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Safety barriers: Organizational potential and forces of psychology

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ABSTRACT

Safety barriers are often described as a safety function realized in terms of technical, operational and organizational barrier elements. These elements, in some shape or configuration are established to ensure that the barrier works as intended.

While technical and operational barrier elements appear fairly definable, the organizational barrier element often remains elusive. An appealing solution oriented strategy is probably to urge for a clear-cut categorization of what applies as 'organization'. This tactic may contribute to a tidy method with respect to barrier categorization. However, the question remains whether it is possible or desirable to confine the organizational influences to categorical classifications?

The aim of this paper is to address this question by examining the run-up to the Macondo blowout from a barrier element perspective.

Hopkins' (2012) analysis of the Macondo blowout is applied to identify patterns of organizational impact in three of the pre-blowout defenses: The cement job, the well integrity test, and the kick monitoring.

By re-analyzing Hopkins' study from a barrier element perspective we argue that the organizational impact may morph and change in nature, be contagious and spread across barriers, and travel long distances. The implication is a need to rethink the impact of organizational barrier elements. Part of this rethinking involves acknowledging the impact of psychological mechanisms like consensus-mode decision-making, confirmation bias, normalization of warnings, groupthink as well as social forces of power and persuasion. It is shown how such psychological forces may serve as 'transmitters' of organizational principles, strategies and decisions throughout the barrier system. In turn, this may contribute to risk transfer, and dependence between barriers.

1. Introduction

Safety barriers are part of orthodoxy in safety science and management. Represented by the classic Swiss cheese metaphor, this is the idea of a string of defenses, or barriers – aligned so that if any of the preceding barriers fails, the subsequent defense in line will do its job of preventing the occurrence of hazardous events or limiting their consequences. The safety philosophy forming the basis for barrier management is often denoted 'defense in depth' (Reason, 1997) (referring to the deep layers of defenses or barriers established to prevent harm). Defending 'in depth' may also trigger associations along the lines of 'going deep into the complexities' and so on. In terms of accident causation and explanation, 'further back' is often related issues of organization. Current efforts to understand the organizational impact is a lucid reflection of the acknowledgment that organization matters (see e.g. Weick & Sutcliffe, 2007). Organizational issues may be a forceful contributor to maintain safety; but also in the development of major accidents. Connections between organization and safety are compellingly addressed and revealed in the literature (e.g. Hopkins, 2008; Reason, 1997; Vaughan, 2005).

A barrier is often described by referring to its function. That is, barrier x is established in order to implement function y (e.g. the flare system is installed to relief the process pressure). The barrier function may here be realized and maintained by barrier elements. These barrier elements are typically classified as technical, operational, or organizational. In this approach, a barrier can be defined as '*...technical, operational and organizational elements which are intended individually or collectively to reduce the possibility for a specific error, hazard or accident to occur, or which limit its harm/disadvantages*' (PSA, 2013, page 3).

While technical and operational barrier elements appear fairly definable, the organizational barrier element often remains elusive. An appealing solution oriented strategy is probably to urge for a

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clear-cut categorization of what applies as 'organization'. This tactic may contribute to a tidy method with barrier elements of unambiguous character. But, will a categorical classification of organization solve the challenges related to acknowledging the actual influences on safety? The aim of this article is to address this question by examining the run-up to the Macondo blowout from a barrier element perspective.

2. Conceptual framework

A rendition of Hopkins' (2012) analysis of the Macondo blowout is used as source and conceptual framework.

The following presents selected elements of Hopkins' (2012) analysis of the Macondo accident. This presentation is limited to looking at episodes related to three of the defenses before the blowout: the cement job, the well integrity test, and the kick monitoring.

A simple chronology of the run-up to the Macondo accident: at 5.45 am, 16 h before the blowout, the cement job was declared a success; at 8 pm the well integrity test was affirmed as ok; in the hour before the blowout there were indications that something was wrong. These signals passed unnoticed as no one was monitoring the well; at 9.45 pm drilling mud were churning out – the catastrophe was a fact.

See also the reports from the National Commission to the President (National Commission, 2011a, 2011b as well as Tinmannsvik et al., 2011). Fig. 1 depicts the pre-blowout defenses.

2.1. Cement job

The rig was about to move and begin its next job. In order to leave the well in a safe state, the bottom had to be plugged with cement. This was a case of a 'temporary abandonment' as the well would later be converted to a producing well. This would involve drilling the cement out for oil and gas to flow into the well. The Macondo engineers planned and executed the cement job. And on completion, they declared it a success; a textbook job (Hopkins, 2012). According to Hopkins, this declaration of triumph was based on indications of full returns of fluid and thereby no signs of losses into oil and gas sands. Full returns denote the process when cement is pumped down into position; equal amount of fluid should be coming out on top of the annulus as is going down the casing. This particular well design demanded high pressure on the cement near the well bottom. This increased the possibility of a loss into oil and gas sands. As noted by Hopkins however, this error mode was only one of at least four plausible error modes. The three others were: (i) instable cement (due to the light weight foam cement that was needed in this particular well design); (ii) channeling (i.e. that the cement leaves mud channels behind it during cement placement), (iii) contamination (i.e. that mud is blended into the cement, leaving a less than optimal cement consistency) (Hopkins, 2012).

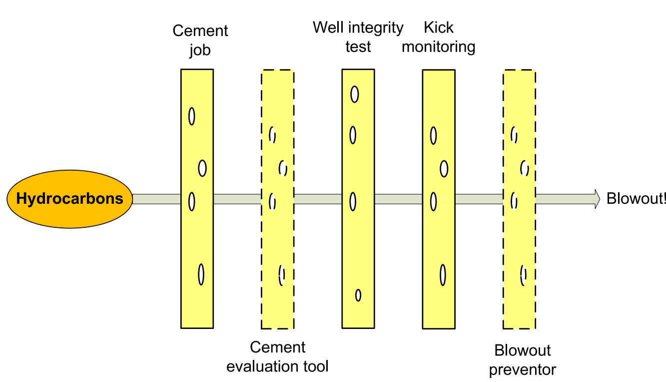

Fig. 1. Pre-blowout defenses in the Macondo accident (based on Fig. 4.1 in Hopkins, 2012, page 54).

Hopkins' point is that a fallacy was made. By concluding that the cement job was successful (due to signs of full returns) the job was affirmed as completed. The declared success rendered the cement evaluation (cement bond log, CBL) unnecessary. The crew that was ready to perform the CBL was brought home by helicopter. By declaring the job a success, corners could be cut by omitting the cement evaluation test, and thereby save money. By the time of the blowout the operation was 38 days delayed and an estimated $58 million above budget (Chief Counsel's Report, National Commission, 2011b). The presumption being, that any needed mitigation regarding cement instability could be done at a later stage. In this way, progression of an already delayed job was ensured. Hopkins (2012) shows how tunnel vision and a consensus mode of operandi contributed to the declaration of a successful cement job.

2.1.1. Tunnel vision engineering

Hopkins argues that the Macondo engineers displayed tunnel vision engineering. Their eyes were fixated on one objective: a well design that was cheaper and would enable easier production when that time came. It was as if peripheral risk awareness was virtually eliminated. Hopkins traces this tunnel vision back to a 'management of change' (MoC) document that had been previously designed to give formal authorization for the well design. Here, the potential of loss of mud into surrounding sands was emphasized specifically. This hazard was in other words primed in the engineers' minds. From the beginning (design approval stage), only one of at least four possible failure modes was addressed (Hopkins, 2012).

2.1.2. Decisions in consensus-mode

Decisions were made in a consensus-mode, effectively made in settings where no one could be held accountable later on. This is according to Hopkins illustrated by (1) decisions that were made in meetings intended to collect information; with the implication of making all – and in effect no one actually responsible; and (2) the management of change documents that were reviewed and approved by a long string of signatures. These signatures often belonged to the same people as those being involved in the plan. In other words, there was no independence, and the system of assurance served only to undermine the process. The MoC process, in reality, was a consensus decision-making process; with the disturbing effect that responsibility was diluted (Hopkins, 2012).

2.2. Well integrity test

Before moving the rig to the next location, the integrity of the well had to be tested (this is part of the temporary abandonment procedure). Removing riser and mud leaves the well underbalanced, meaning that the cement seal must function. In order to test the sealing, a temporary reduction in well pressure is administered. The logic of this test is: a pressure rise indicates that oil and gas flows into the well bottom, meaning that the seal is not working. If the seal does work, the pressure remains steady. The test involves pumping sea water down the drill pipe under high pressure; this, in order to force the mud upwards, thereby creating a water cavity. When the mud level is positioned above the blowout preventer, this is closed with a rubber seal. The cavity (between well bottom and rubber seal) now simulates a situation of no other defense than the cement being in place. Having created this space, the valve on the drill pipe on the rig is opened in order to drop the pressure. The key point is thus that, if the cement sealing worked – the pressure at the top of the drill pipe would remain at zero. The team opened the valve to reduce pressure; but as soon as they closed it, pressure began to rise. The same thing happened in a second attempt. The pressure increased. Still, the team would not accept this result (Hopkins, 2012).

Hopkins shows how the following social psychological processes contributed to this 'denial': confirmation bias, normalization of deviation, inadequate situational awareness and groupthink.

2.2.1. Confirmation bias

In psychology, confirmation bias refers to the unconscious tendency of preferring information that confirms ones beliefs; a tendency of selective use of information. Hopkins (2012) points to several features that contributed to confirmation bias in relation to the well integrity test. First, the rarity of the phenomenon is in itself a dimension here. As a well integrity test rarely fails, this is itself a bias towards viewing the test as a way to confirm that the well was ok, rather than to test if it was ok. Second, it was not only those carrying out the test that executed confirmation bias. The engineers had just days earlier designed a decision tree, at which the well integrity test was defined as a point in a sequence – as opposed to a decision-process. Put differently, the diagram presupposed that the test would be fine. Third, the first draft of the work plan for the day of the blowout did not refer to the well integrity test. According to Hopkins, this demonstrates that it was not seen as a critical operation. Fourth, the cement job that had been completed just hours previously had been declared a textbook operation (Hopkins, 2012). Taken together these are forces pushing to create a strong confirmation bias for those making the decisions.

2.2.2. Normalization of warnings

This is a variation of what Diane Vaughan called normalization of deviance related to the space shuttle Challenger. It refers to a reconceptualization and normalization of a partial malfunction, until it at some point became assessed as an acceptable risk (Vaughan, 2005). Hopkins (2012) shows how a similar normalization took place during the well integrity testing at the Macondo well. The pressure readings were normalized by reference to a 'bladder effect' theory; a suggested explanation for the change of pressure. '*The 'bladder effect' explanation contends that heavy fluids (mud and spacer) displaced to the riser were exerting force on the annular preventer from above, which in turn communicated pressure into the well*' (Chief Counsel's Report, National Commission, 2011b, page 157).

When the riser is pressure tested, the mud in the riser is supported by a rubber seal that is closed around the drill pipe. The intention of this seal is to '*…isolate the water in the cavity below the seal from any downward pressure exerted by the mud*' (Hopkins, 2012, page 43). The bladder theory provided an explanation ("normalization") of the exerted pressure by claiming that this seal is somewhat flexible, so that the mud above exerted pressure on it. This would create added pressure on top of the drill pipe. This was advocated by some. Others had never heard of it, but became persuaded by the concept. According to Hopkins, the bladder effect has no credibility in comfortable hindsight. It was the normalization of an unambiguous warning (Hopkins, 2012). The bladder theory provided a needed explanation of the pressure readings. Still, they needed some evidence to be able to establish that the well was safe. Thus, a decision was made to use the 'kill-line' to perform the pressure test. They filled the kill pipe with water, opened the valve to reduce the pressure, and closed it. This time, the pressure remained at zero in the cavity (the wanted result), but the pressure remained high on top of the kill pipe. The difference in pressure was ignored. It was decided to go with the pressure reading from the kill pipe (showing a steady zero). Hopkins links this with mental models and situational awareness. He draws attention to the fact that if the kill pipe was in contact with cavity, a difference in pressure would not be possible. Therefore, if the team understood the picture, they could not have accepted the pressure difference (Hopkins, 2012).

2.2.3. Groupthink

According to Hopkins, a vital point is to understand the composition of the group. The formal decision-maker was the BP company man. On any shift a company man would be on duty. The well integrity decision was however taken in a shift transfer – meaning that there were actually two BP company men present. In this case then, the decision group consisted of: Two BP company men accompanied by a trainee. From Transocean, there were two long-serving drillers and an assistant driller. Within this group, Hopkins advocates that the psychological process of groupthink took place; a process that deters questioning the wisdom of the dominant view. Groupthink and group decision-making may be affected by 'risky shift', where groups are often more inclined to make risky decisions than individual group members (Shaw, 1976). Hopkins argues that group decision-making tends to absolve individuals of responsibility. Groupthink involves a presumption (within the group) that it will be unanimous. In principle, any doubting group members would be in a powerful position here, as they may well block consensus. However, the pressure exerted on them (from the other group members) is to accomplish consensus (Hopkins, 2012).

Hopkins' point is that, to understand the decision, it is necessary to identify the actual power of the group. This demands looking at the culture on the rig, with a tight rig crew (from Transocean). Hopkins describes the driller culture as a group of highly skilled, opinionated technicians taking personal interest in every well. They take on leadership. Also, the complexity of the operations (drilling) is typically reflected in an esoteric language with extensive use of slang expressions and acronyms. What is more, peer pressure is extensive, with widespread use of teasing and humor. "Unintelligent" questions are heavily sanctioned. This was the culture that the BP company men had to resist. At first, the company men were skeptical to the bladder theory; but one of them found it acceptable leaving one person outside the "good company of agreement". During later interviews, he has told that his reluctance to accept the bladder explanation was found humorous by the drillers. The dominant view triumphed in the end, the test was declared as passed. This is groupthink in action. According to Hopkins, the social processes made it "virtually impossible for them to act independently" (Hopkins, 2012, page 49).

2.3. Kick monitoring

'*A kick is an unwanted influx of fluid or gas into the wellbore. The influx enters the wellbore because a barrier, such as cement or mud, has failed to control fluid pressure in the formation. In order to control the kick, personnel on the rig must first detect it, then stop it from progressing by adding one or more barriers*' (Chief Counsel's Report, National Commission, 2011b, page 165). As kicks are considered blowout precursors, monitoring the circulation of fluids is important. The well monitoring instrumentation and the training of the operators on Deepwater Horizon were however inadequate to effectively detect a kick (Chief Counsel's Report, National Commission, 2011b, page 182).

Drilling involves constant circulation of fluids in and out of the well. If oil and gas enters the well bottom, the outflow will exceed the inflow; the result being that the well is 'flowing'. The fluids going into the well are normally drawn from the pit (input tank) – while fluids coming out of the well go into the outflow pit. The comparison of these pits serves as an instrument to control (monitor) for well flowing. The monitoring responsibility on the rig was shared by the Transocean drillers and assistants, and a mudlogger from the company Sperry Sun. The well was in a critical stage; seawater had replaced the mud, leaving the well underbalanced. In other words, the only defense in place was the cement plug. Still, the Transocean crew had effectively made flow monitoring impossible by running outflow directly to a supply vessel (as opposed to the outflow pit, to save time). The mudlogger made a complaint to the drillers that this prevented monitoring. This complaint was disregarded. (Hopkins also points to a second fluid discharge, something that prevented the second mudlogger (due to shift change) from monitoring). The point is; the drilling crew prevented the monitoring capacity for the mudloggers as well as for themselves (Hopkins, 2012).

2.3.1. *State of mind = finish up*

Hopkins (2012) suggests that the practice of bypassing the outflow pit was a norm on the rig. In any case, the puzzling question is why they did not acknowledge the criticality of what they were doing. Why did the drillers act with so little concern? Hopkins' point is that they acted in a state of mind where the job was defined as over. Drilling was finished, the well had been declared safe twice (cement job, well integrity test). Their modus operandi was now simply to finish up and to move on to the next job. Also, they were short on time. Tank cleaning personnel were arriving, ready to start their work.

In the next section, we present a re-examination of Hopkins' analysis, with the specific aim to identify constellations and patterns of barrier elements.

3. Re-analyzing Hopkins'

We must begin by pointing out that the Deepwater Horizon drilling rig was not subject to a strict 'barrier management regime' with specified barrier elements. Our re-analysis is thus an attempt to identify how barrier elements could look like and interact within the Macondo run-up.

Hopkins emphasizes that contextualization is the key to understand the decisions and actions taken in the *cement job.* He traces the engineers' tunnel vision back to the MoC-document, a document that from the onset established only one error possibility (loss of mud into sands). Also, the possibility of accountability was effectively pulverized by consensus mode decisions (cf. decisions made in information meetings and the long string of approval signatures from people that lacked necessary independence).

This contextualization has an organizational flavor. But, are these features organizational barrier elements?

If we pursue the possibility that they are, this suggests a long distance link between operational and organizational barrier elements. Put differently, we catch a glimpse of a barrier element constellation with operational elements in close vicinity to the actual barrier function, but with an organizational contribution that travels a considerable distance, from managerial echelons straight into the heart of the barrier.

On the other side, what if this kind of influence is rejected as a barrier element? In conventional barrier approaches, a barrier element is defined as a measure or solution playing a direct part in realizing a barrier function. This definition suggests that long distance impact will be an outlier by definition. Even if rejection is the case, we argue that Hopkins' contextualization points demonstrate the crucial importance of identifying paths from further back in the organizational echelons and straight in to the operational core. If this impact falls outside of the conventional definition of barrier element, it is still an active organizational impact; meaning that it affects the performance of the barrier. The challenge is thus for barrier management approaches to find ways to acknowledge and handle this long distance organizational impacts.

The implication by this is that although proximity to hazard may remain a critical criterion when considering barriers and barrier elements, it should not be the only criterion. The scope should be expanded.

Risk transfer is another aspect that is brought to the fore by opening for long distance coupling of barrier elements. In the cement job, the organizational issues acted as a trigger for the operational barrier element actions (declared success) further down the line of defenses. In turn, this declaration of success acted both to transfer of risk and to undermine the defense in depth principle of maximizing each barrier.

Risk transfer is also the case in the *well integrity test*. A relevant approach here is to look at how decisions made in the previous defense (cement job), served to diminish the search for hazards. By declaring the cement job a success, all risk handling was effectively transferred to 'the next in line', in this case, the well integrity test.

What was the declaration of success? Was it just another operational failure; that in turn contributed to a subsequent operational failure (in the well integrity defense)? We argue that the declaration of success can be seen as transforming in character. That is, that it morphs from operational to organizational; it becomes an organizational premise that plays a key role in the subsequent well-integrity test. In this way, the organizational impact stretches out and travels across barrier functions.

The way that the organizational impact stretches across barriers is further demonstrated in the *kick monitoring*. By the time of the kick monitoring, the state of mind was to 'wrap up'. When the defenses are seen in coherence, what springs forward is a total lack of barrier independence. From the onset (cement job), each defense were relying on the subsequent defense in terms of risk handling, creating a systematic transfer of risk throughout. In effect, the principle of barrier independence appeared as completely undermined.

4. Discussion

The key implication in terms of barrier element categorization is that the organizational contribution may come from 'somewhere else'. Put differently, the organizational impact travels long distances. Opening up for long distance organizational influences creates sensitivity towards possibilities of risk transfer and barrier dependence. These are possibilities that must be actively sought prevented in defense in depth strategies.

As per today, barrier element categorization has a strong focus on front end personnel and technical systems. Based on our paraphrasing of Hopkins' analysis, we argue for a need to broaden the scope of barrier management. This involves rethinking the organizational potential and acknowledging the potential impact of psychological mechanisms. Although Hopkins' analysis is saturated with organizational impact, another core issue is psychology.

4.1. *Forces of psychology*

Hopkins points to specific psychological mechanisms as contributors to the barrier breakdowns leading to the Macondo blowout:

- Tunnel vision (inadequate risk awareness)
- Decision-making in consensus-mode
- Confirmation bias

- Normalization of warnings
- Groupthink

A common denominator of these mechanisms is that they are permeated with 'the social'. There are strong social psychological forces at play here. In fact, we are confronted with the powerful potential of social psychological group dynamics and interaction. These forces of psychology can thus be defined as '*dynamics of social interaction*'. For our purposes then, in terms of safety barrier thinking – this strongly suggests paying attention to what happens *between* people.

People affect each other. This is well recognized by Hopkins (2012) as his analysis addresses the impact of broad ranging social psychological forces related to persuasion, pressure, and power. The 'bladder effect' dilemma is a vivid example of the triad of persuasion, pressure and power in action. The social forces in the group effectively defused any attempt to think differently.

But, this triad of persuasion, pressure and power can be said to cut across and be part of all the defenses considered here (cement job, well integrity test, and kick monitoring). In this vein of thought, we argue that the dynamics of social interaction have an additional role in terms of barrier elements. Hopkins' study put emphasis to a critical link between organization and people. Of course, at some point any organization can be said to be the people in it. However, Hopkins' analysis illuminates an additional point: That the organizational impact may be *channeled* by psychological mechanisms. In this way, organizational principles, strategies or decisions are potentially transmitted or carried forward throughout a line of barriers by forces of psychology.

As shown in this article, the forces of psychology that needs attention, is very much part of what psychology denotes *group dynamics*. Groups can be both efficient and important, in terms of trying to ensure safe and adequate decisions. But, the potential negative side effects of group dynamics should be considered seriously. As noted by Forsythe: '*Wh*en a group sacrifices rationality in its pursuit of unity, the decisions it makes can yield calamitous consequence' (Forsythe, 2009, page 313). The potential impact of how the people interact and affect each other in their efforts to realize a barrier function cannot be ignored.

The impact of psychological mechanisms and social forces are important issues that currently receive little attention in safety barrier approaches. More focus on including these mechanisms as an active part of barrier management therefore seems important.

4.2. *Rethinking the organizational potential*

We argue for a need to acknowledge that organizational elements may:

1. *Morph and change in nature* (e.g. from management strategy to operational decision).
2. *Be contagious* (in the way that organizational structures or principles may represent 'default' solutions that travels unquestioned across barrier functions).
3. *Travel long distances* (the unquestioned 'free-passing' (cf. point 2) is a force that potentially propels the organizational influence over long distances).
4. *Be channeled and transmitted* by forces of psychology (dynamics of social interaction).

These points emphasize the value of broadening the scope of organizational issues as part of barrier management. It may also suggest how: A broadening of scope should involve loosening up the categorical approach dictating a finite and static formula to define and establish organizational barrier elements. Alternatively or additionally, these organizational elements must be incorporated in the analysis as part of the risk influencing conditions that may influence several barrier elements (and thus contribute to risk transfer, and dependence between barriers). The 'forces of psychology' are critical here, and should permeate any of these broadening efforts.

This broadening of scope can in a sense be seen as a rethinking of the organizational potential; from organizational impact as a static proportion – towards a sensitivity of organizational elements or influences that in nature may be transient, changeable and context dependent.

5. Conclusions

- The scope of organizational influences should be broadened. One way to widen the scope could involve loosening up the categorical approach dictating a finite and static formula to define and establish organizational barrier elements. Alternatively or additionally, the organizational elements must be incorporated in the analysis as part of the risk influencing conditions that may influence several barrier elements. The approach to establish the organizational potential must be flexible, sensitive to context and open for changes.
- The impact of psychology must be incorporated into safety barrier approaches. Training is frequently emphasized as the curative way to go. People must be trained – to become capable, proficient and effective. The advantages of various training programs are pushed out and promoted by the safety experts. What often lacks is a focus on social forces and mechanisms that may well permeate the suggested measures and methods. In terms of safety barriers, there is a need to acknowledge how forces of psychology may affect the barrier system. A specific action that should be considered is to systematically examine barrier functions in terms of forces of psychology ('dynamics of social interaction'). A parallel critical action in these respects is to thoroughly consider the potential for risks to spread across barrier functions via these types of 'dynamics of social interaction'.
- The organizational and psychological mechanisms discussed in this article by nature influences several barriers and barrier elements and thus contribute to risk transfer, and dependence between barriers. Future barrier management should therefore emphasize more on incorporating these mechanisms when defining barriers and barrier elements, and when establishing performance requirements and indicators for measuring the performance.

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