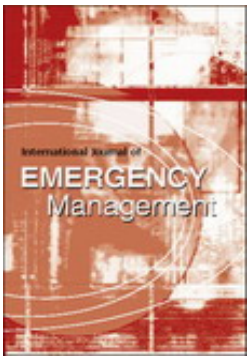

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Professionalisation in safety: in the heart of emergency response

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Professionalisation in safety: in the heart of emergency response

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Abstract: During a large-scale exercise designed to test the effectiveness of a Seveso type emergency plan of an industrial site, a specific observation method of the simulation was implemented. It is articulated around the combination of specialised observers (post graduate students in Industrial Risk Management) that focus on key people, essential tasks and paramount locations that drive the dynamics of the emergency response. Associated with an interpretation model called structure-relation-meaning, this method allows to produce three levels of organisational learning (single loop, double loop and triple loop). Resulting knowledges benefit the company, the administration, the students and the faculties. This paper presents the experimental setup, the analysis methodology, then the results obtained are discussed. The paper's goal is to give useful information to safety professionals in companies who can integrate partly or entirely the observation method for emergency response simulation. It is also useful for faculties that teach on emergency response simulation.

Keywords: organisational learning; loop learning; emergency response; resilience engineering; sensemaking; professionalisation in safety.

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Cédric Denis-Remis is the Founder and Director of the IHEIE (Institute for Higher Education in Innovation and Entrepreneurship) and Vice President of PSL university. He demonstrated ability to develop, manage and lead international institutions, proved track record to develop profitable high level education programs.

1 Introduction

Emergency response to an industrial accident is carried out under severe time pressure and may expose rescue teams to perilous situations. It would be presumptuous to believe to cope to such circumstances without preparation and that is why plans are set on purpose. In practice, an operating commander coordinates the tasks of the different units responding to the emergency and a large amount of data is gathered providing information that will support decision making. Constant feedback from the field is essential to monitor their execution to assess their effectiveness (Mendonca et al., 2001). Teaching about emergency response is quite an educational challenge regarding its inherent complexity. The post master Industrial Risk Management (MS MRI) from PSL University – Mines ParisTech, has grown in the last 14 years to be more and more professionalising. A major guideline of MS MRI is to develop better education in risk management to bridge theoretical aspects to the professional real-life context (Van Wassenhove and Foussard, 2018, 2020). MS MRI address that kind of topics by combining different medias that involve strong implication of safety professionals, the use of realistic case studies and interactions with industry practitioners (Wybo and Van Wassenhove, 2016).

This paper describes an internal emergency response simulation realised by a company using a specific observation method. The company was supported by a group of students of MS MRI who took care of the set up and realisation of the observation method. The results (methodology set up and lessons learned on the simulation) were

presented to the company. The main educational objective is to identify factors that effectively influence the performance of emergency response. Prior to the exercise, theoretical lectures framing concepts of resilience engineering have been given. As a reminder, resilience is articulated around four cornerstones (Hollnagel, 2016) which are

1 anticipating future threats and opportunities

2 monitoring ongoing developments

3 responding to events

4 learning from past failures and successes.

The target for students was to set up an observation method associated to an interpretation model that would enhance learning capabilities of the organisation through the practice of emergency response simulation.

The main goal of the set-up was to provide the organisation more insights into their emergency response system. It was also an opportunity for the students to learn and to experience real life situations. We claim this is a win-win partnership. The first part of this paper describes the company and the emergency simulation organisation (site, scenario, field). The second part describes the observation methodology, principally based on the research work of J.L Wybo. We invite the reader to investigate the corresponding references for more detailed information on the method. Section 3 describes the results and the last part is the discussion.

2 Context

2.1 Internal emergency plans

The Seveso-III-Directive (2012/18/EU) is aimed at the prevention of major accidents involving dangerous substances. It covers establishments where dangerous substances may be present in amounts exceeding certain threshold. Even if prevention measures are set, an accident is still possible and it also aims at limiting the consequences of such accidents. Thus, operators are demanded to take all necessary measures to prevent major accidents and to limit their consequences for human health and the environment. The requirements include notification of all concerned establishments (Art. 7), deploying a major accident prevention policy (Art. 8); producing a safety report for upper-tier establishments (Art. 10), providing information in case of accidents (Art. 16). The article 12 requests producing internal emergency plans for upper tier establishments.

> "The emergency plans shall be established with the following objectives: (a) containing and controlling incidents so as to minimize the effects, and to limit damage to human health, the environment and property; (b) implementing the necessary measures to protect human health and the environment from the effects of major accidents; (c) communicating the necessary information to the public and to the services or authorities concerned in the area; (d) providing for the restoration and clean-up of the environment following a major accident."

The article 12 also states that Member States shall ensure that internal emergency plans are reviewed, tested, and where necessary updated by the operators at suitable intervals of no longer than three years.

2.2 Site description

The establishment is a specialty graphite materials factory which employs 250 workforces. The footprint of the facility is 7 hectares within an urban neighbourhood which includes schools. Most of the production is done by machining, but some workshops use purification processes within high temperature furnaces or chemical vapour deposition (CVD) which require the availability of two main dangerous substances (chlorine and hydrogen) that may indeed be present on site. The amount of dangerous substances is significantly less than the thresholds for upper tier establishment, but the inner-city location of the facility has led to the creation of an internal emergency plan. A last important point worth mentioning is that most of the time, water is the agent of choice for structural fire suppression for many reasons (e.g., general ability of water from fire hydrants in communities or from rivers and lakes in rural areas, cheapest fire extinguishing agents...). In the plant, water should not be used as extinguishing agent nearby graphite furnaces, because when water passes over red hot coke a specific chemical reaction ($H_2O + C \rightarrow H_2 + CO$) can occur and produces significant amount of *syngas* which is composed of carbon monoxide and hydrogen and eventually creating new hazards due to its flammability and its toxicity.

2.3 Scenario description

2.3.1 Synopsis

An autoclave is a strong, heated container used for chemical processes via high pressures and temperatures. The accidental scenario for the exercise is based on the explosion of an autoclave inside a workshop as a primary event. Four casualties (i.e., injured workers in nearby location) are to be cared for. The explosion damages a 2 inches pipeline of methane from the heating network leading to a fire which will escalate to the roof of the workshop. Then, the gas detection system rings an alarm indicating a chlorine leakage, the isolation system of the chlorine network performs its function properly. A detailed description of the action is given in Figure 1.

2.4 Emergency response organisation

The organisation of emergency response of the facility can be described considering two main parts which are *command post* and *field* (cf. Figure 2).

2.4.1 Command post

The management of the strategic apex of the organisation is the duty of the operations commander. This function is held by the Plant Manager with the assistance of a secretary who is in charge of scribing events and recording the timeline of the actions. The Operations Commander has on the one hand, three direct internal reports, each of them oversees respectively relief intervention, field operations and logistics. On the other hand,

the Operations Commander is in relation with the Firefighting Officer who is on duty of the operational command of the fire brigade. If there is any choice to make in the strategy of intervention (e.g., allocation of resources to protect a part of the plant regarding another), the decision is eventually taken by the Operations Commander. In addition, a group is dedicated to public relations to respond to media solicitation while minimising interference with the conduct of emergency operations.

Figure 1 Scenario of emergency exercise

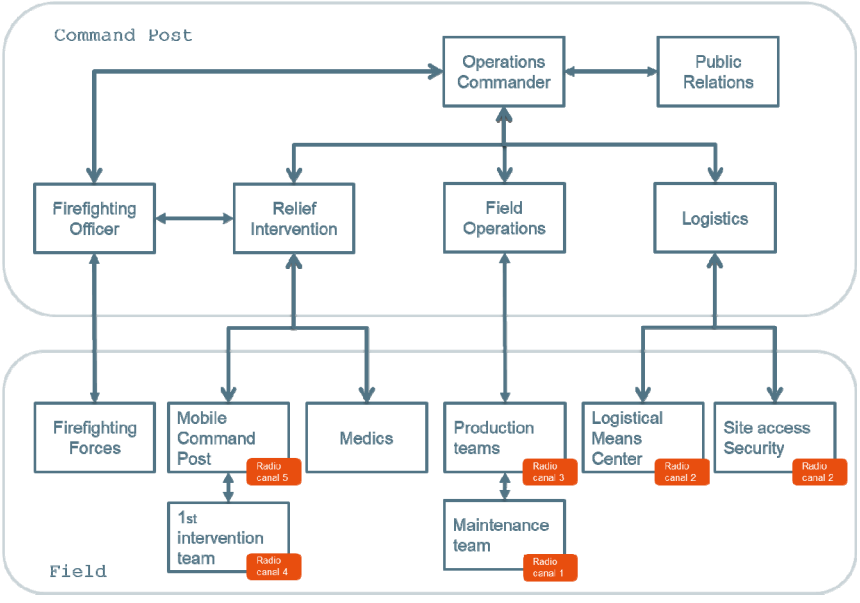
Time	Synopsis of actions
T0	A security agent hears a blast. He sees a cloud of smoke and a victim near the autoclave workshop
	Security agent calls in-site firefighting
	Operation commander called Emergency Response Plan launched : Command Post opened
	External firefighters called
	General Alarm
T1	Situation point of 1st intervention team
T2	Situation point 1st intervention team & mobile command post
	Rescue of 1st victim by 1st intervention team
T3	External Firefighters arrived on site
T4	Situation point : Operations Commander & Firefighting officer
T5	Start of securing facilities process : stopping equipments, energy management, hazardous materials checking,...
T6	Facilities secured
T7	POB counting (1st check)
T8	Firefighters engaged : scouting of missing persons
T9	Chlorine detection alarm rings
T10	Production teams engaged : checking of automatic chlorine distribution shutdown & chlorine bottles closed
T11	Fire propagation on the roof of the workshop
T12	POB counting (2nd check)
T13	Firefighters engaged : rescue of victims inside buildings
T14	Victims rescued, Fire controled, facility secured

2.4.2 Field

The front line of the emergency response mobilises dozens of dedicated people. Firefighting forces have their own chain of command to supervise more than 50 firemen with 10 fire engines. The first intervention team is composed of six operators that are specifically trained (e.g., rescue to person, SCBA, …) run by a team leader who is the official correspondent of the chief of firemen at the mobile command post on the field.

A nurse oversees medics before possible evacuation of the potential wounded to the hospital. Duties of production teams and maintenance team are to ensure safety of operating facilities (i.e., conduct process shutdown, ensure cooling of furnaces, inventory of hazardous materials…). Logistics means the centre should manage the supply of any support needed by the intervention (e.g., cranes, trolley, raw materials, food…). Finally, Security tasks are mainly management of flux of people (e.g., site access, partial or total evacuation, …).

Figure 2 Emergency response organisation as per the emergency plan (see online version for colours)



3 Experimental apparatus

3.1 Data collection

Field observation methods are grounded on immediate contacts between researcher and the studied reality. This type of observation is essentially based on the information that the researcher obtains from the use of his or her senses (e.g., sight and hearing), if necessary supplemented by interviews or documentary investigation (Del Bayle, 2000). The observation method used in this experiment is said to be *external* as the observation is the fact of an observer foreign to the phenomenon studied. Regarding our case study, this method has several advantages, as it is particularly adapted to the fact that the observers are researchers specialised in the disciplines related to the phenomena observed. In addition, it presents rather strong guarantees of validity and objectivity because the risks of interaction are limited by the distance initially existing between the researcher and the observed phenomenon (Patton, 1990). In this case study, observers are post-graduate students from MS MRI who are taught to be safety professional and as a matter of a fact, they are not trained researchers. Consequently, several guidelines and fundamentals of direct observation have been reminded:

1 have an adequate state of mind (e.g., entering the observation process without pre-conceived notions and fixed expectations, being dynamic and curious, be prepared to follow advice from people met, use the opportunity to observe things which were not planned, keep focused to make valuable comparisons …)

2 respect methodological strictness (e.g., clearly note observations made and information volunteered, record contradictory information (i.e., surprising to expectations), be aware of what was not seen. (i.e., note the absence of actions or reactions...)

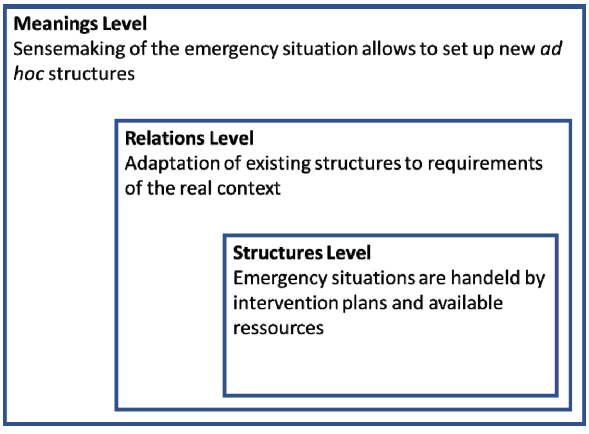
3 demonstrate a proper behaviour (e.g., follow local rules, respect resident culture, observed people also look at observers…).

3.2 Interpretation model: structure-relation-meaning

What are the factors that influence the performance of emergency response? To address this question, we use a model defined by Wybo and Jacques (Wybo et al., 2006; Jacques et al., 2004) which is fitted to address case studies both on real events or on simulation exercises. Three complementary levels (structure, relation, meaning) are noticeable in any process of emergency situation or crisis prevention (cf. Figure 3).

> "The interest of this conceptual framework is to find a balance between a mechanical, structural-functionalist perspective and a perspective that integrates the actors with their own interests, the way in which they participate in the implementation of this structure as well as the sense that they will give to it." (Jacques et al., 2004)

Figure 3 3 levels of responses of an organisation to emergency situations (see online version for colours)



Source: Adapted from Wybo (2012)

3.2.1 Structures

The first level is structures. Structures involve everything that is prearranged by the organisation and give it the form to accomplish its goals (Nelson and Quick, 2011). Structure is mainly composed by elements that can be objectivated. (e.g., time response to an alarm, number of workforces involved in a task, firewater flowrate…). Those types

of elements are supposed to be part of the emergency plan and associated metrics can be set in order to provide measurement. A gap analysis can be conducted between what is expected and what is performed. Regarding everyday life, standards, rules and procedures are parts of the artefacts that allows the organisation to keep routine operations under control. It refers to the formal configuration between people (e.g., tasks' allocations, sharing of roles and responsibilities, delegation of authority) within the organisation (Greenberg and Baron, 2011). A widely used framework to analyse structures has been given (Mintzberg, 1992) by articulating concepts such as strategic apex, operative core, hierarchy line, techno structure and support services. Regarding emergency response situations, structure tallies with elements that has been planned as a response to known events such as emergency plan, procedures, command post, crisis room, human resources, dedicated means... (Wybo, 2008)

3.2.2 Relations

The second level is relations. It matches with the adaption by the actors of the structure to the real context of the situation. In other words, structure is a framework for actions including interactions (Crozier and Friedberg, 1977). The concept of interaction refutes the idea of communication as a linear phenomenon in which a single person sends a message to another one who decodes it. Communication is postulated as a permanent social process involving many verbal and non-verbal behaviours such as speeches, postures, gestures or looks (Watzlawick et al., 2011). Interactions are not only governed by external structures imposed on individuals, but they are the ones who create social organisation through their regular interactions (Garfinkel, 1967; Goffman, 1978). Each actor brings its own influence through a balance of personal concerns, authority and capabilities. Organisations are led to adapt their strategies, their plans and usage of resources to ensure continuity of system operations and this ability is mainly based on the quality of relationship that exist between the actors. Many influential actions, subtle processes and constant changes take place in groups (e.g., competing for social status, tradeoff, pressure on individual, conflicts…) can be described through group dynamics (Lewin, 1951). Relations level gives the organisation litheness to deal with deviations from the plans. To fulfil their assignments regarding management of the situation people regulate their activities through interaction to cope with variations from nominal state (Wybo, 2008).

3.2.3 Meaning

The third level is meaning. It steps in when the first two levels are unsatisfying. It is linked with the ability to understand, to make sense with the situation, which allow the apparition of new forms of organisation or communication. Meaning makes possible the act of organising, the latter in turn makes meaning possible. Creating meaning enables actors to share mental models, values and beliefs, coordinate activities and interact. They build their reality through the interpretations they give it. From this perspective, creation of meaning is a fundamental organisational problem as the inherent ambiguity of the environment makes it necessary (Weick, 2001). This level aims to understand how people within organisations make sense of what is happening around them and build their reality through a process of communication and interpretation of information. This construction of reality (i.e., a process which have the following properties: *identity, retrospective,*

enact, social, ongoing, embellished extracted cues, plausible) is the foundation upon which the actions and decisions taken are next (Weick, 1995). People use it to justify (e.g., values, ethics, legitimacy, center of interests) their actions and every behaviour will be predisposed by the actor's associated representations. On the one hand, the juxtaposition of different worlds impairs the ability to act coordinated for a common task (Boltanski and Thevenot, 2006), but on the other hand, the variety of viewpoints enables to set up new intervention methods in order to guarantee the subsistence of the organisation when the situation has drifted far away from what has been planned.

3.3 Observation method and dispatch

A specific observation method is associated to the interpretation model described in the previous paragraph. The observation of the organisation during the simulation of the emergency response situation is based on a variety of perspectives from dedicated observers. By compiling and confronting their notes, it becomes possible to conduct an in-depth analysis that address the complexity of organisational behaviour. Thus, further than the mere finding of deviations from standard practices, it allows to generate meaning and to learn richer lessons than a conventional debriefing (Wybo, 2004). To gather data from crossed looks, three kinds of observers are defined who respectively deal with observation of key peoples, tasks and locations.

3.3.1 Key people

"Key people" is a term used specifically for an employee or executive who is core to the execution of the emergency plan and his absence or disability could prove to be disastrous for the organisation. For this reason, emergency plan designates spare people for each key function who has the capabilities to take the assignment. The purpose of observing key people is to collect data regarding

1 the way they use what is proposed in the emergency plan (e.g., scenario card, maps, reflex sheet, protective equipment…)

2 relationships with other actors (e.g., information they receive and emit, people with whom they collaborate, time management, steering…)

3 how they express or rationalise decisions they make (e.g., how they comprehend situations, what representations are shared, how they react in front of discrepancies, how they deal with lack of information…).

3.3.2 Task

The implementation of the emergency plan requires the execution of many tasks related to the deployment of relief supplies and communication processes between the different entities described in Section 2.4. The analysis of the tasks therefore requires prior knowledge of these tasks as prescribed in the emergency plan. As part of the exercise, the students will have as available material the observation of activities, that is, the expression of the interaction between tasks and subjects (i.e., the people in charge of performing the tasks) (Leplat and Hoc, 1983). The observation highlights gaps between what is expected and what is really happening. As a matter of a fact, there is always a disparity between how one thinks that work is done and how work is actually done

(Dekker, 2006). Most of the time, work-as imagined is based on previous experiences of work-as done, but the main limitation is the inherent variabilities of circumstances (e.g., expectations, available resources…). The concepts of prescribed task and actual task allow the formalisation of these observations. Obtaining a description of an actual task involves collecting indicators of the course of activity caused by the prescribed task. The actual task therefore appears as a model of activity. Finally, the difference between the prescribed task and the actual task allows the elaboration and testing of hypotheses on the activity (Sperandio, 1977). The purpose of observing activities is to gather data regarding how each specific task is achieved, what are the complications encountered and how people adapt, who actually participates to the execution, what resources are exploited…

3.3.3 Locations

The execution of the emergency plan put in the forefront several specific locations (e.g., accident location, command post, assembly points…) The observation of a specific location includes the description of the environment (e.g., public/private, occasional/ habitual use, condition of access ....). A general map allows to note the different positions of people in space (e.g., occupancy rate, flow, means of access, functions, reason of the presence), the temporal dynamics are also observed (Peretz, 1998). Basically, the purpose of observing specific location is to harvest data regarding who is there, what is done, how this place is perceived by people …

3.4 Group assignments

Sixteen pairs of observers have been set, four in charge of key peoples (operation commander, firefighting officer field, relief intervention manager, field operation manager), three in charge of tasks (alert, counting, wherewithal deployment) and nine in charge of specific locations (accident location, command post, mobile command post, nursery, assembly point (x3), control room, main gate) (Figure 4).

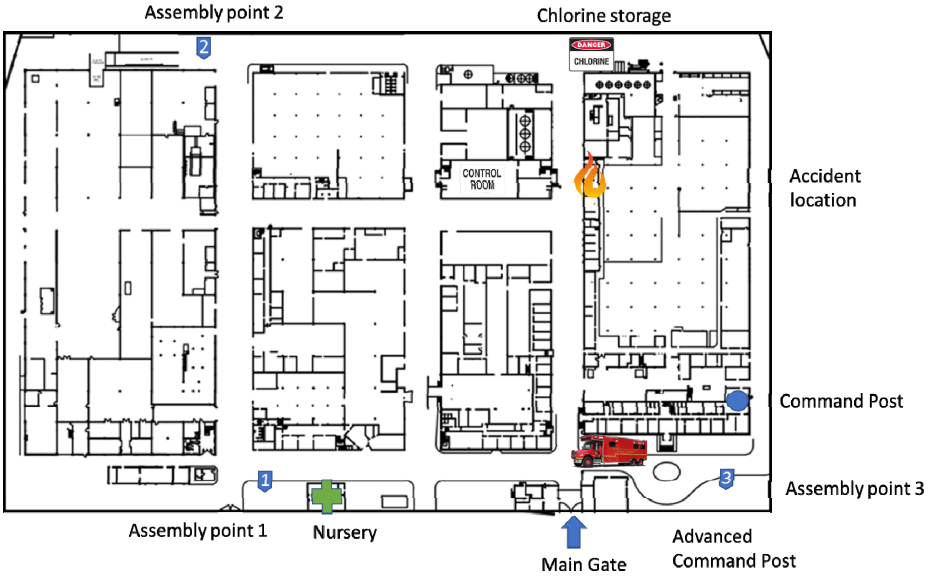
Figure 4 Group assignment for observations

Type of observation	Assignement	Observer's group
Key peoples	Operation commander	Group 1
	Firefighting officer (field)	Group 2
	Relief intervention manager	Group 3
	Field operation manager	Group 4
Tasks	Alert	Group 5
	Counting	Group 6
	Wherewithal deployment	Group 7
Locations	Accident location	Group 8
	Command post	Group 9
	Mobile command post	Group 10
	Nursery	Group 11
	Assembly point (x3),	Groups 12, 13, 14
	Control room	Group 15
	Main gate	Group 16

3.5 Site overview

Figure 5 displays specific locations (accident location, command post, mobile command post, nursery, assembly point (x3), control room, main gate).

Figure 5 Site overview and location of point of interest (see online version for colours)



4 Results

4.1 First impressions

From the initial event (i.e., explosion of the autoclave) to the announcement that the situation is fully under control, the simulation last for two and a half hour of real time intervention. At the end of the simulation, a hot debriefing was conducted by the firefighting chief assisted by a fireman specialised in supervision of exercises related to emergency plans. The management of the exercise was considered satisfactory. The alert scheme operated correctly, the crisis room was implemented in a timely manner, all the members were informed, knew their roles and used the tools provided correctly (e.g., reflex cards). On the field, the collaboration between the intervention teams and the fire brigade was effective: the victims were taken care of, information needed for the deployment of the emergency resources was transmitted, the markup of safety perimeters and evacuation of personnel were properly held. From the firefighters' side, the ramp-up procedures (i.e., ICS-Incident Command System) were effective and those despite the presence of many new comers within the brigade. Lastly, the quality of the performance of the Operation Commander (a role held by the Plant Manager) was emphasised. He demonstrated a coherent and adapted leadership. The usual effects of isolation or seclusion of the crisis room (Lagadec, 1995) have not been observed despite some difficult communication episodes between the field and the command post.

4.2 Corpus

Following the exercise, the administration sent a report attesting that no regulatory non-compliance has been identified. However, seven points of improvement dealing with the logistics of the crisis room, information management and communication modes are mentioned. The transcripts of the observations made by the student groups were formatted by themselves as a timeline. Additional clarification interviews were conducted with key people. Feedback and suggestions from participants (see Section 2.4) following a cold debriefing one week after exercise were collected by an HSE specialist of the plant. Thus, the resulting corpus is composed of the administrative report, the formalised observation book, the key people interviews and the participants' proposals.

4.3 Learnings

4.3.1 Are we doing things right?

The main expectation of such real scale emergency response simulation from the administration and the company management is to gain confidence regarding the ability of the organisation to contain and to control incidents so as to minimise the effects, and to limit damage to human health, the environment and property (art.12, SEVESO III). The expected learning is truly operative: according to the gaps between expected and actual outcomes, organisation will take measure to modify their actions to mitigate discrepancies and improve procedures accordingly. The fact that the exercise was well appraised definitely does not mean that everything went as planned. Emergency plans are set upon the courses of action needed to mitigate impacts of an accident. These response plans can rarely be executed as expected. (Mendonca et al., 2001). For instance, the simulation highlighted that the procedure for counting workforces in case of accident is flawed. The idea is to take attendance at each of the three assembly points, then sum up the numbers and compare with registration from swipe cards at the main access gate. It appeared that several workforces are not supposed to reach assembly points (e.g., emergency response team, people of the command post, nurse, main gate-keeper…), so the counting process becomes dodgy. Counting is a crucial part of emergency plan as it gives information regarding missing people and potential victims. As an operational result, an action plan has been set to clarify roles and responsibilities, a training program for people on duty is in progress and a deeper analysis is driven to enhance reliability of the counting method.

Observations of the locations "assembly points" and of the task "counting" give students the opportunity to appreciate that managing the roll call of over 200 peoples within a 7 hectares facility during an accident have very few in common with counting nuts in a box. This theme is a perfect illustration of the merits of the conceptual distinction between prescribed task and actual task. It allows a fair description of the differences between what is projected and what is really done. The operations are then improved by making correction in both procedures and behaviours. That type of learning is called single-loop learning and it occurs 'whenever an error is detected and corrected without questioning or altering the underlying values of the system (Argyris, 1999). It assesses capabilities regarding structures (Wybo, 2004) by questioning if the organisation has the ability to follow its own rules. It answers the question "Are we doing things right?" (Flood and Romm, 1996). The benefit of this approach is first operational, in

order to correct disappointing results, the antecedent actions are modified according to a deterministic cause-consequence model which will then be reevaluated by trial-and-error protocols. Second, it could be easily seen as part of the continuous improvement models advocated by safety management systems.

4.3.2 Are we doing the right things?

Resilience engineering provides a framework wherein one of the pillars is response defined as knowing what to do (Hollnagel, 2016). This involves doing what is expected in an effective way and this corresponds to the first level of operational learning presented in the previous paragraph. Yet, the richness of the available corpus makes it possible to produce more elaborate knowledge than a mere gap analysis. It shows how the organisation has adapted to the requirements of the actual situation. As pedagogical matter for students, it clearly illustrates that it is possible to go further than the usual definition of safety by reference to its opposite, the absence of safety, or as the freedom from unacceptable risk. (Hollnagel, 2018).[1] It is also aligned with the idea that Safety is created by people. A temptation from the result of single loop learning could be to reduce degree of freedom of people through automation or stringent procedures, but this second level of learning allows to collect evidence that Safety in complex systems is created by people through practice at all levels of the organisation (Dekker, 2017).

Compiling data from all the observers through the conception of a single timeline is a crucial part for the learning. This step elicits the inconsistencies, and makes it possible to apprehend the events in their plurality. Each person develops a singular representation of the circumstances according to the place, his missions, his experience, the level of information, ... (Denis-Rémis et al., 2013). The observation reveals the differences between the field activity and the representations in the Command Post. For example, the operational management of victims (i.e., localisation, evacuation, identification, access to care) was satisfactory, yet the confusion about the mastering of this activity sustained in the Command Post, due to feedback of conflicting information through multiple channels of communication. Conversely, the deployment of the means of extinction was perceived as perfectly controlled from the control room while a group of firefighters was observed in full hesitation, it was established that the tasks that were prescribed to them were confused and that he did not have sufficient information regarding the layout of the plant. Thus, the same event does not generate the same stories, some elements seem irreconcilable. It is therefore essential to question the assumptions that form the various representations. That type of learning is called double-loop learning and it occurs ‘when mismatches are corrected by first examining and altering the governing variables and then the actions’ (Argyris, 1999). The expected learning is rather tactical and it answers the question “Are we doing the right things? (Flood and Romm, 1996).

In the previous section, it is reported that the counting procedure was flawed, but the team became aware of it in real time. It was observed that field ops and logistic managers took the initiative to establish an ad-hoc procedure. By redefining the communication rules and assigning unplanned tasks, it was finally possible to obtain actionable data for the Operations Commander. Other interesting practices have been observed. Due to the use of 5 radiocommunication channels, the command post quickly became the scene of a ceaseless din as soon as the operations took a bit of scale. In order to allow effective communication, the Operations Commander took the initiative of carrying out situation points during which the radio communications are interrupted. This type of organisation

was not initially planned in the emergency plan. During the debriefing, the emergency response specialist indicated that this practice could be formalised by adding a temporal constraint (e.g., one point every 30 min).

It is when situations have the potential to engulf the organisation that he emergence of ad-hoc organisational patterns can be observed (Wybo, 2004). Control is accomplished through sequences of interactions at all level of the organisation that tune conflicting activities to eventually perform effective tasks (Denis-Rémis et al., 2002). From a pedagogical point of view, we consider these aspects as the heart of learning for students. These are opportunities to observe resilient performances as empirical evidence of resilience (Cook and Nemeth, 2017) and to study the features that affect the ability to create and uphold resilience, and this, considering the concept in the richness of its acceptances (Woods, 2015).

4.3.3 How do we decide what is right?

Single-loop and double-loop learning differentiations are a fundamental conceptual distinction for capturing organisational learning (Argyris and Schön, 1978; Argyris, 2004). As mention earlier, single-loop learning consists in correcting errors without enquiring primary assumptions. Then double-loop learning also detects errors but challenges suppositions behind the actions. It is obvious that errors detection and process correction process are of the first importance, but it appears that the efficiency is limited to well-defined problems. Some situations especially those involving dynamic evolution demand problem reframing (Ameli, and Kayes, 2011). In that event, triple-loop learning is operating at a higher level of abstraction, it develops the organisation's ability to learn about learning (Romme and Van Witteloostuijn, 1999). For a review of the ways in which triple-loop learning has been conceptualised, refers to Tosey et al. (2012). Triple loop learning encompasses generating new learning strategies, including determining how prior actions have facilitated or obstructing organisational learning. It should substantially answer the question "how do we decide what is right?" (Nielsen, 1993).

A classic restraint on organisational learning is the reluctance of organisations to face reality. Audits are welcome as long as they say that everything is fine and that they do not question the ordinary ways of operating. The prospect of a simulation that could lead the group away from the typical routine frequently leads to cancellation or is made useless by removing any controversial aspects. (Lagadec, 1997). However, it is this kind of conditions that enables to generate beneficial learning situations. Organisations that can make sense of ambiguity demonstrate their capabilities to cope with the unexpected. Emergence of genuine patterns shows the ability of people to regain control to ensure salvation of the organisation (Wybo, 2006).

> "To sort out a crisis as it unfolds often requires action which simultaneously generates the raw material that is used for sense-making and affects the unfolding crisis itself." (Weick, 1988)

Triple-loop learning can therefore be supported by ourselves, as per researchers and teachers, acting as an interface between the legitimate need for self-confidence of the organisation and its capacity to challenge itself.

Concretely, we have previously mentioned that the concepts of prescribed task and actual task allow the proper formalisation of field observations. The observations from the exercises were then enhanced with key people's interviews and feedback from

participants (cf. 4.2). In order to make sense with these data and to try to build knowledge from these informations, we found useful refine our conceptual tools and to consider four typologies of work: work-as-imagined, work-as-prescribed, work-as-disclosed and work-as-done (Shorrock, 2016). This framework supports interpretation of several aspects of what has been observed regarding sensemaking. Basically, writing emergency plans are paragons of work-as-imagined. It is supposed to give the courses of action needed to mitigate consequences of a hypothetic accident based upon assessment of its potential impacts (Mendonca et al., 2001). Such analysis is supported by:

1 Previous experience of work-as-done (e.g., reliability of alarm systems, responsiveness of emergency services, response time; capacity of rescue…). Lessons learned from earlier work-as-done is for sure a basis for work-as-imagined, but as systems are surrounded by dynamic environments, there are inherent variabilities of circumstances. As a consequence, models can rapidly become obsolete and leads to deceptive conceptions of activities.

2 Knowledge of work-as-prescribed. It is the formal and tangible forms of a blend of the three others *work-as*. It embraces instructions, guidelines, checklists, standards, safety management systems or even regulations. Contrary to work-as-imagined, there is a very limited diversity of work-as-prescribed regarding the few options among prescribed approaches (Hollnagel, 2016). It is often source of misunderstanding as specifications could be far away from reality of operations. Effective emergency plans require more than imagining how work should be done; it entails consideration of people behaviour when the chain of events diverge from what has been initially assumed.

3 Exposure to work-as-disclosed, which is the way things are said. It is how people talk about work, thus it is frequently distorted and tainted with partiality. Formal reporting often changes what really happens into things more politically correct. To prevent possible reproaches or sanctions, one may be perceived as useful to ignore certain details or events.

As a result, this conceptual distinction allowed to go further than a mere gap analysis and we identify several underlying factors that impede sense-making. First, the use of inappropriate tools or the selection of inadequate information leads to the formation of misrepresentation. Lack of knowledge about the potential hazards of products can induce hasty interpretations of material safety data sheets and then generate ambiguous messages and erroneous information. The delusive use of improper risk analysis methods steers to faulty recommendations that favour the illusion that everything is under control. (Foussard and Denis Remis, 2014). This results in underestimation or overestimation of some risks that is detrimental to the management of operations. Second, static visions of events are preferred over dynamic representations. The isolation between the crisis room and the ground induces latencies, as the facts are reassembled as situation points at a given moment, it is difficult to estimate the trends and theirs associated rates. (e.g., in an industrial environment, ignorance of phenomena related to chemical kinetics such as thermal runaways or the consequences of using water as an extinguishing agent on high temperature graphite (cf. 2.2) can be disastrous). Most people have trouble in dealing with exponential growths, as they struggle to foresee how fast situations can change. Third, events are mainly thought according to linear causal logic (X implies Y) whereas

the emergency response implies to act within systemic phenomena governed by network logics (X implies Y and Z which itself acts on W that retroacts on X ...). The investigation of the flawed counting procedure illustrates precisely these features.

5 Discussion

5.1 The observation method enables to build a full picture.

The combination of perspectives from people playing roles and dedicated observers enables the creation of a multifaced representation of the emergency response simulation (Jacques et al., 1999). This full picture can be then shared with the different stakeholders. Combining observations of key peoples (i.e., decision-makers that undertake choices that have a significant impact and often irreversible consequences.), essential tasks (i.e., capabilities and activities required for the overall response to be successful, not as assessment of performance but rather as actions that needs to be properly completed to achieve objectives.) and paramount locations (i.e., theatre of actions where the layout influences behaviours and shapes the quality of interpersonal relationships.) is a preliminary to conduct an in-depth investigation that tackles the characteristic intricacy of organisational behaviour during emergency response.

5.2 Associated to the interpretation model, this full picture grounds the implementation of three levels of learning processes.

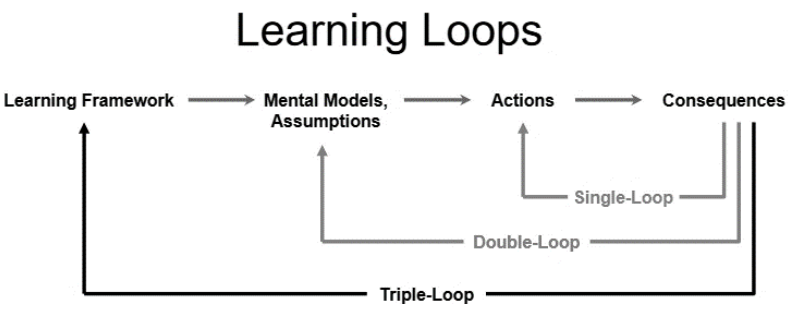
Most of the time, lessons learned from simulations are restricted to prescriptions supposed to fill an observed gap between what has been expected and what really happened. Discounting complexity of emergency response, such a *modus operandi* can be regarded as guileless, and legitimises the use of a more sophisticated model. Framed by a three levels approach of organisation (i.e., structures, relations and meaning), it upholds the implementation of three levels of learning processes (see Figure 6):

1 Single loop learning benefits primarily the plant operator and the administration. It corroborates the legitimacy of emergency plans and makes corrections related to deviations during the execution of operations.

2 Double loop learning is mainly profitable to both general management and students. It allows observation of resilient performance achieved to cope with the complexity generated by command/field duality. It pinpoints the emergence of creative organisational patterns and the appearance of new communication channels, avoiding potential crisis development.

3 Triple loop learning is particularly fruitful for teachers and researchers in that it questions organisational learning frameworks by going beyond challenging assumptions. It supports the analysis of mechanisms and dynamics of sense-making that allow collective control recovery from perilous situation. Ultimately, the elicitation of tacit adjustments generates a better understanding of interactions and fosters construction of mutual knowledge promoting future cooperation between actors.

Figure 6 Three types of learning loops



Source: From Eilertsen and London (2005)

5.3 An innovative pedagogical approach to view safety differently

In harmony with the philosophy of the authors (Foussard and Van Wassenhove, 2019), consisting in bridging theoretical knowledge to the professional real-life context to improve education in risk management, this educational satiation fulfil the expectation required to design effective learning environments (Bransford et al., 2000): Connections between acquired knowledge and current academic tasks are promoted, learnings are done with understanding instead of the acquisition of disconnected sets of facts, feedback is delivered to students and affinity between the school and a larger professional community is provided. This curriculum is clearly aligned with conceptions that sees people as a source of diversity, insight, creativity and wisdom about safety, and not as a source of risk that undermines a system that would otherwise be safe (Dekker, 2014). Through a unique experience, it also gives an opportunity for the students to grab pieces of institutional, relational and individual factors that shape the role of a safety professional (Provan et al., 2017).

5.4 A balance between planning and improvisation

The ability to respond to emergencies promptly is critical and requires indeed competent response teams. Conducting wide-ranging drills on an extensive range of scenarios (e.g., fires, explosions, toxic release, spills, natural disasters…) to prepare for such situations is inner part of effective emergency preparedness. It is a fact that during emergencies, things never go as planned (Mendonca et al., 2001). The adaptation of the organisation requires flexibility and improvisation capabilities in front of moving conditions. It definitely does not mean that preparedness is useless. To address tactical issues related to field operations, emergency preparedness still relies on a structured process of command and control.

> "The function of control is to enable the creative expression of will and to manage the mission problem in order to minimize the risk of not achieving a satisfactory solution. The function of command is to invent novel solutions to mission problems, to provide conditions for starting, changing and terminating control, and to be the source of diligent purposefulness." (Pigeau and McCann, 2002)

Preparation gives clarity and support efficiency, getting through three levels of reflection gives various evidences of factors that undermine clear communication.

> "Equally importantly, improvisation and preparedness go hand to hand. One need not worry that preparedness will decrease the ability to improvise. On the contrary, even a modest effort to prepare enhances the ability to improvise." (Kreps, 1991)

The combination of knowing how we decide what is right, legitimises the fact that we are doing the right things and making sure that we are doing the things right. This effort of abstraction and retrospective deconstruction contributes to the global understanding of emergency response, which ultimately allows a lucid self-confidence.

6 Conclusion

The set-up of this emergency response simulation involved a collaboration of industry with safety education faculty. Professionals and students both learned in this win-win situation. It was also the opportunity to implement an emergency response simulation observation methodology. The factors that influence the performance of emergency response were interpreted by using a model structure-relation-meaning. A specific observation method associated to the interpretation model enabled to gather data from crossed looks (three kinds of observers dealing with observation of key peoples, tasks and locations). Doing so, it became possible to conduct an in-depth analysis that addressed the complexity of organisational behaviour. The restitution of the data and the analysis induced several learning loop levels for both professionals and students and gave insights into risk management practices, safety conceptions and resilience characteristics of an organisation.

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Note

[1]"Safety has traditionally been defined as a condition where the number of adverse outcomes was as low as possible (Safety-I). From a Safety-I perspective, the purpose of safety management is to make sure that the number of accidents and incidents is kept as low as possible, or as low as is reasonably practicable. This means that safety management must start from the manifestations of the absence of safety and that – paradoxically – safety is measured by counting the number of cases where it fails rather than by the number of cases where it succeeds. This unavoidably leads to a reactive approach based on responding to what goes wrong or what is identified as a risk – as something that could go wrong. Focusing on what goes right, rather than on what goes wrong, changes the definition of safety from 'avoiding that something goes wrong' to 'ensuring that everything goes right'. More precisely, Safety-II is the ability to succeed under varying conditions, so that the number of intended and acceptable outcomes is as high as possible. From a Safety-II perspective, the purpose of safety management is to ensure that as much as possible goes right, in the sense that everyday work achieves its objectives. This means that safety is managed by what it achieves (successes, things that go right), and that likewise it is measured by counting the number of cases where things go right. In order to do this, safety management cannot only be reactive, it must also be proactive. But it must be proactive with regard to how actions succeed, to everyday acceptable performance, rather than with regard to how they can fail, as traditional risk analysis does. This book analyses and explains the principles behind both approaches and uses this to consider the past and future of safety management practices." Hollnagel (2018)