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Reanalysing Deepwater Horizon accident with FRAM ? enhancing learning and understanding complexities to improve safety

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Abstract

This study presents a reanalysis of Deepwater Horizon platform accident, occurred in April 2010, in offshore Macondo field, based on books, scientific articles and official reports prepared by the companies involved in the accident. The purpose of this reanalysis is to seek elements, factors, connections, inferences, and propositions that are new or different from those already found using analysis tools and methodologies that were built for simple or linear systems. In order to have a coherent analysis between the accident and the complex sociotechnical systems involved, the FRAM methodology (Functional Resonance Analysis Method) was chosen, as it coherently and comprehensively manages to analyse from simple to more complex systems. And in fact, with this reanalysis using the FRAM, it was possible to perceive the influence of organizational elements, such as culture, in the entire accidental chain of the event. In addition, contractual pressures related to business, fear of hierarchical consequences and failures in decision making, at all levels, were also evidenced. The findings of this study highlighted the need of a differentiated approach for accidents involving high-tech industries, such as O&G. In this sense, the human factors approach applied by FRAM, provides a coherent and evolved analysis of work, ultimately fostering productivity integrated with safety.

Keywords: Accident. Offshore. FRAM. Human Factors. Safety

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1. Introdução

Since the first studies of industrial safety captained by Heinrich in the 30s (Heinrich, 1931), the idea that accidents happen mainly due human error was it was widely accepted and disseminated, solidifying in companies and industries the empirical understanding of the unsafe act of workers as the cause of accidents. For most of the 20th century, this was a recurrent theme in accident analysis, reproducing, also from Heinrich, the Dominos Theory, as well as the statistical analysis that about 80% of accidents are caused by human error (Busch, 2021). This recurrence remained present in 21st century as well, being perceived in major accidents, such as P-36 (2001) and FPSO CSM (2015). This is engendering a misalignment between the increase of technology and sociotechnical interactions in workplaces and how they are (mis) analysed as linear, controlled and predictable. Therefore, despite all the technological and social evolution, it is noted that there wasn't a similar evolution in the safety assessment and practices in workplaces, which were considerably transformed due its technological and social evolution (Friedman, 2009), becoming a true complex sociotechnical system. Tools and methodologies such as PRA (Preliminary Risk Analysis), HazOp, Ishikawa diagram etc emerged former after Heinrich's discoveries to analyse the failures and weaknesses of work systems (Dekker, 2019), and in a way, they remained the same, despite all the techno-scientific evolution that was established in the workplaces and its practices, especially in high-tech industries such as nuclear, aerospace and O&G. Thus, and seeking a fair synchronism between this evolution and the analysis of risks of complex sociotechnical systems, it is necessary to adopt methodologies capable of dealing with all these elements, analysing the increasingly complex interactions and connections.

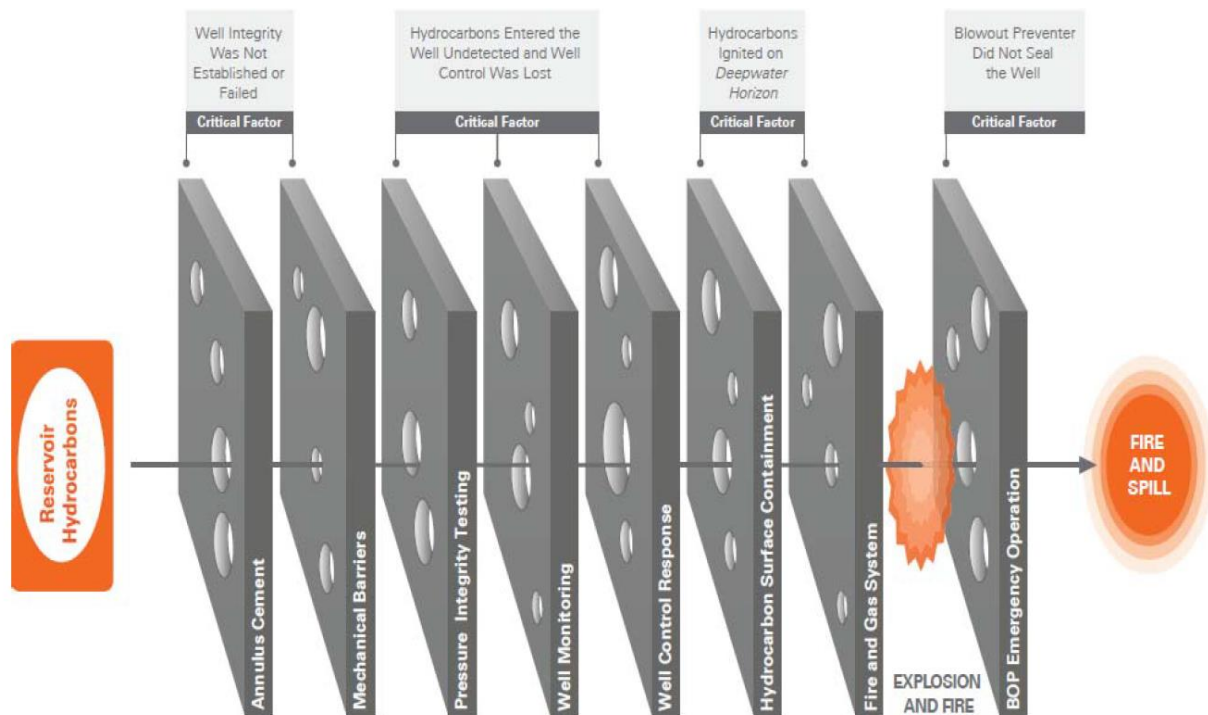
2. The Deepwater Horizon accident (2010)

The Deepwater Horizon was a drilling platform (oil rig) of Transocean, leased BP, that was operating in offshore Macondo field at Gulf of Mexico (Lustgarten, 2012). On the night of April 20th, a surge of natural gas blasted through a concrete core recently installed by contractor Halliburton to seal the well for later use. Once released by the fracture of the core, the natural gas toured up the riser to the topside, where a massive explosion happened, damaging various structures of the platform (DHSG, 2011). The rig capsized and sank on the morning of April 22nd, rupturing the riser, through which drilling mud had been injected. About four million barrels of crude oil leaked from the damaged oil well, during an 87-day period, before it was finally capped on July 15th (NOAA, 2017). The explosion and sank of this platform caused several injuries and eleven deaths, being the largest oil spill in the history of offshore oil drilling operations of US (Shroder and Konrad, 2011). This accident was analysed by all the companies involved – BP, Transocean and Halliburton – not only to understanding what happened, but also defend their point of view regarding the failures through the ongoing. Based on this, a FRAM model was developed, comprising as much as possible the different perceptions and conclusions of these documents, resulting in a comprehensive, coherent, and systematic analysis. Because of this breadth and the

intrinsic ability of FRAM to recognize complex interactions, it was possible to see how organizational issues, such as culture (different), hierarchical pressures, contractual relationships, and so on, were decisive in the decision-making process and how to deal with questionable drilling parameters.

BP has analysed this accident looking for an organizational perspective of how it has escalated, applying the organizational accidents theory, which describes major system organizational accidents as penetration of hazards through the barriers and defences of a complex system (Reason, 1997). In this theory an industrial accident develops when the major hazards confronting a system are able to successfully penetrate the barriers through aligned holes (defects, deficiencies) in the barriers formed by the risk control system. The organizational accidents theory distinguishes between individual worker accidents and organizational (system) accidents, where the prevention of individual worker accidents can be focused on personnel mistakes, and the prevention of system accidents can be focused on a much broader set of issues covering the entire organization structures, identifying the performance of the system (DHSG, 2011). Although there is a genuine search for an understanding of the functioning of the complex sociotechnical system, human error is still very much present as one of the main elements of the analysis, considering a linear, segmented, unidimensional and predictable logic (Robinson, 2017). Such premises, however, proved to be incompatible with the complexity of the entire event, before, during and after its occurrence. The graphic representation of these linear thinking to understand the faults of safety barriers was proposed by BP in its official accident report, being represented in figure 1.

Figure 1 – Deepwater Horizon accident analysis of safety barriers failures.



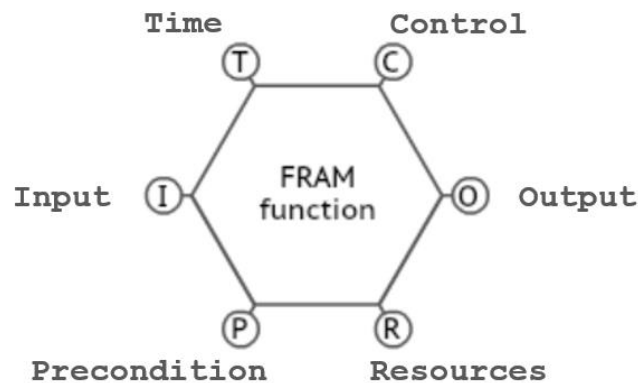
Fonte: DHSG, 2011.

The application of organizational accidents theory to understanding this accident is a valid way of looking for deeper answers and preventing future accidents, but its linear conception of reality is not adequate to deal with the complexity of accidents in the O&G industry. Although this analysis recognized critical failures in the plan for temporary abandonment of the well, notably in the negative pressure test and displacement of the mud (DHSB, 2011), it fails to adequately recognize how such failures reverberate throughout the system, causing other failures, and being feedback by other actions and elements. During this negative pressure test, critical signals (e.g., drill pipe pressures, well fluid volumes) were not properly detected, analysed, or appropriate action taken (CSB, 2011). After the well began blowing out, multiple different inputs into the system functioning dynamically changed its behaviour, leading to even more critical conditions, which invariably culminated, in a complex and non-linear way, for the accident occurrence. In the O&G industry, examining this accident, but also others such as Piper Alpha (1988), P-36 (2001) and FPSO CSM (2015), it is possible to notice that they are complex events, in complex sociotechnical workplaces, therefore, methodologies, tools and approaches that deal with all these dynamics, comprehending systemically how it happens. One of these possibilities is the FRAM (Functional Resonance Analysis Method).

3. The FRAM (Functional Resonance Analysis Method)

The Functional Resonance Analysis Method is a methodology that enables a graphical analysis of how things happen, from a simple production line, till a complex processing plan of an offshore oil platform. Due its structure, it can be used to analyse past events in a complex system, such as an accident investigation, like the study present here with Deepwater Horizon accident, as well as possible future events, such as a human factors approaches or risk assessment of highly complex system (Hollnagel, 2012). To 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 professionals working as a team (Ferreira and Cañas, 2019). It is a kind of complex discussion about the complex relationships of complex sociotechnical systems, but one done in a simple way. To be able to properly analyse the complexity behind systems, workplaces, sociotechnical interactions and other complex relationships, its graphic representation has a broader structure than a simple flowchart, adopting a hexagon of multiple inputs to represent the functions couplings on its models, as shown in figure 2, with its aspects named.

Figure 2 – The graphical representation of a FRAM function.



Fonte: The Authors, 2022.

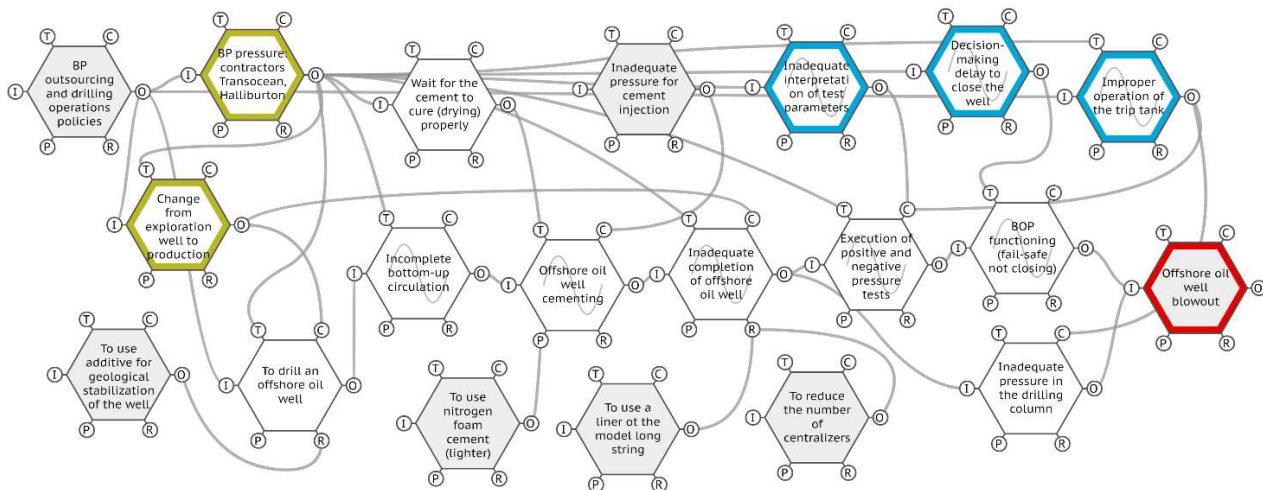
To build a FRAM model, it is necessary to follow four steps. The first step is the identification and the description of the functions, which can be human, technological or organisational (Hollnagel, Hounsgaard and Colligan, 2014). The model seeks to describe in detail how a task is done as a real, everyday activity, rather than to describe it as an overall procedure. Once the function description is done, the second step is the recognition of the output variability of each function of the model, which involves characterising each function by its potential and actual performance variability (Hollnagel, 2012). After the recognition of the output variability, 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 (Hollnagel, Hounsgaard and Colligan, 2014). The fourth and last step is the monitoring and managing of the performance variability of each proposed instantiation, as identified by the functional resonance that characterises the performance variability of the method and can result in positive and negative outcomes (Hollnagel, 2012). Adopting this methodology to reanalyse the Deepwater Horizon accidents will conceive a systemic and integrative view of the whole complexity, which has its understanding limited, or even mistaken, when merely linear methodologies are acquired.

4. Reanalysing Deepwater Horizon Accident with FRAM

Accident analysis and investigation models have the purpose of investigating and analysing occurrences, preventing the recurrence of similar events, and determining whether the systems are suitable for use. The great importance of models is to provide a means to understand the phenomena, record the information found and allow the handling of findings, promoting a learning process and preventing similar events from happening again (Leveson, 2004). In highly complex workplaces, such as an offshore oil rig like Deepwater Horizon, this learning is necessary to not only guarantee the functioning of all equipment and processes, but also to keep the business running, and most of all protect the environment and the personnel onboard (França *et al.*, 2019).

Having this as a background, and FRAM as the applied methodology, this accident was reanalysed in full, seeking to understand how organizational elements, such as culture, hierarchy and outsourcing, can dynamically influence the chain of events that lead to a major accident. The results of this reanalysis through FRAM are presented in figure 3.

Figure 3 – The FRAM model of the Deepwater Horizon accident.

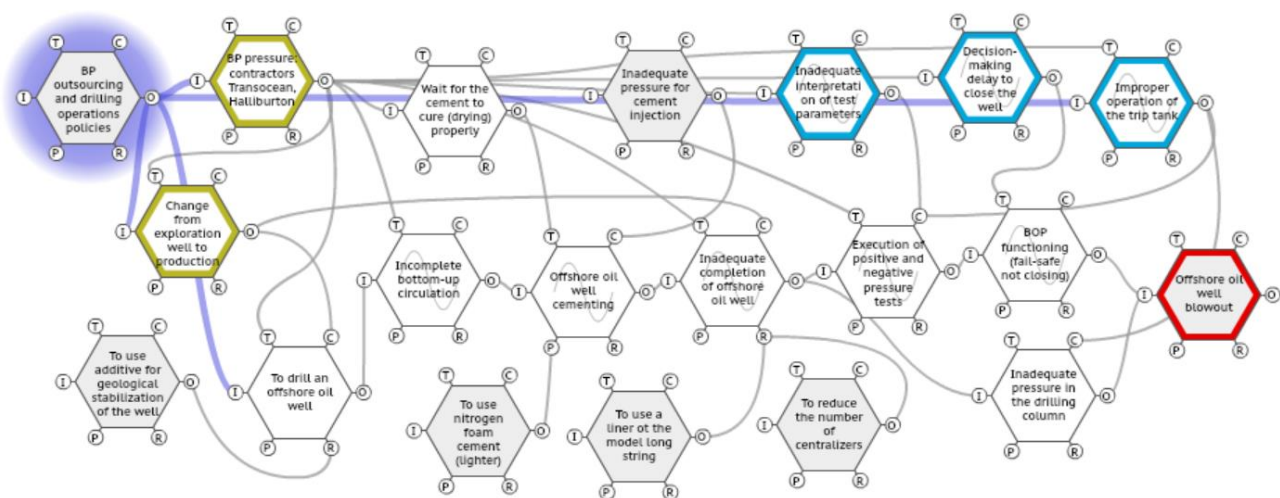


Fonte: The Authors, 2022.

Analysing both figures 1 and 3, it's possible to see how linear, predicable and controllable is the scenario of figure 1, where each barrier is a single step over a long and linear flow of events. It is very comprehensible, once most of the projects, analysis and reports tends to fit what happen in the World considering a linear, segmented, unidimensional and predictable logic (Robinson, 2017). In the other hand, figure 3 shows what happens as its own scale, by FRAM, showing how nonlinear and complex are the interactions of a real accident scenario. As much as technology push forward system, equipment and process in workplaces, they become more and more unpredictable, uncontrolled and complex. And between these two very different scenarios, between what is idealized and what actually happens, it will be up to workers to balance conflicting goals, becoming the balance instrument of an extremely complex sociotechnical system. In this aspect, people's natural neurological plasticity and adaptability play a key role (Damásio, 2005), building the resilience of the entire system. And when reanalysing Deepwater Horizon accident under this wider approach, it's possible to notice how the organizational elements, such as company's policies, contract's SLA (Service Level Agreement), culture and the relationship between outsourcing contractors are in deep associated with the main chain of events that lead to the accident. Indeed, the context and the organizational culture where this context is inserted, it's the driving force of individual and collective behaviour (Hopkins and Kemp, 2021), being observed not only in this accident, but also in the space shuttle Challenger (Vaughan, 2016) and Brumadinho's tailings dam (Hopkins and Kemp, 2021). Observing figure 4 is possible to understand how the function "BP

outsourcing and drilling operations policies” resonates in the system, being directly coupled with “BP pressure: contractors Transocean, Halliburton” and “Change from exploration well to production well”. The Change Management process is also a critical event present in several accidents, specially in the O&G industry. Particularly in Deepwater Horizon accident, these BP’s policies permeated several organizational structures, influencing in the relationship between contractors, the Change Management process and the improper operation of the trip tank. All these elements were part of the chain of events that leads to the accident.

Figure 4 – The resonance of the function “BP outsourcing and drilling operations policies”.

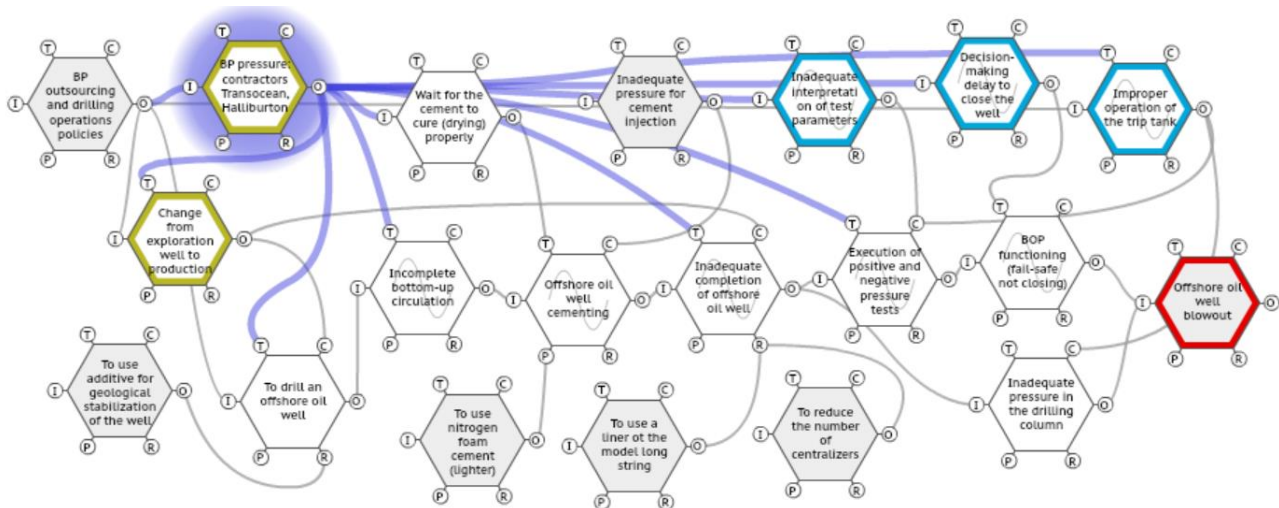


Fonte: The Authors, 2022.

As it's possible to notice, the more technological a system is, the more complex its relationships and processes will be. Indeed, since the beginning of the 3rd Industrial Revolution, characterized by electronics and information technology to automate production, the current 4th Industrial Revolution is building on the bricks of the third a massive digital revolution that has been rapidly occurring since the mid-20th century (Chandler, 2002). It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres (Friedman, 2009), increasing at high scales the complex interaction of the sociotechnical system of workplaces. In this environment, when organizational elements related to pressure over work are placed, the impact in the activities are real and potentially changes the planning done before, demanding a dynamic adaptation over the pressure coming from contractors, Government or regulators (Vaughan, 2016). Analysing the function “BP pressure: contractors Transocean, Halliburton”, it's possible to realize how deeply this pressure is in the entire system, resonating through different and several organizational structures, influencing decisions, the way to perform the tasks and the (incorrect) interpretation of the pressure reading of the instruments. The figure 5 shows how this resonance reach the entire system, since the preliminaries actions of the function

“To drill an offshore oil well”, till the accident management itself, by the function “Decision-making delay to close the well”.

Figure 5 – The resonance of the function “BP pressure: contractors Transocean, Halliburton”.



Fonte: The Authors, 2022.

Thus, hereby this FRAM reanalysis of Deepwater Horizon accident, it is noticed that it's semantically complex (it generally takes a great deal of time to master the relevant domain knowledge), with tight couplings between various parts, and where operations are often carried out under time pressure or other resource constraints (Qureshi, 2007). In this sense, it is necessary to understand that some methodologies, limited to a merely linear analysis, are not compatible with the levels of complexity and non-linearity presented. An adequate and comprehensive analysis of a sociotechnical complex system, which characterizes most of the current O&G industry's workplaces, demands an effective approach towards understanding the social, technological and organisational elements deeply in the system, because as much as technology push forward system, equipment and process in workplaces, they become more and more unpredictable, uncontrolled and complex. To be aware of this and be capable of a proper human factors approach it's not just a safety demand, but also a corporative responsibility for business, environment, Society and, above all, the people who work in these complex sociotechnical systems.

5. Considerações finais

Analysing the Deepwater Horizon accident, by itself, is already a task that requires multiple efforts and, when it comes to high-tech workplaces, it becomes even more complex. The reanalysis promoted by this study showed how complex sociotechnical workplaces can have a limited comprehension when depurated by methodologies or tools primarily designed for linear systems. It

was perceived that a differentiated approach is needed to analyse such systems, both in normal operation as well as when an accident happens, as was this case of Deepwater Horizon. The human factors approach applied by FRAM provided a coherent and evolved analysis of what happened in this accident, allowing the recognition of organizational constraints and complex interactions that could not be evidenced by linear analysis methodologies. In this way, the use of methodologies that make it possible to recognize the complexity of the systems, as it happens, in addition to allowing the understanding of interactions, strengths and weaknesses, will also be able to coherently analyse the occurrence of failures. Therefore, the utilization of FRAM to analyse accidents in high-tech workplaces, such as the drilling floor of an oil rig, demonstrates a possible equilibrate way to widely and coherently understand how the work is done, both in daily routine as in emergencies and accidents.

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