as well as in emergencies, showing, in fact, that the worker, in any type work environment, is not the problem, but the solution.

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Referências

- Akyuz, E., & Celik, M. (2015). A methodological extension to human reliability analysis for cargo tank cleaning operation on board chemical tanker ships. *Safety Science*, 75(1), 146–155.
<https://doi.org/10.1016/j.ssci.2015.02.008>
- Australian Radiation Protection and Nuclear Safety Agency - ARPANSA. (2017). *ARPANSA Regulatory Guide Holistic Safety*. Canberra: REG-COM-SUP-240U v1.1 | June 2017. Retrieved from <https://www.arpansa.gov.au/>
- Bellamy, L. J., Geyer, T. A.W., & Wilkinson, J. (2008). Development of a functional model which integrates human factors, safety management systems and wider organisational issues. *Safety Science*, 46(3), 461–492.
<https://doi.org/10.1016/j.ssci.2006.08.019>
- De Vries, L. (2017). Work as Done? Understanding the Practice of Sociotechnical Work in the Maritime Domain. *Journal of Cognitive Engineering and Decision Making* 11(3), 270–295.
<https://doi.org/10.1177/1555343417707664>
- Flin, R., O' Connor, P., & Crichton, M. (2016). *Safety at the Sharp End: A Guide to Non-Technical Skills* London: Taylor & Francis Group, CRC Press.
- França, J. E. M., & Hollnagel, E. (2019). Recognition and analysis of human factors and non-technical skills using the functional resonance analysis method - FRAM (Vol. 1, pp. 37–53). Presented at the IX International Conference on Knowledge and Innovation - ciKi, Porto Alegre. Retrieved from
<http://proceeding.ciki.ufsc.br/index.php/ciki/article/download/737/425/>
- Hollnagel, E. (2014). *Safety-I and Safety-II - The Past and Future of Safety Management* Surrey: Routledge.
- Hollnagel, E. (2012). *FRAM: The Functional Resonance Analysis Method: Modelling Complex Socio-technical Systems*. New York: Ashgate.
- Hollnagel, E., Wears, R. L., & Braithwaite, J. (2015). *From Safety-I to Safety-II: A White Paper*. The Resilient Health Care Net: Published simultaneously by the University of Southern Denmark, University of Florida, USA, and Macquarie University, Australia. Retrieved from <https://www.england.nhs.uk/signuptosafety/wp-content/uploads/sites/16/2015/10/safety-1-safety-2-white-papir.pdf>
- Labib, A. (2015). Learning (and unlearning) from failures: 30 years on from Bhopal to Fukushima an analysis through reliability engineering techniques. *Process Safety and Environmental Protection*, 97(1), 80–90.
<https://doi.org/10.1016/j.psep.2015.03.008>
- Luquetti dos Santos, I., Grecco, C., Carvalho, P. V., & Mol, A. (2009). The use of questionnaire and virtual reality in the verification of the human factors issues in the design of nuclear control desk. *International Journal of Industrial Ergonomics*, 39(1), 159–166. <https://doi.org/10.1016/j.ergon.2008.08.005>
- Luquetti dos Santos, I., Farias, M., Ferraz, F., Haddad, A., & Hecksher, S. (2013). Human factors applied to alarm panel modernization of nuclear control room. *Journal of Loss Prevention in the Process Industries* 26(6), 1308–1320. <https://doi.org/10.1016/j.jlp.2013.07.017>
- Noroozi, A., Khakzad, N., Khan, F., Mackinnon, S., Abbassi, R., & Autor 5. (2013). The role of human error in risk analysis : Application to pre- and post-maintenance procedures of process facilities. *Reliability Engineering and System Safety*, 119(1), 251–258. <https://doi.org/10.1016/j.ress.2013.06.038>
- O' Connor, P., & Flin, R. (2003). Crew resource management training for offshore teams. *Safety Science*, 41(7), 591–609. <https://doi.org/10.2118/61244-MS>
- Shroder, T., & Konrad, J. (2011). *Fire on the Horizon: The Untold Story of the Gulf Oil Disaster* New York: HarperLuxe.

- Skalle, P., Aamodt, A., & Laumann, K. (2014). Integrating human related errors with technical errors to determine causes behind offshore accidents. *Safety Science*, 63(1), 179–190. <https://doi.org/10.1016/j.ssci.2013.11.009>
- Sneddon, A., Mearns, K., & Flin, R. (2006). Situation awareness and safety in offshore drill crews. *Cognition, Technology and Work*, 8(4), 255–267. <https://doi.org/10.1007/s10111-006-0040-1>
- The International Association of Oil & Gas Producers (IOGP). (2018). *Demystifying Human Factors : Building confidence in human factors investigation understand facilitate*. Houston: IOGP Report 621. Retrieved from <https://www.iogp.org/bookstore/product/iogp-report-621-demystifying-human-factors-building-confidence-in-human-factors-investigation/>
- Turner, B. A., & Pidgeon, N. F. (1997). *Man-Made Disasters*. London: Butterworth-Heinemann.
- U.S. Nuclear Regulatory Commission - NUREG. (2002). *NUREG-0700 - Human-System Interface Design Review Guidelines*. Washington, DC: U.S. Nuclear Regulatory Commission. Retrieved from <https://www.nrc.gov/docs/ML0217/ML021700337.pdf>
- Wooldridge, A. R., Carayon, P., Hoonakker, P., Hose, B. Z., Ross, J., Kohler, J. E., ... Eithun, B. (2019). Complexity of the pediatric trauma care process: implications for multi-level awareness. *Cognition, Technology and Work*, 21(3), 397–416. <https://doi.org/10.1007/s10111-018-0520-0>
- Zheng, Z., Tian, J., & Zhao, T. (2016). Refining operation guidelines with model-checking-aided FRAM to improve manufacturing processes: a case study for aeroengine blade forging. *Cognition, Technology and Work*, 18(4), 777–791. <https://doi.org/10.1007/s10111-016-0391-1>