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Accidents in the gas distribution industry. Some consequences of the introduction of new analysis criteria

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ABSTRACT: The learning from experience process is necessitated by the growing complexity of industrial technical systems. The formerly dominant dependability paradigm has gradually shown its limits in the understanding of human performance. The paradigm of human and organizational factors attempts to remedy this, and is the basis for a new accident analysis grid implemented in a large French gas distribution company. This paper is a description of the technical contents of the grid and an account of the various changes that were introduced in the company. Beyond the implementation of the grid culture and practices have changed that make the effect on safety less easy to characterize than one might expect.

1 INTRODUCTION

This article aims to explain the process that led to the design, development and deployment of an accident analysis grid, integrating human and organizational dimensions. This grid is based on the CREAM method, developed by Hollnagel (1998). Specifically, the grid is based on the use of the concept of Common Performance Conditions (CPC; Hollnagel *op cit.*), known as screening.

This grid has been deployed in the field of gas distribution in France. This business is distinguished by a high level of risk, rather prescriptive procedures and an approach to accident analysis that tends to focus on technical components. In this context, the introduction of CPCs reflects a desire to increase control of safety by broadening the spectrum of causes of accidents. However, beyond these technical aspects, CPCs bring with them a deep change in the accident paradigm and its aetiology. The technical content of the method and the changes it has brought about will be described in this article.

The analysis grid discussed here is the result of two years of work and research carried out by a working group established by the Risk Management Centre at GrDF, Mines ParisTech and the Research and Innovation Department of the GDF-SUEZ group.

1.1 *GrDF in brief*

GrDF was created on 31st December, 2007. As a 100% subsidiary of GDF-SUEZ, it manages all activities related to natural gas distribution in France. With nearly 46,000 employees and 190,000 km of network, it serves 11 million customers.

A business like this is affected by many safety issues. Two main areas of activity can lead to accidents involving gas facilities:

- **Supervision of the network provided by GrDF.** This is the responsibility of the operations manager who manages all access to the network needed for maintenance. The teams involved may either belong to GrDF or be external contractors.
- **Public works carried out by external contractors.** Work may be done under the supervision of GrDF or be conducted in a context totally separate from GrDF. Companies working close to GrDF facilities must apply for plans of the layout of the network.

1.2 *Accidents and the need for learning from experience*

Structural damage such as a leak from a pipe cut by a mechanical digger can have very different consequences. The most benign only affect the physical aspects of the structure, where costs are relatively low. The expenditure required to repair a pipe supplying a building, including repair and travel costs, does not exceed a few hundred euros. However, the most serious incidents can lead to huge material losses and deaths, especially in the case of fire and explosion.

With such high material and human stakes, learning from past events is essential to ensure distribution safety. For GrDF, this training is even more important because the environment that the company is working in is exposed to numerous threats. External contractors work on the network and the dangers of natural gas are factors which make safety management even more difficult. It is hoped that the CPC-centred accident analysis grid presented in this

paper will strengthen the company's ability to learn from experience.

For GrDF and industry in general, learning from experience often takes the form of training. Training is defined by Rakoto (2004) as a "structured approach to the capitalization and operationalization of information resulting from the analysis of positive and/or negative events. It implements a set of human and technological resources that must be managed to reduce the repetition of errors and promote good practice".

In structural terms, the learning from experience process can be divided into four phases (Van Wassenhove & Garbolino, 2008):

- detection of the problem, information gathering;
- analysis;
- formalization of knowledge and capitalization;
- sharing and reuse of knowledge.

This article will focus on the analysis phase.

2 CONSTRUCTION OF THE PROTOTYPE AND DEPLOYMENT OF THE ANALYSIS GRID

Several stakeholders were involved in this project. First, professionals at the Risk Management Centre (GrDF) brought their knowledge of site management and operating procedures at locations where work is carried out; Mines ParisTech researchers contributed their knowledge of the method. Finally, the Research Department of GDF-SUEZ brought technical support in the creation of the initial analysis grids and participated in benchmarking at on-site locations.

Concretely, the design and development of the analysis grid followed three phases:

1. **Development of a prototype.** The major part of this phase was to adjust the terms of the original CPCs to the business of distributing gas. This was achieved by bringing together business and operational experts. The grid was implemented in a spreadsheet to facilitate its development among stakeholders, and to simplify its dissemination to pilot sites. Details of this phase can be found in Besnard *et al.* (2009).
2. **Testing at pilot sites.** This phase involved testing in real-life conditions and the collection of user feedback. Tests were conducted between March and April 2009 on operational sites in the Paris region. Each test provided an opportunity to apply the grid to an active situation, and to receive feedback and feature requests.

3. **Final development and deployment.** The final phase was to assimilate the feedback from pilot sites and produce a final version of the analysis grid. Regional managers were trained, and in turn, trained managers in their area of responsibility. At the end of the first half of 2009 and six months after the start of prototyping, all operational sites had been trained. At this stage, the method was deployed nationally in GrDF's eighteen network units. Integration with information systems took place the following year.

During the development process, the CPCs were adapted to GrDF working practices and professional vocabulary. In addition, sub-criteria were introduced to match the business jargon (Table 1).

Table 1: Performance conditions and sub-criteria of the screening grid

Performance Condition	Sub-criteria
Working conditions	Working environment Personal protection equipment Temperature, noise, light
Materials and tools	Use of a tool appropriate to the task Condition of tools and vehicles Storage and availability IT equipment
Rules and procedures	Description of tasks according to procedures, and relevance of procedures. Deployment and availability Compliance with procedures
Mapping and designation	Availability of maps to GrDF field operators Maps correspond to the terrain Underground maps corresponds to the terrain Consistent mapping Designation of facilities
Workload	Actors undertake more than one activity at a time Rhythm of work
Time management	Preparation Execution Breakpoints to assess the situation
Professionalism	Knowledge Know-how Skills
Collaboration	Sub-contractors respect contract terms Working agreements with fire services are followed Team-working Shared means and objectives Collaboration and respect for team roles Distribution of skills
Communication	Business language Communication methods Traceable/adequate internal information Impact of external information on event management
Technical management	Decision-making chain Management of gas flow Condition, accessibility and maintenance of site Design/operation of sites

3 ACCIDENT ANALYSIS USING THE SCREENING GRID

3.1 *The spirit of the method*

The difficulty of accurately quantifying a base probability for human error is a major problem for methods such as THERP (Swain, 1964). This difficulty has led to a new generation of methods for human reliability analysis which try to circumvent the problem. These methods no longer consider it possible to reduce human error to a basic probability modulated by the context. Instead the context is seen as the factor that influences performance the most. Performance is then defined through concepts such as Performance Shaping Factors, introduced by Swain & Guttman (1984) or the Common Performance Conditions (CPC) of Hollnagel (1998). These concepts see failure as the effect of the context in which the operator performs an action.

This vision is a radical change in the modelling of human failure: the context determines the performance of the operator. This view of performance is a significant advance because it allows us to rethink the concept of human error. The allocation of responsibility bias described by Reason (1997) can be avoided. If the analysis focuses on the conditions, rather than behaviour, the operator's performance is viewed in the context in which they acted, and in the light of the information available to them. In other words, if there is an upstream failure in the organization, human error is not the cause but the consequence of unfavourable performance conditions.

3.2 *The conduct of an analysis*

Depending on the nature of the event, an accident may be flagged by operators. An accident investigation can then begin.

There are four stages.

- **The gathering of information.** This includes all the administrative, technical and factual data on the event. It establishes the initial context and the stakeholders involved in the analysis.
- **The safety debriefing.** This involves the field manager and any operators concerned. An essential action is the preparation of an event summary. Without this, the analysis cannot continue. This summary provides the manager with the material to decide to whether to hold a further analysis of the accident, depending on the impact of the event. It helps to identify areas which the investigation will focus on.
- **The analysis.** This is optional and is carried out on the order of the field manager. Once initiated, it must satisfy the requirement of bringing together the various internal or external protagon-

nists. Its aim is to trace the root causes of the event and identify the aggravating factors that led to deterioration in the situation. The spirit of the analysis must be to seek the contextual factors that had an impact on operations in order to understand the origin of possible errors without seeking to blame someone. This is the stage where the CPC-based grid is used.

- **The synthesis.** This brings together all the material gathered from the debriefing and the analysis. From this, a preventive and corrective action plan can be defined.

Beyond the technical contents of the analysis grid, the adoption of a new tool and paradigm triggered side-effects ranging from the resources involved to new managerial and organisational challenges. Because these changes impact safety one way or another, it is worth considering them. That is what the next section is about.

4 INITIAL LESSONS FOLLOWING DEPLOYMENT

The introduction of the analysis grid took place in a context of profound organizational change. The paradigm shift in accident analysis required managers to master a new mind-set, and impediments to the assimilation of the method proved to be internal (Gaillard, 2008). These impediments showed themselves at three points in time: in the design of the tool, in its implementation and in its use. Design and implementation of the grid did not cause major problems. However, the use phase was enlightening.

4.1 *Limitations noted in the use of the grid*

Four limitations were identified when using the grid in operational conditions:

- **Research responsibilities.** At the beginning of deployment, not many of the analyses produced were useful. This was due to a lack of understanding of the concept of 'performance conditions'. The latter were interpreted as the criteria for dependability. This misunderstanding obscured the analysis in favour of the allocation of responsibilities.
- **Cost analysis.** Managers have seen the introduction of a screening grid as an addition to their workload, and known to be incompatible with the many planned interventions in the field.
- **Cost of data compilation.** The increased complexity of analysis has increased the amount of information that can be collected and analysed. The cost of exploiting this information has increased. It now requires managers to spend time

formatting the results before they are able to disseminate the assessment. This additional workload diminished interest in the grid and did not provide timely information for operators. A computer application has partially overcome this problem.

- **Lack of support from senior management.** A fourth point was the feeling that industrial safety managers were not supportive. Despite the assistance given at the pilot sites (and all other sites), through additional training and on-request methodological help, a feeling of isolation was noted. In particular, the feeling was that managers did not take into account the increased costs associated with accident analysis.

4.2 Contributions of the method

In the two-year period during which the analysis grid has been implemented, several points have emerged which show that the changes that ensued had an effect on working practices.

- **Unification of analysis practices.** The screening grid was an alternative to the heterogeneity of practices that existed at the time. Today, the grid supports the convergence of safety information. The introduction of a simple grid helped systematize the collection and analysis of data.
- **The fault tree is used less.** Historically, this method was widely used in the business, including for the analysis of operator actions. The introduction of the screening grid goes beyond the concept of error and the search for logical combinations resulting in failure, to instead focus on the work of operators.
- **Unification of operating data.** It became possible to exploit operational information related to safety that was previously available only in a piecemeal way. Following analysis of a hundred accidents, the weakest points in the network were identified. They involve mostly the main network connections, which total more than 80% of facilities affected by accidents. In over 80% of these cases, the cause of the accident is identified as a lack of knowledge of the network on the part of the external contractor, due in part to the lack of identification of installations.
- **Perceived usefulness for safety.** CPCs have been seen as a way to conduct an in-depth analysis useful for safety. By using the screening version of CREAM rather than the full method, the analysis grid also served as an entry guide to users in their understanding of the concept of 'performance conditions'.
- **Integration of safety management.** Another positive point was the development of information exchanges and discussions. Transparency was

enhanced and mutual understanding between the various operating sites of local conditions increased. A non-technical aspect of the analysis grid is that it serves as a medium of exchange and dialogue between operators, and national and local managers responsible for risk management. This point supports the development of an integrated safety culture as described by Groeneweg *et al.* (2002). In turn, a larger role is given to exchange and understanding of the causes of errors. Also, the progressive revision of the role of sanctions maintains an active upward flow of information to safety managers at national level.

5 DISCUSSION

The introduction of the analysis grid represents a paradigm change in the practice of accident analysis, which has seen a significant evolution. However, the demonstration of improved safety management does not come easily. On the one hand, compromises have emerged between the cost of using the new grid and available resources. On the other, there are interesting side effects. These two phenomena will be discussed in this section.

5.1 Operational difficulties and trade-offs

Several potential difficulties for operators and managers were identified during the deployment of the analysis grid. For example, the grid was new and the analysis took longer. These difficulties affected the quality of accident investigation and, consequently, the ability of the company to have an overview of the causes of accidents.

The introduction of the grid and the difficulties it caused were not accompanied by new resources. With the same amount of resources, new problems trigger trade-offs (Simon, 1955). It is therefore possible that the screening grid, designed to increase safety management levels, in fact contributed to their degradation. To understand how safety could be affected, it became important to identify the trade-offs created in accident analysis.

- **Trade-off between depth of analysis and usability of the grid.** Because of the newness of the analysis grid, operators and local managers had little experience with its content and use. This problem can be the cause of a loss of analytical depth as they tried to avoid the difficulties introduced by the new approach to analysis. These avoidance strategies and their negative consequences on the desired objectives (more safety) have already been found in other areas (Besnard & Arief, 2004).

- **Trade-off between depth of analysis and workload.** Accident analysis teams are the same people responsible for network interventions. The time spent on analysis with the grid (rather than the traditional debriefing without support) is therefore at the expense of interventions. This poses a risk of loss of depth in the analysis of an accident or concentration on major accidents in order to save resources for network operations.
- **Trade-off between criticality and workload.** This trade-off is related to the previous one. The perceived notion of criticality can mediate the selection of events to be analysed and the time available. The safety risk lies in the underestimation of the criticality of an accident and the implicit revision of the notion of an incident.
- **Trade-off between performance management and operations management.** Organizational changes related to the redefinition of job descriptions for those responsible for the analysis were also identified. As a result, the introduction of the analysis grid means local managers must now manage a double-bind: they must meet the performance requirements of senior managers and deal with complaints from emergency teams who see changes in their job.

5.2 Secondary effects of shift in the analysis paradigm

The paradigm of performance conditions solves the paradox of learning from experience. Limiting analysis to only unwanted events poses a fundamental problem for safety: a decline in the number of accidents and incidents gradually deprives the organization of incoming data to drive safety. In other words, using a learning process based on unwanted events, the effectiveness of the safety management system can only be assessed if accidents occur. Otherwise, how do you know if the safety barriers are working? While senior management considers safety as a top priority, the accident, and loss of control it represents is still, paradoxically, the only means available to determine if the system was safe.

This negative view of safety, that is only intended to limit the consequences of unwanted events, neglects positive performance. Instead, safety is seen as the result of compliance with procedures and use of suitable tools. In this vision, everyday actions that guarantee the absence of unwanted events are not taken into account. In the same way, both the purpose of the activities carried out by operators, and how they mentally represent them are disregarded. Finally, this negative vision of safety overlooks the importance of the organizational context in industrial processes (Davoudian *et al.*, 1994).

The error attribution bias described by Reason (1997) is a consequence of this reasoning. It sees an accident as the result of a lack of knowledge or a lack of discipline in applying tools and procedures. The analysis grid helped to foster exchanges to avoid this bias. It also allowed the company to focus on the conditions surrounding the occurrence of accidents, not just the actions of operators.

The decision to integrate the paradigm of performance conditions into safety management had an impact beyond the scope of accident analysis. Training of local managers was one of the areas affected. Conventional training courses, oriented towards obtaining theoretical and practical skills have been revised. This is now complemented by the design and development of an operation's office simulator in which the operational scenarios are created from the analysis of accident records.

Learning from experience in general, and the analysis grid described here, is much more than a tool for the exploitation of incidental knowledge in a socio-technical system. Indeed, it goes beyond the sphere of safety by creating opportunities for exchange, collaboration and new practices. On this last point, learning from experience is a real tool for the creation or strengthening of safety culture. Safety is no longer seen as the result of the application of procedures or monitoring of indicators, but rather as the result of a collective effort.

6 LESSONS LEARNED AND CONCLUSION

The first lesson to be drawn from the deployment of a new accident analysis tool is that its design and deployment is not only a technical change. Such a belief on the part of management is counter-productive. The introduction of a new tool or a new technique only produces the desired results if it is understood and accepted by end users. 'Participatory prototyping' is instrumental in this respect.

The choice of such a development method requires significant support. The participatory aspect of co-development must extend beyond design, in order to avoid local strategies being deployed that attempt to circumvent or modify the tool. Ultimately, the risk of such a situation is the disruption of information flow back to senior management. Should this happen, safety decisions would no longer fit the reality on the ground. To avoid this happening, senior managers in charge of the learning from experience process must be prepared to guarantee communication and long-term training.

A final aspect of the introduction of performance conditions is disruption of management practices. The concepts of blame and punishment become more difficult to maintain in the corporate culture. There is an acute generational problem as operators with considerable seniority in the company have worked with these concepts throughout their career. The management of technical change therefore goes hand-in-hand with social and demographic variables. This must be addressed to provide the analysis grid with a sustainable anchor in company culture.

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