FRAM Approach for Barrier Management in Offshore Drilling

Seyed Iliya Pezeshki[a,*], Behnaz Hosseinnia[b], Nicola Paltrinieri[b] , Valerio Cozzani[a]

[a] Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Italy

[b] Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology NTNU, Trondheim, Norway

* Corresponding author e-mail: pezeshki.iliya@gmail.com

1. Introduction

- Accident investigations in offshore oil and gas industry indicate that inadequate barrier management has been one of the main causes of many offshore accidents. Event trees commonly have been used for safety barrier risk analysis; however, this approach mostly focuses on technical barriers.
- With the introduction of non-traditional school of thought on safety, so called Safety-II (Hollnagel 2017), and how to achieve it, methods such as Functional Resonance Analysis Method (FRAM) (Hollnagel 2012) have been developed to map sociotechnical systems from a different perspective.
- The need for more advanced approaches for controlling and reducing the risk rises as technology advances, that demonstrates the need for wholesome approaches in socio-technical systems (França et al. 2019).
- This study explores the idea of how Safety-II mentality can add value to the barrier management in offshore drilling operation.

OBJECTIVE: As a method that was developed from the adoption of the Safety-II mentality, FRAM sees the interdependencies of the system as a whole and focuses on the system's success. This approach has shown a promising potential for facing the complexities of the sociotechnical systems (França et al. 2019); therefore, this study has chosen FRAM to model the barrier system for an offshore installation

2. Methodology

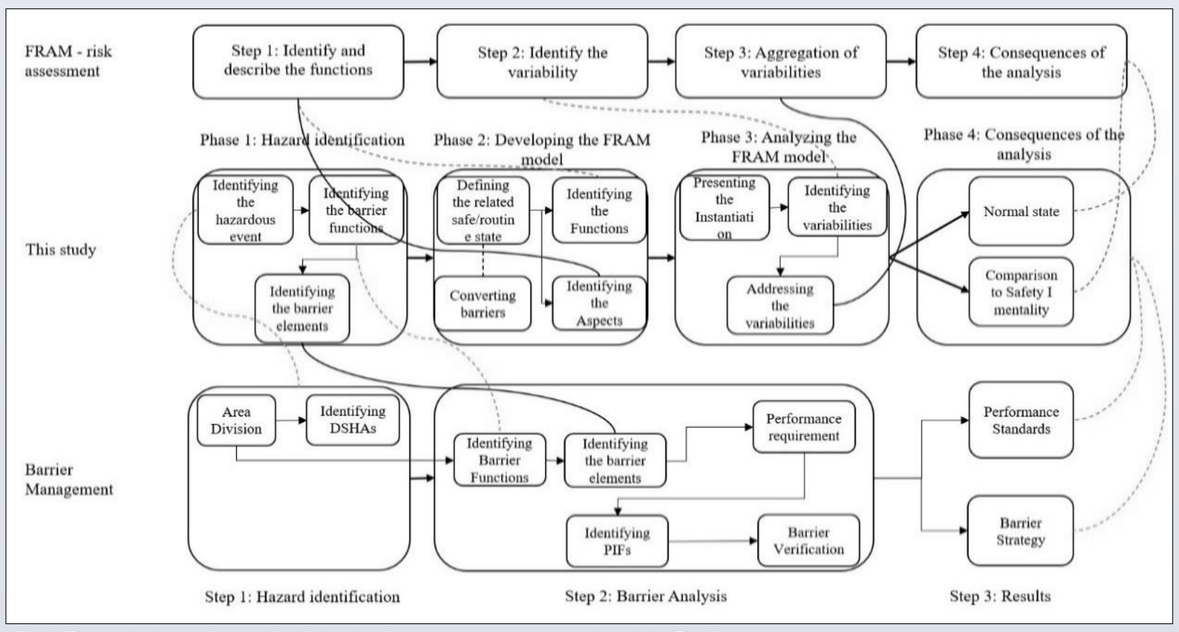

Fig.1. The method overview and its link to barrier management framework and the FRAM steps

The proposed methodology illustrates integration of conventional barrier analysis into FRAM. The first phase, like the barrier management's hazard identification phase, provides a basis for the integration of the Safety-I approach into the FRAM. The second phase is the conversion phase in which based on the system itself, firstly, FRAM functions are defined as well as using the barrier functions to develop the FRAM model. In the third phase, the analysis of the FRAM model is performed based on the FRAM stepwise descriptions. In the last phase, a normal state of the system is analyzed in FRAM model, and later the FRAM model is compared with a Safety-I approach. Figure 1 shows the method overview and its link to barrier management framework and the FRAM steps.

3. Case-study

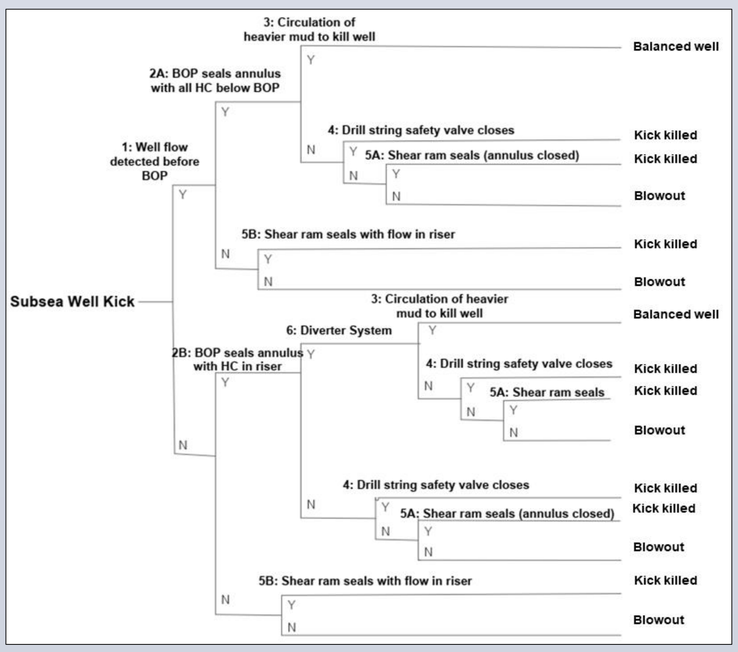

Fig.2. Subsea kick event tree (Source: Hauge et al. 2011)

The proactive barrier functions regarding kick are considered to be out of the scope of the analysis. This is because the mud circulation is what guarantees the exerted pressure on the formation fluid and is identified as a reactive barrier

A subsea well operation in an offshore platform with focus on 'kick' is considered as the case study. The assumptions made in this study are as follows: There is no gas injection, the well is assumed to be producing oil in a normal state, no coil-tubing or side well drilling is performed, only standard bottom hole drilling. The human-machine interface systems are considered as an intermediate between technical systems and human action, not barriers themselves.

4. Results

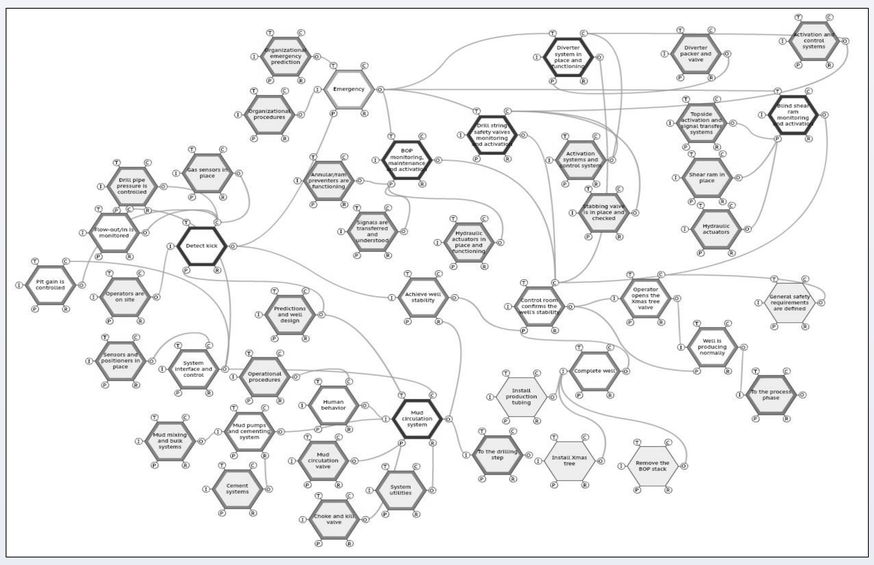

Fig. 3. The instantiation of the system depicted by FMV (Hexagons with bold borders are barrier functions)

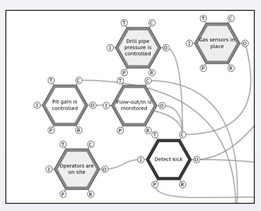

Fig. 4. The <Detect kick> function and its aspects

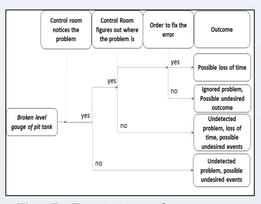

Fig. 5. Event tree for a broken level gauge of a pit tank

Possible variability of Output coupling regarding timing for barrier functions

Function	Output	Possible variability of Output
<Detect kick>	Kick does not exist	Too early, premature start
		Too late, delay in the process, loss of time
		Omission, loss of time
	Kick exists	Too early, false emergency, possible loss of time and resources
		Too late, kick propagation
		Omission, blowout
<BOP monitoring, maintenance and activation>	BOP is functioning	Too early, control room may confirm an unstable situation as safe
		Too late, kick propagation, possible loss of time to perform further actions
		Omitted, blowout
<Mud circulation system>	Mud column	Too late, possible kick propagation
		Omission, drilling is not possible without the mud column, so if the mud column stopped being provided after the drilling procedure, kick and blowout are a possibility
<Drill string safety valves monitoring and activation>	Drill string safety valve functions correctly	Too early, control room may confirm an unstable situation as safe
		Too late, kick propagation, possible loss of time to perform further actions
		Omitted, blowout
<Blind shear ram monitoring and activation>	Blind shear ram functions correctly	Too early, control room may confirm an unstable situation as safe
		Too late, kick propagation, possible loss of time to perform further actions
		Omitted, blowout
<Diverter system in place and functioning>	Diverter system functions correctly	Too early, control room may confirm an unstable situation as safe
		Too late, kick propagation, possible loss of time to perform further actions such as evacuation
		Omitted, blowout, possible loss of life

- **Increased Variability in a Technical Function**

It is assumed that there is an increased variability in the function <Pit gain is controlled>. This can happen due to a broken gauge that shows a wrong number which leads to an imprecise signal as its Output. The FRAM representation clearly emphasizes the interconnectivity of the functions in the system. A broken gauge engages other parts of the system to adjust their performance which leads to a delay in the system.

- **Consequences of the Analysis**

By implementing a FRAM approach to a mostly technical system of barriers, not only the human interactions with a technical system are highlighted, but also the very nature of the human performance variability can be captured and reflected. Ultimately, non-technical barriers can be defined in an organizational level to address these variabilities. This can be done by introducing operators to the 'success-focused' studies and Safety-II mentality in order to emphasize the reasons how a complex system can succeed

- **Comparison to Event Tree Analysis**

For the same variability scenario, an event tree must be developed to understand how Event Tree Analysis (ETA) would deal with instability. While this can be a time-consuming procedure to include every possible reaction of the operators, it will still be incomplete as it needs quantification; for example, a Human Reliability Analysis, to be meaningful. Figure 5 tries to emphasize on ETA application simplicity, while bringing out its general limitations by illustrating a stepwise series of tasks on how the human behavior changes due to a broken gauge in a pit tank.

5. Conclusions

- Safety barriers in offshore drilling are mostly not only technical but a combination of technical, operational, and organizational elements with intense interaction between them. Therefore, managing them requires a methodology capable of understanding how this complex sociotechnical system works,
- This study has explored the possibility of providing additional information that can be used in barrier management by utilizing the Safety-II mentality. The FRAM barrier model was primary built based on a mostly technical system, and still managed to capture the human and organizational aspects of safety barriers.
- The FRAM representation of the case study demonstrated its potential to identify various sources of variability that can provide useful information regarding barrier strategy and performance standard for decision-makers in early phases of barrier management development.
- **The application of the FRAM in this study showed that neither FRAM nor ET are perfect, and both are needed to create a comprehensive safety overview.**

References

França, Josué E. M., Erik Hollnagel, Isaac J. A. Luquetti dos Santos, and Assed N. Haddad. 2019. "FRAM AHP approach to analyse offshore oil well drilling and construction focused on human factors." Cognition, Technology & Work.

Hauge, Stein; Kråkenes, Tony; Håbrekke, Solfrid; Johansen, Gorm; Merz, Mariann; Onshus, Tor. 2011. "Barriers to prevent and limit acute releases to sea." https://tinyurl.com/y5zn4hxd.

Hollnagel, Erik. 2017. "Safety-II in Practice: Developing the Resilience Potentials." London: Routledge.

—. 2012. "FRAM - the Functional Resonance Analysis Method: Modelling Complex Socio-Technical Systems." Boca Raton: CRC Press.