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Organisational accidents investigation methodology and lessons learned

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Abstract

The purpose of this paper is to reflect on accident analysis methods. As the understanding of industrial accidents and incidents has evolved, they are no longer considered as the sole product of human and/or technical failures but also as originating in an unfavourable organisational context. After presenting some theoretical developments which are responsible for this evolution, we will propose two examples of organisational accidents and incidents. We will then present some properties of organisational accidents, and we will focus on some "accident-generating" organisational factors. The definition of these factors comes from an empirical approach to event analysis. Finally, we will briefly present their implications for accident and incident analysis.

Keywords: Organisational accidents; Accident analysis methods; Organisational incidents

1. Organisational accidents

Over the past decade a significant change has gradually occurred in how we perceive events—both accidents and incidents.

They are now understood not only as the immediate and direct consequence of adversely combined technical failures and/or human errors, but also as the result of a historical background and an unfavourable organisational context. A historical background in as much as a number of decisions and unfavourable circumstances at safety level progressively generate a pre-accident situation, long before the occurrence of the initiating event and the triggering of the accident sequence.

The historical context of the accident is analysed through the progression in time of the pre-accident situation. In 1978, Turner named this time frame the "accident incubation period" [7].

In addition, this situation of pre-accident safety deterioration may be worsened, speeded up, or even precipitated through specific conditions in the organisational context such as increasingly heavy competition, new environmental and climatic conditions, etc. The analysis of these conditions and their impact on the organisation in charge of managing the hazardous system (aircraft fleet, nuclear power plants (NPP), chemical plant facilities, railway network, etc.) constitutes the second specific aspect of an organisational accident.

Therefore, it may be useful to re-examine the relevance of the notion of organisational accidents and its implications in terms of safety and prevention.

2. Towards a change in paradigm: from a behavioural approach to an organisational approach

All accidents are subject to in-depth investigations leading to a diagnosis (explanation models for accidents) and recommendations. Understanding the causes of accidents in order to obtain knowledge of a general scope and to prevent them from reoccurring—i.e. implement the "lessons learned" within a prevention approach—has become the constant concern of industries, and more specifically risky industries.

The Three Mile Island (TMI) accident has become a landmark in the "understanding" of accidents. It has shown that

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controlling the technical dimension was not enough to control risks (as a guarantee of safety). The conclusions of the first accident analysis (Report of the President's Commission on the Accident at Three Mile Island) highlighted the significance of the human dimension in the genesis of the accident [1–3]. Responsibility for the accident was attributed to a failure—or successive failures—of an operator(s): the concept of "human error" considered as the fundamental cause of an accident was born. But the President's Commission had attributed the deep causes of the TMI accident to a failure of the United States safety organisational system *as a whole*. However, the "restrictive version" of human error was generally retained; looking for immediate human failures has become too often the fundamental objective. Although this approach may be quite effective—accounting for progress in the fields of training and of man–machine interface among others—events remain partly incomprehensible, and even enigmatic since it only grazes the surface of deeper conditions which led to, or furthered, "operator errors". Moreover, this approach puts the analyst at a disadvantage in handling events where the direct initiating event does not involve one or several operations made by one or several operators, as for example in the case of the explosion of the Challenger shuttle, the Erika shipwreck, or the Mont-Blanc tunnel accident.

Since the mid 1980s, American researchers (Perrow, Sagan, Vaughan, etc.[1]), and European researchers (Turner & Pidgeon, Reason, Llory, Becker, etc.[2]), have amply demonstrated that the notion of "human error" as the explanatory cause of an accident was too limited. They highlighted concepts such as: "accident incubation period", "latent" factors (i.e. unfavourable factors with respect to safety, which are present but not "clearly" visible), and "deterioration" of organisational processes prior to the accident. Today, the scientific community involved in the field of accident study agrees on the fact that if any event (accident, incident or crisis) is generated by direct and immediate causes ("human errors" among others), it has been induced and favoured by underlying local causes or conditions (specific technical and ergonomic conditions, local modes of personnel management, environmental characteristics, etc.) and more global organisational conditions which may be at the origin of the local conditions or have an impact on the direct or immediate causes (e.g. weak safety culture, primacy of production pressure, failure or lack of communication between business entities, technocratic reorganisation, a deteriorating social climate, etc.).

We will present two examples of accidents chosen to illustrate and to help define what is an organisational accident:

- the train collision which occurred on 5 October 1999 near Paddington, in a Western London suburb;
- the corrosion incident discovered on the reactor vessel head of the Davis-Besse nuclear power plant in the United States (Ohio), on 5 March 2002.

We will then identify organisational accident properties in order to probe deeper into the accident analysis method with an organisational outlook.

3. Two cases of organisational accidents

To illustrate our point of view, we have chosen a serious accident, the collision of two trains moving in opposite directions on the same track, and an incident on a nuclear NPP, which may be considered as a near-accident. Our presentation of both events is deliberately simplified. For more detailed information one may refer [10,11] concerning the Paddington accident, and to [12,13] for the Davis-Besse NPP incident.

3.1. The collision of two trains at Paddington

On 5 October 1999, two trains running in opposite directions on the same track collided head on near Labroke Grove, in the suburbs of London. This accident took the lives of 31 persons and left 400 injured.

The initiator of the collision was a Turbo train of the Thames Train Company, coming from Paddington station, running through a red signal (signal "SN 109"). This signal prevented access to the main track. Thirty-three seconds after running through the signal, the train collided with a Great Western Company High-Speed Train moving in the opposite direction on the main track.

The local cause of this serious accident resides in the notorious ergonomic imperfections of this signal system, in the inadequate training of the turbo train conductor and his lack of experience (the accident occurred after he had only been on the job for 2 weeks), as well as in the failure of the signaller(s)'s attempts to avoid the imminent collision which obviously came too late.

Despite the apparent simplicity of the explanation for the catastrophe, a more subtle analysis of the event reveals its organisational origin.

The highly elaborate and thorough study made by Lord Cullen and his team, undertaken at the request of the British government reveals the inadequacies in the organisation and safety management of this Western geographic zone of the railway network (Western zone, including the London surroundings):

- eight previous cases of trains running through signal SN109, from 1993 to 1998, were not taken into account. Nothing was undertaken by the infrastructures manager, i.e. Railtrack Company, to remedy the high risks of this "black point";
- some "whistle blowers", attempting unsuccessfully to draw attention to these risks; the remarkable perseverance

[1] For further information see: [4,5,6].
[2] For further information see: [2,7,8,9].

of an operation and safety manager of a company using the railway network, was not rewarded;

- the taking into account of risks, through their assessment and operational feedback, was most inadequate with respect both to the design of the signal system and traffic on the tracks (choice of bi-directional lines), as well as conductor and regulator training.

The situation of the Western zone at the time of the accident was the object of very serious criticism, including from managers appointed shortly before, or immediately after, the railway catastrophe: deteriorated safety culture, excessive turn-over of managerial executives, and numerous inefficient working groups. The zone had been on the decline for a decade, diagnosed one of these managers.

The collision occurred after what appears to have been a "black series" of accidents, starting with the one at Clapham Junction in 1988. It did not stop with the Paddington accident either, as it was followed by accidents at Hatfield, Selby, Lincolnshire in 2000, up to the one at Potters Bar in May 2002.

The deteriorated safety conditions in the railway network, strikingly illustrated by this accident, raised the issue in the media and public opinion of the railway privatisation which had taken place in the 1990s. However, statistical studies do not lead to the conclusion of a deterioration in safety since privatisation; overall results do not appear more unfavourable than at the time of British Rail, the national company, before the Clapham accident in 1988. In-depth studies tend to show that the deterioration and decline of British Rail occurred *prior* to privatisation [14].

Persons in charge of Railtrack Company itself fear that the climate of competition led to an alteration in the incidents and accidents accounting process, rendering thus problematical any complementary study on the safety evolution trends of the British rail system, beyond recorded "major accidents", from Clapham Junction to Potters Bar.

The analysis undertaken by Lord Cullen and his team on the effects of privatisation, such as an extreme fragmentation of responsibilities with respect to the railway network management and train traffic, highlights a certain number of organisational drawbacks and dysfunctions, with a potential negative impact on safety conditions: multiplication of interfaces, poor communication between companies, overriding role of production and performance criteria over safety, managerial difficulty in carrying out big projects, inadequate practice of "research and development", poor management and inadequate control of a multitude of contractors and sub-contractors.

The unfavourable impact on local work, staff motivation, quality of cooperation as well as experience and basic skills of those working in the field, is also obvious.

In conclusion, beyond the mere direct causes, the historical, organisational and managerial dimensions of this accident are also evident. The number of precursor events, which remained unaddressed, also shows that the accident had been in the making for a long time. For a number of reasons, whether it was the inadequate signal system put in place following the refurbishing of the Paddington Station (technical cause), the increase in the average train speed, the predominant safety culture leaving full responsibility to drivers for running through light signals, the lack of in-depth defence, the lack of involvement by management, who let a high collision risk build up and endure, the difficulty in addressing safety problems when several companies are involved (Railtrack, and the various operator companies), or the lack of large-scale preventive initiatives in a competitive context, the accident was... highly predictable.

3.2. *Davis-Besse NPP incident*

3.2.1. *An incident and near-accident*

On 5 March 2002, serious damage to the vessel head was discovered during shutdown works for reloading the American Davis-Besse (Ohio) NPP. It was due to corrosion which, on a surface area of about $160\,cm^2$ ($\pm 30\,cm^2$), had destroyed the *entire thickness* of the head in Alloy 600, or about 168 mm, so that primary pressure remained contained by only a very thin (4.8 mm thick) internal lining of stainless steel which, moreover, presented a swelling and a fissure going right through at the level of the corrosion cavity.

This incident can also be considered as a "near-accident" since the possibility of a serious accident seems very likely.

This incident was ranked at level 3 on the INES[3] scale.

3.2.2. *An organisational incident*

Fortunately the incident was discovered in time. It was of an organisational nature. The organisational self-diagnosis carried out by the operator, First Energy Nuclear Operating Corporation (FENOC), through an intermediate "Task Force" gathered on this occasion, clearly highlighted the fundamental characteristics of an "organisational" event:

- one has to go back several years, to the mid 1990s, to notice a drastic change in the Davis-Besse plant management style;
- the fundamental orientation taken privileged production; safety was overlooked;
- high-level management (*senior*) was hardly involved in safety activities and very seldom went into the containment on-site;
- the consequences of this policy became obvious at all levels of safety management: analyses of potential superficial problems; wait and see: tendency towards remedying rather than anticipation and prevention; weak—and also obvious—signals of the unidentified deterioration of the vessel head.

[3] International Nuclear Event Scale: scale for the classification of nuclear events developed by the International Atomic Energy Agency. This scale has seven levels.

Following an inquiry, a team from the Nuclear Regulatory Commission (NRC), put together to address the Davis-Besse event, identified 10 clear violations by the NPP with respect to compliance with NRC regulations.

3.2.3. An institutional crisis

However, a more in-depth examination of the causes of this incident highlights the deep involvement of the American Safety Authority, the NRC. The first obvious signs of circumferential fissures and penetrations on the vessel head assemblies control mechanisms were discovered in April 2001, on the Davis-Besse twin units. EPRI[4] set up a program to study the vulnerability of American units. Its results, released in May of the same year, showed that Davis-Besse was one of the units most vulnerable to corrosion. All unit operators were requested by the NRC to carry out inspections of the vessel heads by 31 December 2001. They all replied to the NRC agreeing to these controls, except FENOC. At this stage, the NRC was about to issue a "Shutdown Order" to the Davis-Besse NPP, effective on 2 November. Finally FENOC provided justifications, though not very convincing and proposed to carry out controls, but only in March 2002 on the occasion of its programmed unit shutdown for reloading. FENOC proposed to undertake compensatory measures in the mean time, but they appear not to have been very decisive. Then FENOC announced that the unit shutdown had been moved ahead to 16 February 2002.

However, while acknowledging that the presence of circumferential fissures on the Davis-Besse vessel head was almost certain, the NRC nevertheless accepted this "trade-off" (according to the statement of an NRC manager).

This lack of rigour on the part of the NRC was severely criticised. An official petition in the form of a long and well-argued letter of criticism requested an independent expert assessment[5] of the FENOC works and studies undertaken following the discovery of damage on the vessel head [15]. At first, in August 2002, the NRC proposed to turn down this request based on the following arguments:

- the sufficient number of investigative teams set up both by the NRC and the operator FENOC to address this event, and the fact that most of these teams included independent experts;
- the absence in the past of protracted and/or repeated regulation violations by the Davis-Besse NPP.

The NRC was later put in the hot seat in political spheres. The incident triggered a crisis which remains unsettled at the time of drafting this paper. FENOC is liable to financial sanctions and legal charges.

[4] Electric Power Research Institute. The EPRI is a study and research centre financed by the contributions of electricity operators and companies.

[5] There is a precedent: in 1996, during the Millstone NPP crisis, the NRC had requested that the operator develop an independent verification programme of corrective actions.

The deeper reasons for the NRC agreeing to push back twice the shutdown of the Davis-Besse plant (first from 2 November to 31 December 2001, and then to 16 February 2002) in spite of the potential risks, remain somewhat enigmatic. Results of the inquiry on the in-house functioning of the NRC are not available. It seems that the NRC personnel involved were at variance with its management.

3.2.4. Recurrent lessons

This organisational incident presents a number of general but wide-ranging lessons, which may be summed up as follows:

- the unfavourable and determining weight of production pressures bearing on the safety climate;
- the significance of the care given by the organisation to identifying, analysing and solving technical problems, or indeed to their prevention and anticipation;
- the decisive influence of management, in particular *senior* management, on the direction of *daily* organisation, in other words the significance of the presence and involvement of management, and the style of management;
- safety cannot be managed *solely* on the basis of formal objective and quantitative considerations, such as management principles based on risk information (*risk-informed regulation*). These considerations may be distorted and used for quibbling, while ignoring the deeper technical reality of safety and of the nuclear unit. Safety decisions should rely on considerations related to the actual daily functioning of the socio-technical system, including its informal dimensions (personnel involvement and motivation, flow and quality of communication, etc.).

In addition, meaningful results obtained by FENOC's "Task Force" show that any organisation can avail itself of the necessary means for performing an exhaustive and reliable organisational diagnosis, provided that management is willing to acquire them.

4. Organisational accidents: some properties

The concept of organisational accidents refers to an accident examined from an organisational perspective. Here, organisation is taken in the broad sense of the term; it is the in-house organisation of the business directly implicated in the accident, but also by extension of other businesses or institutions indirectly implicated, including sub-contractors, safety control organisations, etc. It may extend to the organisation of an entire industrial sector. This point of view may be extended according to the requirements of the accident analysis and an effective curative or preventive action. The benefit from this concept is its capacity to escape the fatality of unforeseen accidents and repeated accidents or incidents, apparently all different, and to develop preventive action insofar as possible. We will examine below some major aspects of the theory of organisational accidents.

4.1. Organisational network of an accident

One of the most significant aspects of this theory is that it considers the accident as resulting from concurrent local, technical and human causes, and broader organisational causes or factors, possibly generic, often pre-existing, which play an aggravating role in the case of a dysfunction, namely by reducing defences, or even by generating other dysfunctions which make it worse.

Accident analysis, seen under this organisational angle, owes its richness to the construction (implicit or explicit) of what may be called an "*organisational network*" of the accident. Little by little, research done by all those involved in various capacities in the accident, as well as by their institution and, within this institution by their managers and senior managers responsible for the work organisation and work situations, leads to empirically building the actual accident network in time and space, and beyond the organisation theoretical structures.

Acting this way enables us to highlight, something which is rarely done as a rule, the consequences of the most recent decisions taken in real time at the moment of the accident or just before, as well as the most distant decisions going back to the design stage of the technical installations or the setting up of the business organisation, the weaknesses of which were suspected if not clearly identified by their designers.

4.2. Incubation period

Another major aspect of the theory of organisational accidents is to show that, as a rule, according to an operator formula, "the accident gives warning". For a whole time period, dysfunctions and their deep causes and aggravating factors, both of a technical and organisational nature, pre-exist without any accident occurring. These latent, known or unknown failures on the part of those involved, known as "pathogenic residents" [8] of the organisation are present but their consequences do not necessarily appear clearly. A combination of them, which is more difficult to identify, may also prove to be pathogenic. Thus, the incubation period of the accident sees the emergence and development of unfavourable organisational factors with respect to safety, creating thereby a vulnerable "terrain" more propitious to the development of an accident. This time period, varying in length, allows for preventive actions, since it is rare that more or less clear alarm signals do not appear during that period.

4.3. Signals announcing the event

During the incubation period, the signals announcing the event range from the weakest "weak signals" to the most obvious "precursor signals".

The strongest warning signals are *precursor events*, incidents or accidents which fit into a series of incidents or accidents of the same type, without necessarily entailing catastrophic consequences because they were controlled in time, or because an unfavourable factor kept the accident sequence from developing.

All warn of the dysfunction and the potential catastrophe inherent in them. Such events may be considered as operational feedback to be taken into account as a priority. That is the reason why safety management places such importance on precursor events, provided that they are identified as such, that their consequences for safety are acknowledged, and that initiatives are taken to correct and improve them.

The least obvious warning signals are known as "*weak signals*". These signals are less evocative of a potential catastrophe because they may have a more distant relationship with the accident. They are the symptoms of a deteriorated state of organisation, which should be a warning about a whole set of possible dysfunctions namely owing to their continuous recurrence [16].

4.4. The case of "whistle blowers"

Sometimes "whistle blowers" make the effort of writing to signal a dysfunction and express their concern for safety. These written exchanges occur among certain operational staff-members, or their management, who sound the alarm about persistent dysfunctions, the treatment of which falls to others, and they often underline the accident-generating consequences of these situations. These persons take their responsibility and also take risks through personal involvement, especially regarding their careers. Their objective is to reach the decision making centres of the business in order to remedy the situation they are concerned with [17].

5. Predominant and recurrent organisational factors

Incident and accident analysis, seen under the organisational aspect in fields as diverse as process industries or transportation, reveal the recurrent and repetitive nature of the presence of a certain number of factors playing a decisive role in the origin of the occurrence of an incident or accident. In this paragraph, we will list a few of these factors derived from an empirical approach to event analyses [18].

Identifying repetitive phenomena requires on the one hand proposing a classification of the factors and phenomena leading up to the occurrence and/or the development of the event and, on the other hand, a sufficiently synthetic and macroscopic level for designating these phenomena. This approach presents some difficulties.

First, the "incriminated" organisational factors are not always chronological, in the sense that there is not a cause leading to an effect. The observed or detected phenomena are interlinked, even circular: the effects of organisational factors and the latency period of these effects may differ according to the situation. In the same way, it may seem hazardous to distinguish apparent original causes. However, even if these factors do not belong to the world of mechanical causality (cause-consequence approach), they may be considered as “indicators”, symptomatic of accidents, incidents or crises.

Each class must also be both sufficiently generic to prevent the factor from being tied to the particularities of an event, and sufficiently detailed to have a resounding effect and be implemented in the field of analysis. In addition, a classification of factors is somewhat arbitrary since, owing to the multiplicity and complexity of the phenomena at the origin of an event, what is considered as a factor in one situation may be considered as a consequence in another situation.

Some of the major types of recurrent factors are as follows:

- weakness of the organisational safety culture;
- complex and inappropriate organisation;
- limits of operational feedback;
- production pressures;
- failure of the control organisations.

We will see below some indicators showing the presence of organisational factors.

In addition, these factors may be interlinked, i.e. while carrying out the analysis of a situation, one may observe their simultaneous presence with mutual enhancement, both of these factors and their effects. Therefore, classifying an observed indicator as belonging to one type or the other is somewhat arbitrary.

Finally, the outlook contemplated in this paragraph does not integrate specific factors but rather exemplary ones, that is to say factors observed in a single event with implications that can be generalised.

5.1. Weakness of the organisational safety culture

By organisational safety culture, we mean a set of factors put in place or favoured by a business, which concur to achieving the latter’s production objectives thanks to the safe functioning of its operation processes. This culture relies on established rules and defined structures, but it also has more diffuse aspects which are barely formalised or not at all, which bind together and keep alive these rules and structures as a whole. In this sense, it is considered that the safety culture within a group is not achieved only through adding together the behaviour of each actor, who once his responsibilities and field of action(s) have been clearly defined, acts with a “questioning attitude”, a “prudent and rigorous approach”, and “communicates” in a satisfactory way with his/her colleagues (necessary but not sufficient conditions).

The “indicators” of these factors are: managerial deficiencies regarding safety instructions and prescriptions, the management’s lack of involvement in on-site work, the absence of analysis of local and/or global risks, inappropriate training, inadequate operation procedures (poor or, conversely, complex, thereby institutionalising deviations, etc.), “practices” in conflict with regulations, etc.

5.2. Complex and inappropriate organisation

The consequence of the introduction of protection systems in risky industries is an increase in the system’s complexity parallel to the enhancement of its safety level. This increased complexity may have the opposite effect, at the origin of the system’s failure if, in particular, the organisation put in place (relations between the actors of the system) is inappropriate. It turns out that the organisation may not facilitate, or may even slow down or impede, efficient and coherent decision making.

The “indicators” of these factors are: co-ordination or liaison problems between entities, dilution and/or lack of knowledge of the actors’ responsibilities, multiplication of tasks, absence of planning, etc.

5.3. Limits of operational feedback

In a number of businesses, operational feedback is considered an essential tool for operation or installation safety enhancement. However, its functioning and actual taking into account is often liable to criticism. Thus, in order to be effective, operational feedback must be the object of a truly determined policy and must be given adequate means.

The “indicators” of these factors are: superficial incident analyses, lack of taking into account unfavourable organisational factors in respect to safety, the burden of formalism for carrying out analysis, censorship and/or self-censorship for some aspects of analyses.

5.4. Production pressures

Production pressures and uncontrolled financial constraints (i.e. tending to become the alpha and the omega of decision criteria) usually generate in the long run an environment unfavourable to safety.

The “indicators” of these factors are: the organisation’s sensitivity to economic arguments, a culture favouring production imperatives, “financialisation” of safety, constraints leaving only margins (on costs, and planning) and risks as adjustment variables, etc.

5.5. Failure of the control organisations

In order to ensure an acceptable safety level, risky industries must be accountable to control organisations for their performance in this field. In-house control measures are also taken in order to assess and maintain the best safety level. But are these control organisations, both in-house and external, absolutely reliable? Can one rely on them and be content with their evaluation when they are positive? In other words, should one raise the problem of the effectiveness of controls and relations between control organisations and controlled organisations?

The “indicators” of these factors are: the quality an exhaustiveness of the elements taken into account for the evaluations (for instance: analyses carried out directly in the field versus information provided by the industrialist), the lack of independence or a conflict of interest, the control organisations, the tendency of these organisations to restrict themselves to performing formal safety audits and analyses, etc.

6. Methodological implications for accident analysis

The understanding of an accident, incident or crisis, and therefore a possible improvement through preventive action, must take into account the deeper organisational causes where its roots lie. Standard accident analysis methods rely on “causal methods”, the most famous tool of which is the method of the event tree. This approach helps, on the one hand, to rebuild the logical sequence of facts in a nearly exhaustive way and, on the other hand, to put these facts back into context. This is relevant for updating the immediate causes of the event. On the other hand, this approach shows its limits for taking into account interactions between events, temporal dependencies and non-causal relations between events. In other words, these methods are insufficient to reveal the organisational factors at the origin of the occurrence and/or development of an accident.

One way to progress in the field of accident analysis would be to carry out an analysis of the organisational type addressing three issues, as a complement to causal analysis:

- historical reconstitution of the event, going as far back as possible in order to “catch” the first signs of situation deterioration;
- development of an organisational network of the event, or “laying bare” the relations, dependencies and interactions of the actors involved and their entities, in order to locate the organisational dysfunctions;
- inspection of the organisation’s background in order, among other things, to identify decision making, and “re-question” the role of managers and their level of implication in the occurrence of the event.

In conclusion, the approach recommended fits into a company policy of organisational vigilance concerning safety problems, contributing to a more effective prevention policy.

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