A study about changes and their impact on industrial safety

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A STUDY ABOUT CHANGES AND THEIR IMPACT ON INDUSTRIAL SAFETY

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ABSTRACT

The aim of this paper is to introduce a case study aiming at better taking into account the impact of changes on industrial safety. It has been well documented in the past years that many accidents did happen because of changes, combining together technological and social dimensions, making of this issue a complex one. This case study had as a purpose to reduce the complexity of the problem by choosing a technologically and organisationally rather limited system, exploiting hazardous processes, where implications of changes could be identified and discussed with a limited number of persons. Silos, with risk of fires and explosions, are main installations of the seed industry and exploited by a limited number of persons within often medium size organisations. This was therefore a rather good case to start with. After that a company agreed to take part of the research, interviews with individuals and visit of a site was organised. Changes were identified and analysed in relation to industrial safety. Regulatory, organisational and technological changes were retained as significant. The interesting turn of this study occurred when a serious accident happened a few days before the feedback session on the outcomes of the study. The company asked then an investigation to be performed and this provided a very good opportunity to go further in the appreciation of the impact of changes in the light of the accident. The investigation showed that many of the changes identified in the first part of the study did play a strong part in the genesis of the accident, although they were not formulated with the level of details one is able to produce retrospectively with an investigation. This case study brings therefore very interesting empirical data to the question of whether or not one is able to anticipate incidents or accidents given specific technological and organisational configurations and evolutions. This approach of combining both perspectives (a study of changes in normal operation and an accident investigation for the same case) also brings diachronic considerations to the mainly synchronic approach explored so far in studies of normal operations.

1. INTRODUCTION, THE PROBLEM OF CHANGE IN RELATION WITH SAFETY

After many incidents or accidents of the past years across high risk industries (transport, chemical, nuclear) , it appears that, when reading investigations reports, changes always play an important part in the genesis of these events (i.e. our own investigations do show this very well too, Le Coze, 2010). Yet the problem of change is quite complicated because it includes a wide range of issues, better identified in favour of hindsight. It is indeed much more difficult to predict beforehand these changes that will combine together to lead to a specific unexpected accident scenario. Several problems can be related to this difficulty, problems that one finds when dealing with any complex systems linking technological, psychological, cognitive, social, cultural, economical and political dimensions together (Le Coze, 2008a). One of them is that changes are permanent. Changes happen all the time. But their effects are not always immediate. They might need for instance to be associated with other changes to generate an adverse outcome. Another problem is that there is not necessarily proportionality between the magnitude of a change and its effects. A last one that is mentioned here is that one change somewhere might have some effects somewhere else.

Organisations that need to ensure safety to employees and to external parties due to hazardous processes must, in their daily management, integrate this issue. Very often, one of the items of formal safety management system (sms) is therefore dedicated to it ('management of change'). However, it is also known from accident investigations or studies of normal operations, at least in the chemical industry where the author is knowledgeable, that beyond technological modifications, little is done formally to tackle other type of internal or external transformations (social, cultural, economical, and political) on safety. Little is done as well with regards to the effects of technology on other aspects than technology itself (i.e. ergonomics or team coordination). One reason is that there is a lack of methodologies in this area but also because there isn't really any clear typology of changes available and their link with industrial safety.

2. DESIGNING A CASE STUDY TO APPROACH CHANGES

In order to approach this problem in a way that was manageable and not too ambitious given the complexity of the topic, a study has been designed to start with, in an industry where installations are simple and number of employees exploiting them limited. Silos were in that respect good candidates. Silos are hazardous installations exploited by a small amount of people, are relatively simple technologically speaking and decentralised entities within bigger organisational structures, comprising traditional functional departments (i.e. production, maintenance, human resources, safety, quality). The opportunity to do so has been made possible through the health, safety and environment director of an organisation in charge of centralising supportive actions for several organisations of the seed industry, in many areas such as safety, quality, production, etc. This organisation plays a lobbying role in general in favour of this industry at National or European level. As I worked with him previously on designing policies on learning from experience, I asked him if his organisation would take part of a project on changes sponsored by the ministry. He thought the subject to be very relevant as the companies he works for all evolve continually and, according to him, even more so in the past years. One issue is definitely for them to better anticipate potential safety problems as a result of these evolutions. I explained to him that I needed access to voluntary companies willing to ask themselves questions and to be open enough to be perhaps challenged about their own practices in this respect. I agreed to present the project in a few hours to any interested companies he could gather through its network of members. We agreed on a date and about ten persons participated (I don't know the number invited initially and the proportion who responded positively, but this was a good enough figure) to a common presentation about the purpose and implications of the study.

2.1 Finding an interested organisation

To sensitise the audience, the presentation relied on some of the results of the investigation of the BP Texas City accident, mainly from an organisational point of view, and ended up with identifying some of the key changes found in the analysis (i.e. decentralising of safety function, high turnover of managers, poor design and aging of some installations, see Le Coze, 2008b for some discussions of these findings), and their impact on safety. It then introduced the steps likely to be followed for the study (individuals to be interviewed, observations needed, documents required). The meeting was successful and individuals, for the most part of them health, safety and environment managers, were really keen on openly debating these issues referring to their own experiences and current situations within their organisations. They could refer easily to some of the findings of the BP Texas City investigation. Many even believed that it would be relevant to introduce these results to their top managers, because as hse managers, they often couldn't make anything about organisational changes that were not their decisions but sometimes strategic decisions of executives. One person showed a lot of interest in applying this kind of approach in her organisation. Following the session this person was the quickest to contact me and to create the opportunity for being part of the project. She had first to convince her boss but thought that she could do this quickly, and so I had the case that I was looking for. As it will be shown, it turned out that this person had already some ideas in the back of her mind when creating this opportunity. It is assumed now that she could see in the presentation of BP Texas City accident investigation some of the problems of her company in a rather accurate way.

2.2 The 'turn' of the study

I performed interviews during three days between October and November 2009, then organised the feedback session for the end of February 2010. One very interesting side of the study is that some of my initial outcomes about changes and their potential impacts on industrial safety anticipated an accident, a fire due to self-combustion of colza (a specific kind of seeds) of several cells in a silo, which happened only a few days before my planned feedback session in February 2010. This accident represented a costly event for the organisation, damaging silos infrastructure and destroying seeds, although there was no harm to any employees. It was publicised in the local news because of its spectacular effects (flames and smoke) but also because of the intervention of firemen. The image of the organisation also suffered within the profession, when for years it had been seen as an example to follow. One immediate conclusion about the origin of the events was that temperatures monitoring of seeds in the cells of the silos, an operation carried on site by operators and considered as a basic practice, was not performed according to standards. Self-combustion of products is one of the risks of the activity and checking temperatures (about twice a week) is as much a requirement for quality of product as a safety parameter (more about this later). Above a certain temperature threshold, the likelihood for a fire is very high.

The feedback session in February (only a few days after this accident) happened without much debating whereas I expected conflictual interpretations over some of the findings that questioned, for example, strategic decisions of top managers about changing the structure of the organisation and its impact on safety practices. I started again this session with BP Texas City presentation to indicate why and what I was looking for, and then moved on with my findings. As mentioned, there was almost no opposition from the members of the organisation attending (managing director, human resources manager, maintenance manager, safety manager and operational managers), but a sense of general approval instead about my attempts to elaborate on the links between changes and level of safety. They, in fact, at that moment, could easily project themselves in what they then already knew about the recent accident, and these relationships that I was trying to establish. The managing director intervened once or twice to approve problems of information flow between silos operations and top management. Given the implication of the results, the hseq manager asked me to proceed with an investigation of their accident, with a specific focus on the organisational dimensions. She convinced the managing director again of the interest of doing so, and he then participated quite openly as much as he did for the first part of the study.

This situation transformed the initial approach on changes in a rather unique opportunity to compare what I was able to foresee, and what I had missed, in hindsight. This study became also therefore a very relevant input to the debate about the possibility or not to infer from the state of a system (i.e. from a specific technological and organisational design), the likelihood of an incident or an accident. It gave the possibility to deploy an approach (as experienced and described elsewhere Le Coze, Dupré, 2006) that can be seen as a way to move beyond the 'normal accident' and 'high reliability organisation' dead end (Rijpma, 2003), by combining within a same case study (figure 1, from Le Coze, Dupré, 2008), an approach of normal operations ("*what's happening when nothing's happening*?", the left part of figure 1) with an approach of investigating incident or accident (getting into the '*darkside of organisation*', Vaughan, 1999).

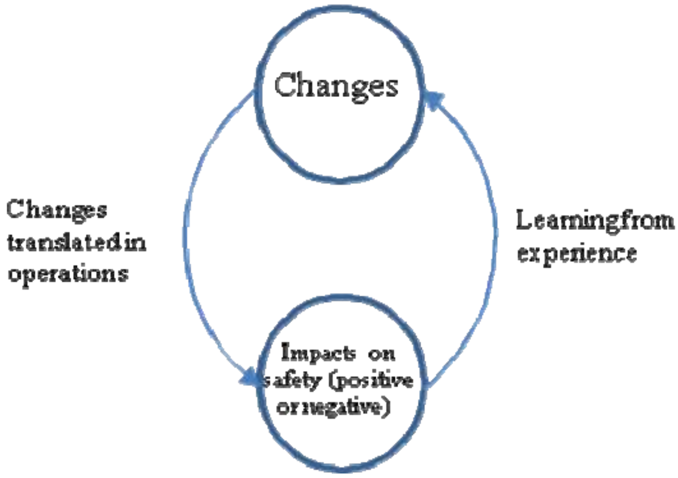

Figure 1. Combining study of normal operation (targeting changes) with investigating incidents/accidents (in relation to changes)

The second phase of this study (the right part of figure 1), investigating the accident, was pursued between March and April 2010, and results were presented in the beginning of June 2010. The presentation went well, although given this time to a much more restricted audience (managing director, hseq manager and human resources manager). Apart from few problems with some wordings, they accepted the interpretations and conclusions, although these were debated and that it remains, as always, a bit unclear what has filtered and has been acknowledged by the different persons. Some indications for strengthening their current safety management and strategy were discussed, and could be developed in the months to come.

3. METHODOLOGICAL APPROACH

Methodologically, the first part of the study consisted in visiting and interviewing, within a three days period, people operating a silo, chosen for its importance (three persons working full time) and key people of the organisation (six persons from various departments: human resources, safety, maintenance) including the managing director. The angle followed was to question all the interviewees about the changes that they could think of in the past, present (and in the future, as expectations may have an influence on the present) in relation with their work, without restrictions and without imposing a specific typology to them. According to positions and experience, it was expected to hear about different type of changes. The study confirmed this assumption. The next phase consisted in extracting changes more likely to raise safety issues, but also to specify, in general or more precise terms, how. This requires defining the underlying model(s) directing choices of relevant changes. Such an effort has been done elsewhere (Le Coze, submitted, Le Coze, 2011), but has also limits given that expertise always contains implicit dimensions, such as intuition (Klein, 2004). It can't be fully developed here for lack of space and is only described very briefly. In this model, safety is understood as a dynamical property obtained by the systemic articulation of environmental (macro), organisational (meso) and individuals (micro) dimensions (Vaughan, 1999) while performing safety management activities (Hale, 2003). This property is obtained through the on-going interactions of internal and external (or collective) actors with technology, mediated by structure(s), culture(s) and power. Balancing conflicting goals (safety, production, quality, social climate, etc), defined for instance as tradeoffs quandaries (Perin, 2005), is at the heart of this vision of safety. The power of safety department (i.e. relationship between this department and executives) is one of the elements of the quality of the tradeoffs operated within the system, but other dimensions, such as the ability to deal with controversies over technological problems (i.e. handling of whistle blowers) is another one. Obviously, high sensitivity to the impact of a wide spectrum of changes is an important factor too. Identifying changes is therefore closely related to the model directing choices, and therefore somehow, a test of the adequacy of the model.

The second part of the study consisted in investigating the accident. Interviews with the same people were conducted again this time retrospectively in the light of the events, and interviews were also extended to other individuals in order to compare practices across territories of the company, and silos (twelve persons in total). Of course, persons directly involved in the accident were interviewed, although indirectly for two of them, out of three. Indeed, the company, before the beginning of my investigation, ended up firing these two employees, not so much because of their implications in the genesis of the accident, but rather because of their behaviour after the facts, especially one of them, who kept on taking decisions against the organisation's position, and compromising safety of silos while the latent risk of fire was still dealt with. As sanctions, they demoted them to lower positions within the organisation, an offer that two of them declined, and were as a consequence fired. One of these two intended suing the organisation through the legal institutions in charge of judging conflicts between employers and employees. Quite understandably, they did not wish to be part of the investigation. However, interviews with these two persons were in fact conducted by the hseq manager the day following the accident, weeks before this accident investigation. These interviews were written down and signed by the individuals, before that any sanctions were taken and therefore before the tensions and conflicts experienced afterwards. At this stage, they were open minded and not reluctant to admit what they considered to be 'mistakes' on their part in retrospect but also organisational problems in the background of their 'mistakes'. These interviews were then available and provided a lot of information needed for interpreting the case. The focus of interpretation was not so much on the technical side of the event, but rather on its 'organisational side', as requested by the company. Identically, underlying models are here very important, as for any accident investigations. This question has also been discussed elsewhere previously (Le Coze, 2008c). Main models behind these were borrowed both from the more normative tradition (i.e. Johnson, 1973) and the more descriptive one (i.e. Turner, 1978, Vaughan, 1996) of investigating accidents.

4. SOME FEATURES ABOUT THE TECHNICO-ORGANISATIONAL SYSTEM STUDIED

4.1 A decentralised type of company

The organisation which participated to the study is highly representative of this type of industry, both from an organisational and technological point of view. One of the core businesses of these types of organisations is to collect and store different kind of seeds (i.e. wheat, barley, corn, sunflower, colza) in silos, and then send them through either trucks, train, barge or ship. It is based on a physically decentralised mode of working created by the geographically dispersed situations of silos. One of the challenges is to plan the flows of seeds between silos for organising transport between destinations and type of transports (trucks, trains or barges). Covering sometimes very large territories, silos from a same organisation can be far apart, sometimes four to five hours away by car.

This situation met in many of companies in this industry results from a trend of mergers of the past years, where cooperatives[1] have started to group together to form bigger entities. Headquarters of the organisation involved in the study has for instance a more or less central position so that silos are all in a maximum range of 3 hours by car from the administrative building of the company, which obviously constraints the number of visit and oversight that can be performed. The very nature of this geographical situation of dispersion makes of this industry a good example of decentralised system.

4.2 Industrial risks of silos and barriers

Depending of the location of the silo and its design, different type transports are, or are not, available. More complicated silos are those cumulating:

- Railway tracks allowing trains to be used for sending seeds,
- a canal allowing the use of barges for sometimes very large quantity of products (depending on the depth the river) and,
- for all of them, roads for trucks.

They are therefore a bit more complicated technologically and require an ability to manage all the type of installations involved but also a higher level of activity (which is normally compensated by adequate staffing level). There is however very rarely a silo combining the three types of transport, and other features contribute to distinguish between a simple and a complicated silo, for instance:

- the number and size of cells constituting the silos as well as their shapes,
- the type of human machine interface and level of automation of the silo (including temperatures, alarms, etc)

Photo 1. Examples of silos

The organisation studied operated around 65 silos, divided in three territories or areas, with two main areas of about respectively 25 and 30 silos, and about the same number of employees to operate them, out of about 250 employees, including administrative, support and other functions or activities such as stores (about 50 persons). Some silos, the small ones, are left without full time operator, and the bigger silos require sometimes two or three persons, full time, a silo manager and silo operators. The exploitation department is the biggest, with a third of the total amount of people (with the maintenance department). Main industrial risks are fires and explosions. Fires can be produced by self combustion of seeds, and explosions can be generated by clouds of dust ignited by any sources of energy coming from mechanical equipments. Dust is a normal by product of loading, working or transporting grains. Prevention relies on different type of barriers, including aspiration of dust through automation or through manual work, but also actions such as checking temperatures, either directly in silos with instruments

[1] The term "cooperative" defines the specific status of these organisations. A cooperative is owned by farmers who put resources together for planning, collecting, selling and distributing their crops. However, although represented by elected pairs who take part of an administrative committee of the company, they do not interfere directly into the management of the company that is left in the hands of a managing director, part of the administrative committee himself but who remains the formal manager of the cooperative. However, these farmers remain a strong source of power. One of the task of the managing director is to handle the many interfaces with the farmers, on site (farmers live around the sites all year long and have regularly opinions or comments about the silos exploitation), and through the administrative committee.

or through computerised systems. Although for years silos had not really been perceived as high risk technologies, two accidents in France, in 1982 (Metz, 12 casualties) and 1997 (Blaye, 11 casualties), demonstrated the potential severity of dust explosions within confined spaces such as silos.

4.3 Regulatory context

These two accidents led to new and then successively updated regulations, in 1983, then 1998, and a new version of the law came out in 2004, and then again in 2007 to add requirements including near miss management system, to be available for inspections. Early regulations required prescriptive technical measures (aspiration of dust, etc) for preventing fire and explosions, whereas latest versions moved on to safety management principles (in line with other regulations in industrial safety), including:

- producing risk analysis,
- safety procedures to be written and available to personnel,
- training to be ensured to personnel,
- establishing a learning from experience process to be.

It is however only after the Blaye's 1997 accident that a certain level of consciousness gained strength in the industry and in the control authorities, throughout specific programs of inspections targeting silos safety.

5. RESULTS

5.1 Identifying relevant changes in foresight (1st part of the study, oct/nov 2009)

During interviews, many changes were identified, ranging from technological to organisational but also environmental ones. Among all of them, four attracted my attention: new regulations leading to the creation of a hseq function, a new managing director designing a new organisational structure, a new generation of employees and some gradual and rapid technological modifications. They seemed to be significant for safety, either positively or negatively (which is one of the fundamental difficulties with changes, to distinguish or weight their value and drawbacks). They are now introduced. This section attempts to present the findings such as I saw them before investigating the accident. In hindsight, things appeared sometimes differently, for instance more radically than it seemed to be at first, but this will be explored in the section dedicated to the accident investigation. For each of the change retained, there is a conclusion about the potential impact on safety associated with it.

5.1.1 Introducing a new hseq function

The few elements already mentioned above indicated some of the changes of the past years in the environment of the cooperative. During our interviews, many indeed discussed about the increase of regulations (and not only in industrial safety, but also for instance in product quality) and the resulting higher number of outside constraints and inspections throughout the years. One consecutive major implication of the new context after the Blaye accident in 1997 and the new regulation of 1998 was the recruitment of a person in charge of quality, safety and environment. Indeed, facing a more demanding regulatory environment, the organisation had to respond with more resources in order to cope with it. Recruiting someone became a pressing option whereas they had managed all these years without it. A woman was chosen to take on the task of implementing a quality system, then to slowly improve the way safety and environmental issues were managed, for aligning the organisation with the new external pressures. As a result, the department grew, and there are now two more persons working full time under the hseq manager. Describing the ups and downs of her experience as hseq manager for the past ten years, it appeared, while interviewing other individuals about this too, that this new function had to overcome many oppositions from the other departments, which used to be more autonomous before. Introducing quality and safety across the organisation meant sharing information and centralising actions in order to ensure compliance with quality and safety requirements. People, including the hseq manager, talked nevertheless about it in the past, as if all these problems were now behind. Many of the identified tensions with the other managers, like the maintenance manager or human resources manager, were seen as things no longer significant.

One of the key discussions and conflicts throughout the years between these managers was about the relevance of elaborating formal procedures to prescribe working practices (either for quality or safety). As many emphasised during our interviews, the work culture of silos operators had been for many years an oral culture with little description through written rules. This was sustained by a managing style based on proximity with employees, what they described as a family approach of the business. It was a work culture shaped by the autonomy of silos operators, a feature well understandable given the decentralised configuration of this kind of organisation (Antonsen, 2009, as described a similar situation on boats, creating strong work cultures). As most of their days are spent out of sight of managers, trust had become throughout the years the glue holding the system together in this decentralised mode of functioning. Without definition of what is expected at work (as found in modern quality and safety management systems), trust put in expertise and involvement of operators in their activities (in the past, first line managers or operators were very often local individuals that worked for life in the same silos, and the turnover was low), replaced the interest of having a formal approach where everything is specified under a quality or safety assurance principle. This was an important feature of the organisation for many years, and some of the top managers defended the idea that too much description did not serve quality or safety, as a drawback could be that operators would only apply rules without stepping back or thinking for themselves. Globally however, it seemed that, after ten years and despite tensions due to the introduction of a new and constraining function in the organisation (qhse), the trend was rather positive, and according to a majority of interviewees, the company did progress in quality and safety.

My conclusion was also rather positive but I remained cautious whether this change could be seen as a fully 'digested' one or a still potentially conflicting one. It seemed indeed that some recent event told by some had demonstrated enduring frictions between the hseq and some departments (especially maintenance and its manager).

5.1.2. A new managing director followed by a new organisational structure

A new managing director was appointed in 2007. The profile of this new manager was different than his predecessor. His experience was not in operating silos but was based and developed in another department of the organisation, dealing with other issues, including developing products to enhance quality of crops, a central department within the organisation although not as influential as the department of exploitation (which included silos operation and maintenance). The previous and experienced (in exploitation) director left the organisation in 2005 to take other functions in another company, after almost 25 years of acclaimed management. After an ambiguous and unsuccessful replacement by a manager appointed from outside who didn't fit the job, the current new director from inside the company took the position in 2007. Not long after, he designed a new organisational structure. Because of his lack of knowledge of silo exploitation (and following an inspection by control authorities identifying a regulatory non compliance in a silo, leading to a fine), he decided to move on with a new structure. Safety would be in the hands of operational managers with knowledge of silos exploitation, while he would step back and deal with strategic and managerial issues. In order to do so, his approach consisted in transforming the current organisation (figure 2), and moving from one model to another. While previously there were 'silo operating managers (or operators)' under the supervision of 'area managers' (between 7 or 8 of them), themselves under the supervision of the 'exploitation manager', he added a layer with an almost equivalent function to the ex 'exploitation manager', but not completely so: the 'area exploitation managers' (aem) function (3 of them, recruited internally). Under the 'aem' function, he created a 'team managers' (tm) then an 'operating silo managers (or operators)' (osm) functions. Figure 2 illustrates also the years before 2000 when the hseq function was introduced.

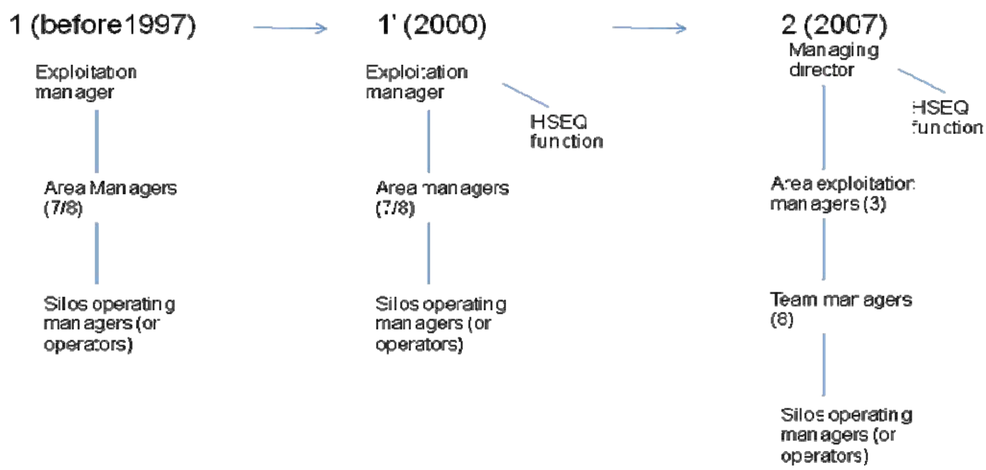

Figure 2 : Moving from model 1 to model 2

In order to ensure the efficiency of this new organisational structure, the managing director required from the newly appointed 'aem' to develop auditing frameworks to be used as guiding principles for ensuring compliance with good practices. This type of reporting system based on auditing implemented by the 'aem' themselves would allow him to maintain supervision from a centralised point of view, without being physically on site. It would help taking on the challenges for these persons appointed to these new functions. This new strategy went along a formal delegation of responsibility, developed in 2009, written with the help of a lawyer who advised the top manager to be less exposed to personal liability in case of an accident. This delegation was introduced to the selected ‘aem’, who had to sign and agree with its terms. As the managing director told us, he expected these changes to increase motivation towards safety. He acknowledged the pressure that it had put on them with the auditing framework as much as with the legal delegation of authority but thought that it was for the good of the organisation. In order to ensure the configuration to work as best as expected, he also spent time describing job definition of the new functions created (‘aem’ ‘tm’). His view on this was that a system is full proof if resources are dedicated to define precisely ‘who’s doing what’ and that information about how things operate in reality is produced and made available. It is therefore confidently, but not without a bit of anxiety because of the mix of trust and pressure that he had to put in the ‘aem’, that he talked about these changes that he himself introduced and designed.

My conclusion was that these changes were major ones, with implications on real practices and safety that were nevertheless difficult to predict exactly. One was obviously, in theory and in line with the managing director strategy, that these ‘aem’ would better integrate safety as they would be legally in charge, at least on paper. But I however identified two potential issues, first in the relationship between the hseq manager and the new ‘aem’. While for the past ten years the hseq manager had, slowly and with pain, established a centralised position in the organisation, at the right of the managing director(s), the new configuration would be likely to create problems or/and tensions. Safety was to be indeed more decentralised with these three new ‘aem’ positions and I wondered how safety decisions would be taken between the managing director, hseq manager and them. It seemed that in this domain, decisions would be likely to suffer some difficulties, in case of divergent opinions. Who would have the last word on safety topics, the hsqe manager or the new ‘aem’? How would the managing director position himself in case of conflicts? The second point that I raised was the problem of the distance this new structure would create between real operations and the managing director. I could imagine that more difficulties would be met for the information to circulate from top to bottom. A known issue, as found in many accidents, is for difficulties met by managers to be discussed with top managers. Aem, especially with the pressure that they had from the managing director, could be in a position of trying to deal with their problems without revealing them in order to be seen as efficient. As the managing director didn’t have much knowledge of silo operation, he wouldn’t be in a position to challenge real practices when discussing them.

5.1.3. A new generation of workers

In the past three years, fifty percent of the experimented silos operators had been replaced by young ones. A clear impact was well explained by the maintenance manager. For his service, the increase of younger employees implied a higher number of interventions. Whereas in the past, maintenance problems were partly treated locally without informing the maintenance service, the new recruits, on the contrary, called now for any problems, even minor ones. They do not do anything themselves. Even changing a bulb is processed through a maintenance form request, for many of them. This has put stress on the availability of the personnel of the maintenance department. Interestingly these many requests helped also to find out about some corrections brought to silos before, unknown to the maintenance service. Previous common practices of silos managers and operators in some areas consisted, instead of filing a request, of finding themselves solutions to their technical or maintenance problems. This supports well the idea that the decentralised nature of work contributed to the development of local practices and of a specific work culture.

My conclusion was that this change in the maintenance regime had two faces in terms of safety. One positive side exists in the fact that there is a better view on the technical problems that need to be treated properly instead of independently with solutions that can’t be evaluated by an adequate level of expertise. But, at the same time, this also means potentially that younger generation is not as knowledgeable about the installations as before. If they do not try to find, at least temporary solutions, could indeed also mean that they have less understanding of silos. One can therefore wonder in case of safety issues whether their knowledge would be sufficient to improvise adequate solutions preventing incidents. A decrease of resilience, at least from the time being, could result from a lack of technical expertise about the functioning of silos. Somehow, this point of view based on the inputs of the maintenance department can be linked with the feeling shared by many of our interviewees that new recruits were not as much involved as their elders, who were really dedicated to the company. From what I exchanged, it seemed that younger employees came to work and left when expected to leave (working from 9 to 5, and not more), and did not show much interest in the company or to silos. Many said that these could be working somewhere else, it wouldn’t make a difference to them.

5.1.4.Some technological evolutions

A last category of changes that were retained concerned technology. Many different aspects of technological evolutions could be linked together, some more gradual, some more rapid. First the gradual automation of silos changed working conditions, with slowly removing operators from manual work and silos. The nature of the work changed due to these transformations, but was also combined with a higher demand of quality of the seeds. This new demand, a combination of quality and safety constraints (from customers and regulations), led to the introduction of many new instruments of analysis, requiring different competence, in line with a more and more computerised working environment. Throughout the past 25-30 years, the number of employees dropped considerably because of these higher levels of automation allowing more to be done by less people. To these gradual technological changes, recent ones caught my attention: the higher level of transport capacity of farmers' truck, from seven tonnes to forty tonnes. One activity of silo exploitation consists in collecting crops. Farmers unload their crops in the silos, from july to september. It is the busiest period of the year for silos operators or managers (they employ then temporary workers in order to compensate with increase of workload). The rest of the year is quieter and involves different type of activities (cleaning of grains, control of temperature, drying the grains etc).

One part of their job at this busy time is to organise the unloading of trucks. Farmers can at that moment, queue, wait for their turn. Handling of this situation is important as the pressure is at its highest, farmers do want to proceed as quickly as possible, and do not hesitate to try to influence the workers in this direction. It is indeed within these three or four weeks that farmers ensure their income for the year. A safety issue is to know whether this change consisted in higher chance of bypassing of safety rules in order to accommodate with the new situation. When it took only one minute to unload a truck of seven tonnes, it now takes six minutes. Queues are longer, and impatient farmers can push for greater speed.

But, for the silo that I visited, this was not the only technical change involved recently. For this silo, barges could also be used for transport thanks to the canal nearby. Similarly, barges have considerably increased their capacity, from 500 to 1500 tonnes. One consequence was the need to augment the unloading rate capacity of the installations of the silo. However, it turned out that the project to modify the installations with this objective did not include any consideration of the impact of this technological change on the local practices of managers and operators. My conclusion was that, in terms of safety, there could be concerns about the cumulative effects of these many changes, more gradual throughout the years, but also more rapid ones. Although I couldn't specify exactly how and in what way, I expected problems to be met in the future on this specific silo if the modification was to be carried out without care about impacts on practices.

5.2. A synthesis of identified changes

One way to organise data and conclusions was to show that the changes identified as relevant to investigate in relation with their impact on safety could be located on a continuum including past, present and future (figure 3). Some changes were older than others, and the closer they were to the present the more difficult it was to predict how they would impact safety. My conclusion was that it would be very interesting to study more precisely how they might interact in the future, especially the change of organisation and the hseq position. But other issues such as the integration of the new generation in relation with the changes (gradual and more rapid) of technology could also be seen as interesting to explore. And overall, it would be useful to attempt to go further into the interactions of all these changes together. Whereas for convenience, the four categories of changes extracted were discriminated indeed at first, it was clear that it was an artificial view that could give the wrong impression of independence between them. The challenge consisted in imagining scenarios resulting from their combination (figure 2). For instance, would safety issues related to change of practices resulting from the combined effects of technological evolution and the presence of the new generation be adequately dealt with, given that the safety department had a different position in the system (with latent tensions) and that safety was in the hand of a new decentralised 'aem' function?

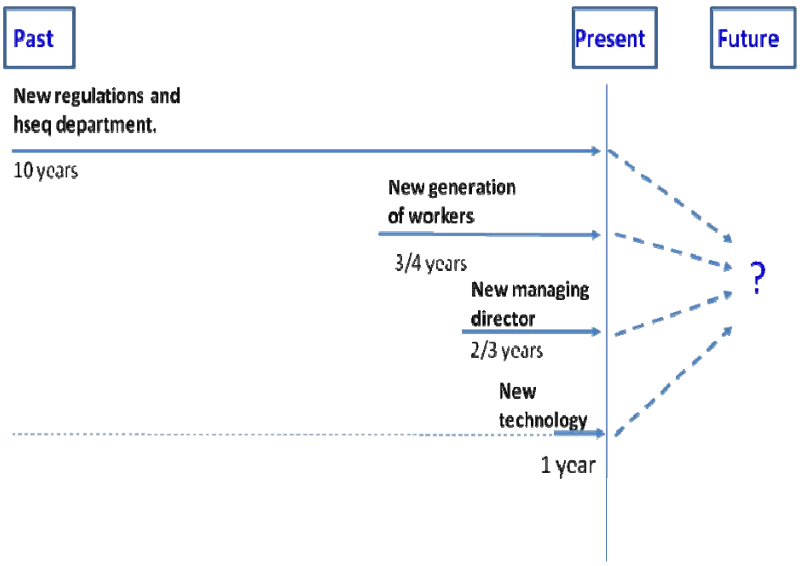

Figure 3. Different changes, what combination in the future?

The accident that occurred demonstrated exactly this, namely how some of these changes (and others not identified in foresight) combined, towards a specific scenario.

5.3 Investigating the accident

As introduced earlier above, the accident, from the silo operator perspective, can be introduced as a lack of temperature checking, although a basic practice of silos safety and product quality. In order to understand why, one needs to describe the sequence of events that led to the accident (the proximate events) then to go back in time and within organisational dimensions to understand the remote conditions that made this accident possible. Some of the changes described in the first part will be met along the way, with some more precision due to the hindsight position.

5.3.1 Proximate events

- **Silo operator**

Technically, the fire was caused by a self combustion of colza seeds. It appeared quite quickly while investigating that one of core human 'sharp end' contribution was the lack of follow up on temperatures that is meant to prevent such dangerous rise. If temperatures had been followed regularly and communicated, the tm and aem would have intervened to stop it, by either emptying the cells of the silos concerned by the rise, or by using fans to cool down the seeds. However, beyond a certain threshold of temperature when combustion has slightly started, using air to cool down the seeds is doing exactly the opposite, namely increasing combustion speed and intensity. The operator in charge of this was a young recruit, with less than two years experience. One immediate interpretation by many in the organisation, especially managers, was to blame his lack of involvement and professionalism. It was a good example of this new generation of employees. This young recruit was indeed depicted as not really professional, for instance not tidying up the silo, not logging into the system for recording the temperatures checking, or other parameters. He was described as not really involved, and farmers living nearby, coming around the silo from time to time, once witnessed him playing with his gameboy in the office during working hours. Nevertheless, opinions were divided as some who knew him were saying that he worked hard when being part of a team and under the supervision of a manager. He was not that lazy person described now that the accident happened. Many stressed in this respect that the fact that he was working on his own in the silo did not help.

But as in many accidents; it is only when 'mistakes' are put within their context that one can understand them. Here again this principle applied fairly well. When questioning his working conditions, it appeared that he was not allocated full time on this silo, whereas in the past there was an experienced full time operator for the same silo. So he couldn't dedicate as much time to it, and didn't have time to get to know the silo very well. Looking at his working conditions, he appeared then to have a very disturbed schedule, making it more difficult to work as expected. One day he would be helping other operators at a different silo, and another day he would be at his silo. This lack of stability played a role in creating a degraded situation. Another issue was the problem of working the seeds. Because of the really good crops of the year, all cells of his silos were full, and he couldn't easily perform this task, as one needs to be able to transfer grains between cells to work on them (mainly filtering and cleaning). To do so they need one empty cell for the rotation. Another limiting factor was that the installations designed for transfer were very slow ones in this silo, and instead of taking less than a day to do one transfer, it took him two and half days. Given his schedule, being one day there and another somewhere else, this made his work rather difficult to plan and to carry out, especially as he was not fully trained and had to learn on his own.

But that's not all. It turned out that colza is also the most difficult and most dangerous seed to store. In the past and as a consequence, colza was not stored in this silo, but in another one, equipped with automatic temperature checking and also powerful fans that cooled down well the colza, much better than the fans then available in the current silo where the colza was now stored. The density of the colza is high, and powerful fans are needed to go through the tons of seeds from the bottom to the top of the cells. The young operator didn't really know how long it took for the air to go through the seeds stored in the cells. In the past, the colza was also stored where an experimented silo manager was available. All these constraints combined together (disturbed activity, full cells due to good crops, slow transfer rate between cells, rather inadequate fans in comparison with other fans) revealed a particularly complicated context, especially for a young and inexperienced operator. An interesting story demonstrated his lack of awareness over colza's rise of temperatures. Few days before the fire, a farmer said that he saw at the top of two silo's cells (out of ten cells) that snow had melted, indicating high temperature inside these two cells. He informed the operator but it did not trigger any response from him apart from only putting the fans under the cells to cool them down (in retrospect, the fans must have contributed to accentuate the problem). He did not pass on the information. This clearly shows that he didn't have the expertise to understand the severity of the situation.

Even if issues of lack of involvement, laziness and unprofessionalism could be heard and partly accepted as contributing factors to the absence of systematic follow up on temperatures (the operator did say nevertheless that he was checking them but not recording them in the system), his working conditions nevertheless guided the investigation towards the organisation: first for the lack of supervision by the tm, and secondly for the choice of the aem to store colza in this silo (not the best equipped for it), and allocating it, without worrying about the risks involved and consequently ensuring tight supervision preventing drifts, to an inexperienced operator not working full time on the silo.

- **Team manager**

Supervision was supposedly ensured by the new tm function. His tm was working in the silo nearby, about ten minutes away by car. First of all, this silo manager, in charge of one of the busiest silo of the company, did not have much enthusiasm for his new position, as he commented to me. He didn't like to be on the back of people, although an excellent silo operator, employed since 1982 on that very same silo, he didn't have much interest in supervising people. He had three silos to supervise but didn't have much time for them anyway given the level of activity of his own silo. He nonetheless knew about the problems of this young operator, he did notice his lack of recording, his poor tidying up of the place. He also admitted that this young operator had trouble doing his job given his level of expertise but also because of the feature of the installations (i.e. transfer issues). He recalled telling him to be careful about neglecting visual aspects such as housekeeping or recordings because he could be in trouble one day for not doing it (following an audit or incident for instance). He therefore notified few times these problems orally to the aem, who, although acknowledging his comments, did not intervene with the intensity expected. Secondly, his relationship with the aem was not great. For him, he didn't see the aem often enough, communication was very little and from a distance, without strong presence on the field, he also regretted, as tm, not to be included in decisions involving strategies for organising flows of seeds between silos etc. Given that they know well their silos, it is best for them to be asked whether such or such option is more appropriate or not. That was not all. The tm complained about the fact that the aem decided without consulting him about where to put the silo operator in one place or the other to compensate for personnel variation (holidays, illness, absenteeism). We know now from the analysis of the sharp end of this accident that the silo operator was moving from silo to silo according to the varying needs. This was done while bypassing the tm. Given all these elements, the tm was far from being fully involved in his supervising function. The result is that the silo operator, who didn't see the temperature rise, lacked close supervision.

- **Area exploitation manager**

The last comments indicate the part played by the aem in the genesis of the accident. His 'mistake', as he admitted himself during interview with the hseq manager the day after the accident, was to maintain colza for too long in this silo without full time supervision, and with an inexperienced young operator. It is indeed out of good practice, but not impossible to manage such a situation, if close supervision is granted. Thus, in another part of the company's territory in 2004, before the new organisation of 2007, they had already proceeded like this, namely storing colza in a silo not dedicated and supervised by an inexperienced operator, for a few months. They then got really close to a similar scenario (the colza started to heat) but stopped it thanks to appropriate supervision. On commenting this previous incident, an interviewee explained a very interesting side of silos management. He explained that one difference with younger operators is that they didn't oppose to aem decisions (or previous 'area managers', before the 2007 new structure) as older operators used to do. For example, storing colza in silo not very well equipped for it (in comparison with better and available silos) was not accepted by operators with expertise. They knew that it was difficult and more dangerous. However, according to interviewees, they still had to fight their case because aem would insist. Young operators nowadays did not resist and did not oppose as much to aem decisions.

One wonders why the aem made this 'mistake'. One explanation that comes to mind is that he experienced a blind spot, he didn't see the situation developing, while struggling and juggling with allocating personnel to silos (according to most people there was less people than in the past to operate silos, a statement that human resources manager did not confirm, although the figures did show it). One possible answer is found in his trajectory within the organisation. Recruited in 2007, he is one of the employees who made the best out of the reorganisation. The managing director and human resource manager were looking internally for profiles to take on the new aem functions. This silo operator stood out for his leadership qualities. While under the supervision of a silo manager, he slowly seemed to have taken over. He came to be informally recognised as the manager of the silo. He was selected, among other internal candidates, with the help of an outside human resources consulting company comforting them in their assessment of the potential of this employee (at least on the non technical side). This consulting company saw him as confident, ambitious and with good leadership skills. Although a big step in his professional career, this silo operator became an aem.

One could have expected difficulties, as many commented. So far in the history of the company, only individuals with knowledge of silos and team management could gradually go up and take positions such as aem (or equivalent), and are about ten years older than the new aem when taking on this kind of position. Considering the huge gap between his previous function and his new one, his 'mistake' is not so surprising. Is it not a 'mistake' of someone who is still learning his job? In this respect, it is relevant to note that no specific training was dedicated to non technical skills, either for the aem or the tm, although as stated by many of the interviewees, you can be good technically but bad on the non technical side. This is all the more important for a managing position. I compared then the 'non technical' practices of the other experienced aem (elicited during his interview) with the information that I could gather during all the other interviews about the practices and profile of the aem who made the 'mistake' (some are found in the 'team manager' section). A strong contrast appeared (table 1). As this table show, the contrast helps understanding what decreases likelihood of 'mistakes' for an aem. The experienced aem also added that despite offering the new aem to come and exchange on practices and on his difficulties from his new positions, he never heard from him.

Table 1. Comparing style between experienced and new aem

Style of the experienced aem	Style of the new aem involved in the accident
Cautious	Highly confident
Collective decision making process	Individual decision making process
Technical knowledge of silos and their individual specificities in his area	Little knowledge of all the silos of the area and their specifities
Visit of every silos regularly	Selective visits of some specific silos instead of all
Ensuring motivation of employees	/
Building a network of experts and building trust among them	/
Not being afraid to question oneself	Excess of confidence in the quality of his judgments
Accepting difficulties and being able to discuss them with hierarchy	Hiding problems to keep an image of control in front of hierarchy

In fact, in the light of the accident, the hseq manager revealed the many problems that she had with this aem since he started in his position. He would for example refuse to apply basic safety rules and would oppose many of her suggestions for improving safety. She gave me three concrete examples of procedures not really followed or argued by this aem. Although she would refer to the managing director about these difficulties with this aem, there was no strong action taken. While getting into the different interviews, the profile of the aem slowly took shape (see table 1) and did enlighten the context of his 'mistake', but then triggered also questions about the handling of this individual by top managers.

5.3.2 Remote conditions

The managing director summarised his interpretation of the accident as '*a silo operator who doesn't do his job + an aem and a tm who do not supervise him enough and control his work=a fire*'. Although quite right, it only covered the proximate events. What about the organisational side of this accident? In line with previous models established on grounded analysis of disasters (Turner, 1978, Vaughan, 1996, Hopkins, 2008) and previous personal experience (Le Coze, 2010), it was easy to show the very organisational nature of their accident. Two lines of approach showed this very well. The first one is the absence of treatment of signals (conveyed by the hseq manager), in favour of the new structure, supporting the new aem positions. The second is the absence of understanding that the organisation moved on to a new mode of functioning where trust did not play anymore the regulating role it used to fulfil in the past.

- **Missed signals**

In light of the accident, the interview with the hseq manager went further into the description of the tensions that were mentioned, but only lightly and as a thing of the past, in the first part of the study on changes. The day of the fire, the events started with outsiders (most likely neighbours of the silos) calling firemen because of a gas odour nearby the silos (at the time there was no one working there, the silo operator being somewhere else to replace someone, a frequent situation, as discussed). When informed about this both the hseq manager and the aem came on site to assess the situation. At that point their opinion differed radically about what course of action to take. They realised quickly that it was not gas but smoke coming from one of the cell due likely to a (beginning) self combustion of seeds. But while the aem suggested a conservative angle consisting in emptying the cell and to transfer the good seeds to other cells in order to save what could be saved, the hseq manager had a much more radical strategy consisting in completely emptying the cell to minimise risks. Given these two options, the decision had to be taken by the managing director. After hearing both positions over the phone, the managing director decided to follow the aem. It appeared to be a 'mistake' afterwards as it was already burning to the point that it was not possible to save the seeds by extracting separately the good from the bad. But confronted at that moment with the uncertainty of the situation, he preferred following the aem rather than the hseq manager, although the most expert person on this matter.

This exemplified the fact that for the past months, the hseq suffered from a weakened position within the organisation, and in her relationship with the managing director. With a strong personality and straightforward approach of problems, some did not find it easy to interact with her (and tensions of the past with other departments were also put partly on her personality). The new aem was one of them. He openly complained about her attitude to the managing director and human resources manager (there were written traces of these complains found in his yearly individual appraisal that I had access to). Confronted with tensions between the two, the managing director, given the good results obtained by the aem in general, favoured his judgment and position over the hseq manager. An audit, few weeks before the accident showed that there were problems in that very same silo (housekeeping, recording of temperatures checks, etc). But instead of triggering the right answer to the problem by ensuring for instance a closer supervision, the managing director was satisfied with emails from the aem stating that he was taking care of the situation, by refreshing silo operator's knowledge. The aem's own audit, a few weeks before, did show problems too, but it will not be followed by the appropriate managerial response to the situation.

The hseq manager could see how the aem was influencing the managing director for getting away with safety issues that he thought he could handle without having to be told how to do by the hseq manager. It worked so well, as far as the managing director threatening the hseq manager of job loss if she would carry on interfering with the aem and creating more constraints that needed. At this stage, it really became difficult for the hseq manager to impose and to convince the managing director while taking risks of losing her job. As she described it well, the power plays and influences around the managing director blinded him, who, without knowledge and experience of silo operations, found it very hard to assess the concrete situations for which existed conflicts between the hseq manager and aem. Looking back, the managing director confessed that he had been blind. His will to support the new structure that he created, to facilitate aem new position and to find ways of appeasing the recurrent state of conflict between the two managers (aem and hseq) by favouring one over the other led him to neglect the warnings of the hseq manager. As he revealed it after the accident, for him (and for the human resources manager), the accident was a huge surprise. It was like a shock that they did not appreciate the situation correctly, and gave their trust to the aem without acknowledging some of the issues pointed at by the hseq manager.

- **From one organisational model to the other, the issue of trust and control**

This failure of hearing the hseq warnings was the indication also of a lack of understanding by the managing director (and human resources manager) that the organisation had shifted from one model to another, and that the hseq function had a very strong role to play in this new model. Table 2 indicates the different features that can be seen as creating a transition or 'rupture' with the past. Putting now together many of the observations and data collected throughout the first part (figure 1) and second part of the study, it is possible to sensitise to key differences between the two models and to dig into why the second model failed to prevent this accident.

Model 1 (before 2000 then gradually)	Model 2 (from 2007)
A exploitation manager with experience of silo operation and visiting silos regularly	A new managing director without exploitation experience and more distant from silos
Experts workers with many years of experience and committed to silo operation and to the company	• An gradual replacement by young recruits: • with another relationship with work, silos and company, • who need supervision and training • who do not oppose to aem decisions because of lack of expertise
Proximity of area managers to teams due to small areas (less than 10 silos) and presence of a centralisation of exploitation through the exploitation manager.	A wider area covered by area exploitation managers (between 25 and 30 silos) compared to previous areas after new structure and formal legal responsibility of safety
A gradual progression through the organisation	Possibility of going up quickly without going through all steps
A short distance between silos and operations, a good flow of information • Limited hierarchical chain • Direction frequently on site	A reduced information flow, a greater distance between silos operation and direction • Longer hierarchical chain • Less time spent on site
No strategy of control of practices through audits, trust and professionalism as principles of functioning of the system	Two different audit systems implemented under the supervision of the hseq manager and areas exploitation manager, trust and professionalism replaced by formal approaches
A limited external regulatory pressure • No exposure to oversights by control authorities on industrial safety matters • A low level of external constraints on industrial safety compliance and integration in practices	A highly regulated context • Compliance with regulation requirements • A pressure for more proceduralisation as a demonstration of safety • Frequent interaction with control authorities

One question that one has when investigating such an accident is very much why for so many years such an event never occurred in model 1 and that it suddenly happened in model 2. The answer to this is the absence of understanding that the old model based on trust needed to be based on a different perspective. This evolution has been in fact well described by the managing director who said many times during interviews that '*trust doesn't exclude monitoring'*. This sentence sounds right in this new context where audits have slowly become a core safety tool and where the external regulatory environment requires a formal approach of safety. But his first 'mistake' was to put trust in an aem who should have been supervised and trained to learn good practices of the position (knowledge available in the organisation through experienced managers). If trust is a lever for managing, it can only be granted to experienced people, not someone that should have been seen as a beginner requiring close supervision. His second 'mistake' was to pretend ensuring monitoring when audits and signals conveyed by hseq manager were denied and not followed up with adequate actions. The model 2 is not necessarily less efficient in principle than the previous one, as long as the logic of auditing and safety management system is fully implemented and not maintained in a 'in between state', which was very much the impression that the organisation gave, to be in an intermediate regime.

The same reasoning that the managing director applied, in retrospect, to both the tm and aem who did not act accordingly whereas they had information about problems with the silo operator, could be used at a higher organisational level. Indeed, whereas the managing director had information about problems with the aem (hseq manager) and audits showing problems at the silo, nothing had been done to act accordingly. To replace the managing director's summary '*a silo operator that doesn't do his job + an aem and a tm that do not supervise him enough and control his work=a fire*', the following sentence was thus suggested '*a new organisational model in place + weaknesses not corrected in this new model= a fire*'.

6. DISCUSSION

This rather unique case study was an excellent opportunity to test the attempt to predict the likelihood of accident due to changes. It is very interesting to see through the investigation that many of the changes retained in the first part of the study played a part in the genesis of the event. The most accurate predictions were about the difficulties of the hseq to position itself within the new structure leading to potential conflict in decisions, but also the fact that information would be likely to be retained at local levels (one of the criticism from the managing director to the team manager was to not report to him about the young silo operator) and not reaching the managing director. There were however information completely missed or unheard of during interviews, although there were clearly important changes. I think for example of the fact that nobody mentioned the decrease and lack of personnel and the resulting constraints for the aem and the tm on work planning. Also surprising is that no one mentioned, especially the hseq manager, the problems met with the aem. I was surprised that the hseq manager did not tell me more about the difficult current situation she was in (the threat of being fired, the conflict with the aem), although not really a change, it was a direct outcome of the change. A last change that was not identified but a very important one is that young people do not oppose as much as experienced silo operators or managers used to.

Perhaps that with more time, more observations and more interviews, these changes and related problems that were not identified in the first part would have come up. Perhaps also that it is much easier for interviewees to talk about some of these issues of change and their impact with the help of an accident in mind, as much as it is easier to reconstruct events in hindsight than in foresight for an investigator. Another aspect is that although I did identify some important issues beforehand through changes, it is only thanks to the investigation that a much clearer picture appeared about what I saw as constituting a shift from one model to the other (table 2). Whether spending more time observing and interviewing people in normal operations would have led to the same conclusion is not sure. It is like if this accident had stopped time and revealed that a new model failed, whereas without the accident, I considered only a flow of changes, instead of a shift with the past. As well explained in many writings, the hindsight bias is a very strong one, and things are not seen the same before and after. This applies to this study. This of course introduces the question of normality of accidents, one of the classic questions of the field since Turner (1978) and Perrow (1984) and further challenged by followers.

In this respect, this experience is rather encouraging and does favour a more optimistic view than the normal accident one, at least on limited systems of this kind. This experience seems to indicate that looking at changes can contribute to see weaknesses and to consider a system more likely to suffer an accident than another system not confronted to these types of changes. This points to the interest of a complementary diachronic emphasis (introducing a time dimension) for studies of normal operations, to the mainly synchronic angle of early high reliability organisations (Roberts, 1993). While at first initiated in studies of accidents (Vaughan, 1996, Snook, 2000), this move has also started in normal operations, from a theoretical point of view (Shrivastava et al,

2009) and from a more empirically based perspective (Roe and Schulman, 2008). This paper has also attempted to show the importance of considering the interaction between a wide spectrum of changes, when they imply, diachronically and synchronically, a shift from one model to another and the ability of the organisation to learn from this shift in order to be able to adjust before the occurrence of bad surprises. Combining both views, bringing together synchronic and diachronic perspectives, is needed in order to understand and assess better dynamical safety properties.

7. CONCLUSION

This paper has introduced then discussed a study conducted in the seed industry, with the purpose of better anticipating impact of changes on industrial safety. Starting with an identification of what appeared to be the most significant changes and how they could translate into practices to challenge safety, it moved on to the investigation of an accident produced by the combinatory effect of some of these identified changes (but also others) of different kind: regulatory, social and organisational over a period of time (2, 3 and 10 years). The interest of the study was to show how these different evolutions defined a new model containing weaknesses not identified and prevented by managers and operators of the organisation. Two next opportunities following this study have been discussed with the managers of the organisation and other people from the seed industry. One would consist in helping the company to implement recommendations, and see how these can practically put in place within the organisation. Some options have already been suggested but it is not sure what will be done. Another one would be to compare a similar organisation of the seed industry which also evolved in the past years and has recently experienced several incidents for which explanations could be found in these evolutions.

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