VIOLATION OR RESILIENCE? A COMPARISON BETWEEN TWO FRAMEWORKS FOR MAKING SENSE OF WORK-AS-DONE

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Abstract. This paper compares two frameworks that help to make sense of work-as-done. One of these frameworks was proposed by Saurin, Costella and Costella (2010), and it allows the identification and classification of types of human error according to the skill-rule-knowledge based structure (Reason, 1997). The other framework was proposed by Rankin et al. (2014), which emphasizes the identification and classification of performance adaptations according to the resilience engineering paradigm. The comparison is illustrated by the analysis of a safety incident related to the work of electricians who perform emergency maintenance on overhead power distribution networks. The type of human error identification framework indicated that there was a violation on the part of workers, while the adaptation analysis framework revealed a resilient action. Although the type of human error identification framework revealed issues related to the quality of procedures, training, and technical failures, it did not provide visibility of resilience aspects and encouraged oversimplified analyses by relying on yes-or-no answers.

1 INTRODUCTION

Deviations from the prescribed work are often treated as violations by accidents investigators and even in academia. From this perspective, deviations occur intentionally and the typical corrective measures involve the reinforcement of training so that people follow rules, disciplinary sanctions and, less frequently, the redesign of the prescribed work. On the other hand, several studies stress the context in which the violations occur. For example, in complex and high-risk environments, such as nuclear power plants, Leveson (2004) found that rule violation seemed to be quite rational when one takes into account the overwork and time pressures under which operators perform their tasks. Violations may in fact be an inevitable by-product of the need to achieve the desired performance in complex systems (Polet; Vanderhaegen; Amalberti, 2003). In this light, violations are not a risk, but rather a reflection of the intelligence and adaptability of workers (Amalberti; Auroy; Aslanidès, 2004).

By contrast, the resilience engineering (RE) view emphasizes the need for the continuous feedback of work procedures so as to minimize the distance between the prescribed and actual work, which tends to reduce the incidence of violations. In fact, RE argues that monitoring and modifying the rules is as, or even more important than their initial development (Hale; Guldenmund; Goossens, 2006). Based on this, organizations should give support to workers so that they can make performance adaptations when necessary (Grøtan et al., 2008). From the RE perspective, therefore, adaptations by workers serve to adjust imperfections in procedures, which will always be incomplete (Sandberg; Albrechtsen, 2014).

This paper discusses how these two perspectives - violations and resilience - can be used to make sense of safety incidents. Two tools that are representative of the two perspectives were chosen to support the analysis: a framework for the identification and classification of human errors (Saurin; Costella; Costella, 2010), and a framework for adaptation analysis (Rankin et al., 2014). Both tools were applied to the analysis of a safety incident related to the work of grid electricians who perform emergency maintenance in an electricity distribution network. This sector was chosen since it has characteristics of complex socio-technical systems, such as uncertainty and a dynamic work environment.

2 THEORETICAL BACKGROUND

2.1 Identification of types of human error

The tool for the identification of types of human error is based on a classification of three levels of cognitive performance proposed by Rasmussen, known as the SRK model. Reason (1997), however, discusses these levels at length. According to this author, the three levels of performance are:

- Skill-based (SB): carrying out routine tasks in an automatic way. This is the mode in which people work most of the time.
- Rule-based (RB): applying memorized or consciously written down routines in order to verify whether the solution is adequate or not.
- Knowledge-based (KB): this is a level in which people enter reluctantly, only as a last resort and in new situations, which applies neither routines nor rules.

The framework for the identification of types of human error was developed on this foundation by Costella and Saurin (2005) based on the observation, in a case study, that accident investigations defined most accidents as being caused by a "lack of attention" of the victims. However, in a more in-depth analysis this did not fit reality, which motivated the development of a tool that could assist in the investigation of accidents and give visibility to the context in which the human error occurred.

The final version of the framework consists of 10 questions (Figure 1), which will be further explained below according to Saurin, Costella and Costella (2010), and which may lead to five types of final answer: slip, lapse in memory, violation, knowledge-based error, and no worker error.

In question 1, the word "task" has a broad meaning, referring to a set of operations carried out to achieve a certain objective. If the answer to question 1 is negative, question 9 should be answered to lead to an end result representing either a violation or the absence of operator error. This part of the framework was introduced because of situations in which the worker was performing tasks outside his usual post.

Subsequently, question 2 should be answered to verify whether the procedure and/or training were appropriate and applicable. If not, the flow chart indicates that the final answer should be "no worker error". If the answer is "yes", on the other hand, then question (3) should be made: "Was the procedure and/or training followed?"

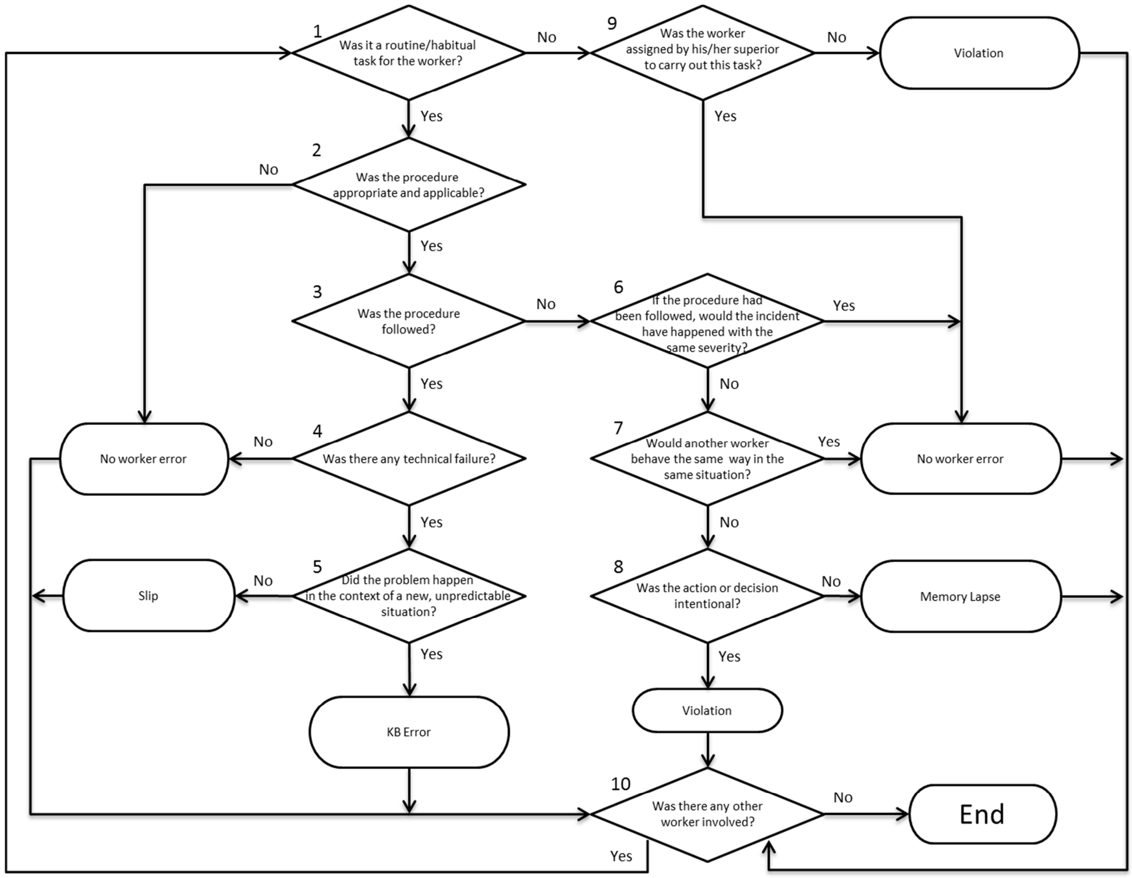

Figure 1. Human error identification framework (Saurin; Costella; Costella, 2010)

This question opens up two large branches in the flow chart. In case of a positive response, one should ask if there was a technical failure (question 4), which, if confirmed, indicates that there was no worker error. If no technical failure occurred, the question whether the problem occurred in the context of an unforeseen situation (question 5) should be asked, which characterizes an error at the level of knowledge (error KB). If it's a routine situation, then the slip is confirmed.

A negative answer to question 3, on the other hand, opens a new branch that starts with question 6. A positive answer to this question indicates that the causes of the event were not linked to either the quality of procedures or the compliance with them, leading to the response "no worker error". In the event of a negative response, question 7 should be asked, which Reason (1997) called the substitution test. If the conclusion is that other workers would have acted in the same way, the chart indicates that the conclusion has to be that "no worker error".

Subsequently, question 8, which asks if the action or decision was intentional or not, will establish if there was a memory lapse. Otherwise, a violation will be registered. It is worth pointing out that after obtaining a conclusion about what type of error occurred, or after concluding that there was no error, one should always question whether other workers were involved (question 10), and if so, run the framework again.

Studies with this framework have been applied in the agricultural equipment sector (Costella; Saurin, 2005), in a fuel distributor (Saurin et al., 2008), in the civil construction sector (Saurin; Costella; Costella, 2010) and in the slaughterhouse sector (Costella; Masson, 2012).

2.2 Framework for the analysis of performance adaptations

Furniss et al. (2011) conducted case studies in the context of a control room of a nuclear power plant in order to observe the strategies used by people during adaptations related to the trade-off between safety and efficiency. To support the analysis of these strategies, a framework was developed that was then perfected by Rankin (2013) and Rankin et al. (2014).

The framework supports the analysis of adaptations performed by workers, targeting three main areas: (a) a contextual analysis, (b) enablers for successful implementation of the strategy, and (c) reverberations of the strategy on the overall system. These three areas are in turn subdivided into:

- Strategy: describes the adaptations used to respond to variation in the environment. “The strategies may be developed and implemented locally (sharp end) or as part of an instruction or procedure enforced by the organization (blunt end) or both (Rankin et al., 2014, p. 6)”.
- Objective: the target for which the adaptation was performed should be described. According to Rankin et al. (2014, p. 6), “the objective is related to identifying demands, pressures, and conflicting goals”.
- Forces and situational conditions: “describes the context in which strategy is carried out (Rankin et al., 2014, p. 6)”. This category helps to make sense of the objectives, which depend on internal and external forces of the organization.
- Resources and enabling conditions: this category describes the existing conditions for the adaptation to be implemented successfully. For Furniss et al. (2011), these conditions may be hard (e.g., availability of a tool) and soft (e.g., availability of knowledge).
- System ability (resilience abilities): the adaptation should refer to one of the four cornerstones of resilience described by Hollnagel (2009), which are, anticipating, monitoring, responding, and learning.
- Sharp-end and blunt-end interactions: first, it is necessary to define at what level the adaptation occurs and how it relates to the sharp/blunt end. In addition, it is necessary to identify how organizational changes affect work performance.

3 RESEARCH METHOD

The study was conducted in an electricity power distributor, which performs works in electrified and un-electrified networks. The study focus was defined as the maintenance procedure of high-voltage electrified networks, given that this was linked to a serious incident detected by the behavior-based safety program, and because it's one of the more complex activities carried out by the company.

In order to understand the real work and obtain data to apply the two frameworks, interviews were carried out with 12 electricians, all male, of which two were shift leaders. The interviews followed a script with twelve questions related to training and procedures – e.g. training and refresher courses, considering the frequency with which they are carried out; whether any of the processes in the procedure are considered unnecessary; whether changes occur in the procedures, how often these occur, and whether such adaptations are re-laid to the safety department and integrated into the working procedures; how each electrician proceeds when the work situation is not covered by a procedure; whether they ever refused a task on duty, and whether they knew that this is provided for in the company's internal rules; whether they consider themselves competent to perform the activities of their profession.

In addition to the interviews, the actual work was observed and documents were analyzed, such as the procedure associated with the incident analyzed and the training records associated with it. This enabled the application of the frameworks and, subsequently, the discussion of the results.

4 RESULTS

The safety incident under study was covered by the maintenance procedure of electrified high voltage networks, which is quite extensive. This procedure covers the repair of the electrical network when something happens that interrupts the supply of electrical power, such as tornadoes, transformer explosions, falling trees, etc. The procedure consists basically of three steps: the stabilization of the pylon(s), after which the cables of the electrical and other existing networks are extended and, subsequently, connected to the pylon and the transformer. This last step is critical since it requires the worker to climb up the pylon.

The procedure studied was the climbing of the pylon, which requires a maneuver to transpose the lower hanging wires, including wires for telephony, cable TV and the low-voltage power network. The most frequent and serious non-compliance with this procedure is related to this transposition, which tends to be adapted by electricians because most of them don't consider the rope grabs coupled to the safety belt to be a reliable piece of equipment. As a result, they perform this transposition by simply fastening the safety belt without the rope grabs. This activity is not safe, because during the transposition, the electrician's safety belt will not be attached. Two fall accidents happened in this company as a result of this situation.

The framework for identifying types of human error, as indicated in Table 1, pointed out that this non-compliance could be classified as a violation, following the response path: 1-2-3-6-7-8-Violation.

Table 1.Human error identification framework paths

N.	Question	Answer
1	Was it a routine/habitual task for the worker?	Yes, all interviewed workers said that they had received training for this task when they joined the company.
2	Was the procedure appropriate and applicable?	Yes, because the procedure is in compliance with national legislation and has appropriate technical principles. They also reported that there is follow-up by a responsible person, who verifies the applicability of the procedure.
3	Was the procedure followed?	No, because they used the safety belt and rope grabs differently than requested. At a given time, while passing the lower cables, they disconnected the belt, which is not allowed.
6	If the procedure had been followed, would the incident have happened with the same severity?	No, since the electrician would not have fallen on the low voltage transition if the safety belt had been fastened to the rope grabs.
7	Would another worker behave the same way in the same situation?	No, because most workers follow the procedure. However the fact that several electricians complained about this step of the procedure indicates compliance can be difficult.
8	Was the action or decision intentional?	Yes, he was aware that they were not following the procedure, since he reported that they felt safer that way.
	Results:	Violation

The application of the adaptation analysis framework (Rankin et al., 2014), on the other hand, produced the following results (Table 2):

Table 2. Adaptation analysis framework paths

Categories	Answer
Strategy	The strategies developed to interpret and respond to changes in the environment were carried out, firstly, by the electricians (sharp end). They also reported that there are adaptations in the procedures and that the written procedures do not occur exactly as the activities in the field, i.e. the sequence of tasks "on paper is one thing, but another in practice". The explanation of electricians is that procedures are created for ideal work situations, but the actual working conditions are rarely ideal, either because of time pressure, failure and/or unavailability of equipment or inadequate planning. The result was that electricians did not trust this piece of equipment and sometimes improvised ways of climbing up the post.
Objective	The objective was to re-establish power in the shortest time possible.
Forces and situational conditions	These are related to the lack of specific training based on the procedure, which is made worse because of the high turnover rate. Furthermore, the field conditions during the execution of the task are often a drawback, since teams could work at night and in the rain.
Resources and enabling conditions	Despite the need for more effective training, there is a formal structure for admission and periodical training.
System ability (resilience abilities)	Responding
Sharp/blunt end	Sharp end, since it is the field teams who respond to the maintenance need.

In summary, the result of the type of human error identification framework was that there was a violation on the part of workers, while the adaptation analysis framework revealed a resilient action. This means that although the type of human error identification framework reveals issues related to the quality of procedures, training, and technical failures, it does not provide visibility of resilience aspects and encourages oversimplified analyses by relying on yes-or-no answers. In fact, this result is consistent with the experience of two authors of this paper who have taught the Saurin, Costella and Costella (2010) framework in undergraduate and graduate courses. Although it is explained to the students that the framework's purpose isn't to find culprits, and that it should only be the first step or an element of a more comprehensive investigation, many students have difficulty in accepting this recommendation. Terms as "errors" and "violations" tend to be immediately associated with guilt, and the analysis of the event is focused on the negative aspects. The adaptation analysis framework, on the other hand, managed to detect the resilient actions performed by the workers as a result of evaluating six aspects in a descriptive manner, inducing questions that were able to assess resilient actions.

4 CONCLUSIONS

This paper discusses how traditional safety management practices, such as error analysis frameworks, contribute to hiding the adaptive capacity of individuals, teams and organization. This subject was discussed in a highly regulated environment, where non-compliance with procedures occurred as a result of various failures. Most of these were adaptations the workers made during the execution of the work, which, when analyzed through the adaptation analysis framework, could be classified as resilient actions. As such, the two frameworks represent opposing views about the nature of the work in complex socio-technical systems, and it is worth noting that neither completely captures the ambiguity of events. In fact, although the Rankin et al. (2014) framework takes resilience into account, it does not question its side effects, such as hazards that could cause an accident under slightly different conditions.

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