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AN INTEGRATED VISION TO ASSIST THE EVOLUTION IN INDUSTRIAL RISK MANAGEMENT PROCESS IN FRANCE

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Abstract

Management in the field of environmental protection and risk prevention has evolved to the increasing participation of all stakeholders in the decision-making process. It certainly results from the development of the Information society and the global increase of knowledge of the population, combined with the concerns of the populations related to a sustainable development of our civilization. Our "risk society", following the big industrial disasters (Flixborough, Tchernobyl, Bhopal, Challenger, and more recently AZF), has also developed a cautious attitude towards the role of the expertise when it comes to assessing risks, along with a question of the ability of science to give definite answers.

This has lead in particular to the adoption of the Aarhus convention in 1998 and the evolution of several regulations in the developed countries. For example, in France the new law n°2003-699 of 30 July 2003 about the "prevention of the technological and natural risks and to the compensation for the damages" has introduced an important innovation into the process of technological risks prevention.

This law has enabled the involvement of the stakeholders in the decision-making process related to risk prevention and has urged the development of specific tools to deal with the complexity of risk management issues, in particular for those related to land-use planning.

As technical support to decision-makers in risk management from both public and private sectors, INERIS has played an important role for the evolution of the French risk management system.

This paper describes an analysis on the difficulty to control major accident hazards in an evolving context where the industrial systems becomes more and more complex and where the expectations of the civil society has increased. Then, the authors describes how an integrated vision for industrial risk management has emerged in France and is being implemented in a new law adopted after the Toulouse disaster.

Key-words:

Risk management, Multiple-criteria methodology, multi-disciplinary approach.

Introduction and context

France is known to use a deterministic approach in the control of major accident hazards (Christou & Porter, 1999). In the deterministic approach, the term deterministic means that the major accidents that are assessed in the risk assessment process are pre-defined and considered independently of their likelihood, which is not assessed. The underlying philosophy is based on the idea that if measures exist sufficient to protect the population from the worst accident, sufficient protection will also be available for any less serious incident. The deterministic approach gives a first importance of the limitation of the consequences of possible accidents.

This idea appeared first in an imperial act in 1810, then in a law published in 1917 on hazardous and insanitary plants, but it was clearly reinforced with the law n°76-633 dated 19/07/1976 that became the 'Environment Code' on 18th September 2000.

The adoption in 1999 of the Seveso II directive within the European Member States has initiated evolutions in the various national risk management systems. In France, it has reinforced the importance of the prevention chapter of the risk management as the operator has to demonstrate the implementation of a safety management system. This has lead the authorities to admit that risk management can not only be organised with the limitations of the consequences of accidents.

At the same time, the ISO/IEC standard 73 was adopted and has described risk management as a decision making process based on a risk assessment. For the control of major accident hazards, this means that potential accidents and the way they are controlled have to be assessed in their context.

This paper describes the difficulty to control major accident hazards in an evolving context where the industrial systems becomes more and more complex and where the expectations of the civil society has increased. Then, the authors analyse how an integrated vision for industrial risk management has emerged in France and is being implemented in a new law adopted after the Toulouse disaster.

1. Difficulty to control major accident hazards as required by the Seveso II directive

The number of major accidents in Europe seems to remain more or less the same, despite of the efforts developed to control the major accident hazards since 1982 with the first Seveso directive.

A recent communication from the Commission (European Commission, 2002) indicates that the number of accident collected in the MARS database (Major Accident Reporting System of the European Commission) is between 25 and 30 major accidents par year. (see Figure 1)

Using these data, the frequency of major accidents is estimated at about 3.10^{-3} per year if we consider the number of accidents reported in the database versus the number of hazardous installations throughout the European Union.

The 1999 annual report from the European Environment Agency (Pettitt, 1999) has also indicated that in spite of measures on major industrial accidents in force since 1984, the trend in accidents shows that many of the often seemingly trivial 'lessons learned' from accidents have not yet been sufficiently evaluated and implemented in industry practices and standards.

There are probably many reasons of the stagnation of the number of major accidents in the studied period. They will not be discussed in details in this paper. But as a remark, it is important to notice that if the number of accidents would have been normalised with the total production of hazardous products, the number might decrease.

According to these elements, a positive interpretation is suggested. The relative stagnation of the number of industrial disasters might show that the efforts in risk control have been efficient despite of the increase of the complexity of the industrial systems and the production. If not, we should have observed a growing number of industrial disasters. As a matter of fact, it appears that the limits of the technical systems like the chemical processes are better known and the instruments to control them are more reliable.

2. Evolutions in both the industry and in the society

2.1 Increase of the complexity of industrial systems

Long term structural changes have occurred in the industry, in particular through the concentration of companies in some branches. Moreover, often these structural changes were carried out with staff reductions, that may have an impact on the ways to manage the safety aspects in a given plant.

At the same time, the complexity of industrial systems has considerably increased in the last decades. It is due to the increasing of the knowledge in the technological fields and also to the development of technologies. Sciences have become wider, deeper and quicker, and the technological systems, that integrate knowledge from various disciplines, have become more complex for the operators.

These statements might explain that the number of major accident is not reducing as described in the previous paragraph.

2.2 Evolution towards a knowledge society and increase of society awareness

Several industrial catastrophes have strongly marked the public opinion : Bhopal (December 1984) in the chemical Industry, Chernobyl (April 1986) in the nuclear industry, the explosion of the shuttle Challenger (January 1987) in the aerospace sector. More recently the catastrophe of Enschede (May 2000, pyrotechnical material) and the catastrophe of the AZF factory in Toulouse (September 2001, ammonium nitrate storage) have shown that politicians and risk-decision makers are facing difficulties to manage technological risk. This situation is probably due to, on one hand, the complexity of the issue, and on the other hand, citizen's loss of trust in politics, since in a knowledge-based society, citizens expect more access to information and require transparent decision-making processes. Thus, the awareness of the general public about technological risks has increased and as well the demand for effective, consistent and adequate risk management.

All these catastrophes have showed that the dialogue and the consultation of the public as of the various actors were not independent of the risk management process whose objective is to ensure

long term safety of the populations. Thus the maintaining of an industrial activity is strongly dependent of the acceptance of the risks which it generates.

In general, three tactics of implication and communication with the various actors of risk prevention process are used.

The first tactic consists in being unaware of the opinion of the different actors (public or other). Our "risk society", following the big industrial disasters, has developed a cautious attitude towards the role of the expertise when it comes to assessing risks, along with a question of the ability of science to give definite answers.

The second tactic consists in providing the necessary information in order to convince the various actors "knowledge based theory approach" (Maharik and Fischhoff, 1993). This second approach is in the starting point of various current practices (e.g. the communication phase of the risk prevention process is a linearly posterior phase to the risk analysis one; the use of the concept of "grid of acceptability" within the framework of the safety studies, etc).

The third tactic consists in taking into account the opinion of the various actors upstream and during the decision-making process related to risks prevention: "value-oriented approach ". That it is on the international scale, with the Aarhus convention (1998) on "access to information, public participation in decision-making and access to justice in environmental matters" translated at the French national scale by the law n° 2002-276 of 27 February 2002 relative to "the democracy of proximity".

More recently in France the law n°2003-699 of 30July 2003 relative to "the prevention of the technological and natural risks and to the compensation for the damages" has provided a great step in the direction of the implication of the various stakeholders (e.g. Public, elected officials, etc.) in the decision-making processes related to the prevention of the risks.

According to the discussion presented here, the key issues seem to be both scientific and societal.

2.3 Increase of the public participation in public decisions

Thus, management in the field of environmental protection and risk prevention has evolved to the increasing participation of all stakeholders in the decision-making process. It certainly results from the development of the "information society" and the global increase of knowledge of the

population, combined with the concerns of the populations related to a sustainable development of our civilisation.

By nature, technological risks are required to be treated at both national and local levels. The national level should define general rules, and the local level should apply the rules and reach agreements according to the local socio-economic, political and cultural context. It has long been recognised that increasing public participation is an essential element in improving environmental and risk-related legislation (Aarhus convention, 1998).

When the various stakeholders are aware of risk issues, and involved in early stage of the decision-making process, the solutions inevitably become more sensible and legitimate. The quality of stakeholders participation in risk decision-making is often determined by how well informed they are about the nature of risk issues, and how responsible institutions deal with them.

The participation of the various stakeholders became possible by taking their different opinions and preferences in the risk decision-making process. The multiple-criteria decision- making methodologies can be really useful to aggregate this different opinion (criteria, preference, weight) to choose the most appropriate decision both at the national and local level.

One of the most famous problem in risk management dealing with both national and local constraints is the "land use planning around the industrial zones". INERIS has an important experience in land use planning dealing with natural risk: Natural Risk Prevention Plans (Didier and al., 1999), Mining Risk Prevention Plans (Merad and al., 2004). INERIS has developed a new methodology based on a multiple-criteria method to control the urbanisation around the Seveso sites. This methodology in line with the increasing participation of the public will be presented in chapter 4.3.

3. A vision for a global risk management system

As written in the *Third Assessment from* the European Environment Agency (Pettitt, 2003), "holistic approaches, which take an integrated perspective, are becoming more prevalent, with increasing attention to the reduction of risk of long-term environmental impact as well as acute health and property damage from accidents".

As technical support to decision-makers in risk management from both public and private sectors, INERIS has an important experience in risk prevention and is urged to answer to actual needs in technological risk prevention. To help risk decision-makers, INERIS has made its structure evolving and it has developed a integrated vision for risk assessment and management.

3.1 Evolution of the structure of INERIS team

The missions of the collaborators of the Accidental Risks Division of INERIS are to provide technical support to the industry and to the Competent Authorities, thanks to the expertise gained by combining research work and practitioner experiences.

On one hand, INERIS helps the industry to identify the hazards and to control the associated risks, on the other hand, INERIS gives support to the Competent Authorities to develop methods and tools to facilitate the implementation of regulations and control industrial installations.

Five years ago, to do its job, the Accidental Risks Division of INERIS employed only engineers and researchers with technical background in the "hard sciences". The engineers were able to find technical solutions to complicated problems related to risk management. Then, in 2001, the staff was reinforced with new skills, in particular from the "human sciences". Engineers and human factor specialists started to work together, sharing premises and interacting on a regular basis.

It was not easy to develop common view and to establish a common language according to the different backgrounds and cultures. Hard science is synonym of equations, quantification… on the opposite, human science is more qualitative and tends to use mathematics and numbers only for limited areas within their field of research.

By working on research projects on the development of an integrated risk assessment approach, INERIS facilitated the opportunity to develop a team expertise combining the two cultures. Now, this team can offer to the industry integrated and global audits by multi-skilled teams, that allow studying the hazard of a plant and the appropriateness of the safety management system implemented. The requirements of the Safety Management Systems are therefore proportionate to the hazards of the plant. This is a quite innovative point in the risk control of the chemical process industry.

The constitution of the multi-skilled teams was a great step forward in the direction of global risk assessment, but the maturity of the team still has to be developed thanks to the introduction of systemic (science of complexity) concepts in risk assessment and management.

3.2 Development of an integrated vision for risk management

At the same time when the structure evolved, INERIS has initiated several projects both at European and national level to develop an integrated vision for risk assessment and management.

This paragraph describes several integrated projects carried out by teams with multi-disciplinary skills.

3.2.1 The ARAMIS method

In order to characterise the hazard potential and to demonstrate that the associated risks are controlled, an integrated risk assessment methodology has been developed within a project called ARAMIS for "Accidental Risk Assessment Methodology for Industries in the framework of the Seveso II directive". (Hourtolou & Salvi, 2003)

The ARAMIS project initiated by INERIS was submitted for funding in the 5th Framework Programme of the European Commission. This 3-years project started in January 2002 and builds further on methods studied in the 4th Framework Programme such as in ASSURANCE[1] project (Christou, Nivolianitou, Lauridsen, Amendola, Markert, Crossthwaite, Carter, Hourtolou, Molag, Spadoni, Tiihonen, Kozine, Aneziris, Gadd & Papazoglou, 2001), a benchmark exercise on the uncertainties in risk analysis, and developed in I-RISK project[2], which provides a methodology for in-depth judgement of safety management requirements for the design, operation and maintenance of major hazards plants.

The development of ARAMIS was justified by the need of the elaboration of a methodology giving consistent rules for the identification of scenarios that take into account mitigation devices and some aspects of safety management, and being recognised by risk experts from Competent Authorities and Industry.

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[1] Assessment of the Uncertainties in Risk ANalysis of Chemical Establishments, n°ENV4970627

[2] Development of an integrated technical and management risk control and monitoring methodology for managing and quantifying on-site and off-site risks, n°ENV4960243.

Beside, there was a need to establish a method that is capable to assess the risk level of an installation by integrating the preventive measures implemented by the operators. Such a method is a prerequisite in order to reach the goals of the Seveso II Directive, that are to improve the prevention linked in particular with the safety management.

So, the ARAMIS methodology proposes to characterise the risk level with an integrated risk index composed with independent parameters related to the consequence severity evaluation of scenarios, the prevention management effectiveness and the environment vulnerability estimation describing the sensitivity of the potential targets located in the vicinity of the hazardous establishments. The application of this method will result in a more consistent and harmonised risk evaluation and safety management strategy in all European Countries.

The innovation in this method relates to the integration of the 3 parameters. Moreover, for the evaluation of the prevention management effectiveness, not only formal aspects of the safety management system are assessed, but also the safety culture in the plant. This is done by human factor specialists who built questionnaires and interviews methods.

ARAMIS is therefore a good example of the new kind of methods that have to be developed to assess risks in plant with a global approach.

3.2.3 Risk assessment in France

The same questions as discussed at the European level where risen also in France.

In 2000, the French Ministry in charge of the Environment asked INERIS to take stock of the situation regarding risk assessment and land-use planning in France. Then, several studies were launched both on technical issues and also on risk decision making process to analyse in particular, the procedure to write the safety reports required by the Seveso directive, and the relation with land-use decisions and zoning according to major accident hazards.

The following lines describe several examples of the projects launched.

- Risk analysis methods and scenario identification that takes into account risk reducing measures

This project consists in defining a method to choose a set of scenarios that will help for the demonstration that the risks are properly controlled by the operators and for the determination of the safety distances to be used for land-use planning and emergency plans. In this project, INERIS has suggested to move from the deterministic approach used until now to resolve purely technician concerns to a multiple-criteria decision-making method.

This type of projects needs to be addressed through multi-disciplinary approaches combining physical and natural sciences with human science as disasters have been revealed to be the product of the interface of technology with human activities.

- Assessment of the scenario consequences

As described above, the original competencies of INERIS related to the knowledge of dangerous phenomena like fire, explosion and atmospheric release of toxics. These projects continued to be funded in order to improve the comprehension of the phenomena and therefore, to enable the development of models to predict the consequences of accidents.

- Decision making process to improve the efficiency of the risk assessment

This project leaves the only competence of the technician and relates to the choice of urbanisation measures on the residential areas concerned with high risk levels. These measures are the result of concerted choices between various groups of actors (industrialists, representatives of the local communities, local associations, committees of hygiene, safety and the working conditions CHSCT, administrations, etc.). Such a project depends on the ability to generate appropriate criteria. In the project, INERIS has proposed to develop and use a dialogue grid to help the various stakeholders in the choice of the most adapted solutions to both the local and the national context.

In relation with the last project, the team has worked on a project that relates to the creation of an inclusive risk culture through the integration of the various visions and the various analyses produced by the different groups of actors implied in the dialogue process and the risks prevention decision process. This European research project (TRUSTNET-*in*-ACTION) is carried out within a multi-field and pluri-cultural group.

All these projects combine multi-disciplinary expertise from engineering sciences, social sciences and management. They have contributed to develop an integrated and global vision to accompany the evolution of the industrial risk management process in France.

4. A new law about the prevention of the technological and natural risks and to the compensation for damages

A new law about the prevention of the technological and natural risks and to the compensation for damages was adopted in France in July 2003 after a deep debate initiated by the Toulouse accident. This paragraph describes the Toulouse accident and its consequences, and the main elements of the new law, in particular the evolution in the definition of the safety distances for land-use planning.

4.1 The Toulouse disaster : food for thought and catalyst for changes

A terrible explosion of ammonium nitrate occurred on 21st September 2001, in Toulouse, in the AZF plant belonging to Grande Paroisse Company, TotalFinaElf Group. It killed 30 persons and injured up to 2242 people. The plant was located in the suburbs of Toulouse and the extent of damages was very large both on and off site with a cost estimated by insurers of 1.5 billion Euro.

The plant produced mainly ammonium nitrate, ammonium nitrate-based fertilisers and other chemicals including chlorinated compounds. The explosion took place in a storage warehouse where roughly 400 tons of off-spec materials were stored. The TNT equivalent mass of the explosion was estimated in a range of 20 to 40 tons of TNT.

After the accident, several studies, enquiries and analysis where initiated by the Authorities, the operator and several governmental services.

- Enquiry by the IGE (General Inspectorate for the Environment) to report one month after the disaster to French Prime Minister about the administrative aspects,
- Regional and national debates that lasted 3 months reported to the Prime Minister by the high level public servant,
- Analysis by 2 rapporteurs of the Parliament who wrote more than 80 recommendations covering structural, organisational, scientific, administrative,juridical and financial aspects,
- Study by the FFSA (French Federation of Insurance Companies) to analyse the reparation of the damages,
- Enquiry by ATOFINA, the operator of the plant to explain the technical causes of the accident,

Moreover, other governmental services like INVS (National institute for sanitary watch) or the ministry in charge of urbanisation and public equipment released also their report in the two years after the accident.

As far INERIS is concerned, it lent its technical assistance to the IGE during the administration enquiry set up after the explosion and wrote 6 reports added in the annexes of the IGE report.

Thus, the Toulouse disaster initiated a large debate and a deep thought that ended up with the proposal of a new law to improve the risk management system. Several ideas brought to the fore after the accident were developed thanks to the studies and the projects mentioned in the previous paragraph. The Toulouse accident operated as a catalyst for changes that made the politicians aware of the need to make the system evolving by taking advantage of the preparatory work carried out by INERIS.

4.2 The new law for risk management

The new law n° 2003-699 of July 30th, 2003 about the "prevention of the technological and natural risks and to the compensation for damages" introduces an important innovation into the process of technological risks prevention.

First, the new law enables the involvement of the stakeholders in the decision-making process related to risk prevention. This involvement is performed into a local structure of information and dialogue called "Local Committees for Information and Dialogue" (CLIC). Second, the system defined by the new law promotes the participation of the Local Committees in the elaboration and implementation of Technological Risk Prevention Plans (PPRT) devoted to draw up the configuration of the urbanisation around hazardous plants with a long term view.

This innovation reveals the concern in giving solutions to two practical needs: (i) to combine a controlled urbanisation and a sustainable economic development in the area around hazardous plants; (ii) to rehabilitate the local decision in the risk prevention process and contribute to the creation of a risk culture.

4.3 Methodology to establish a hazard zoning for the Technological Risk Prevention Plans

To establish a hazard zoning, INERIS has developed a multiple-criteria methodology. This methodology consists in characterising the hazard partially, according to a set of criteria, and then aggregating this different evaluation to choose the appropriate decision.

A factory site can join together several companies (firms) from which the activities are sometimes different. Each site comprises several installations (Figure 2). In case of a failure of one of these installations, toxic release, thermal effects, missile or overpressure can harm people or the environment.

The path which goes from the failure of the installation to the appearance of an effect is called "accident scenario" noted Sc. One can thus counted, for each installation, a set of accident scenarios $S_{installation}$ gathered by group of effect (toxic, thermal effect, missile or overpressure).

For each installation, the set of accident scenarios is evaluated according to five criteria, which characterise the hazard (Table 1).

A ranking of the scenarios by installation and by type of effect is carried out on the basis of a multiple–criteria method called ELECTRE III. The head scenarios by type of effect are selected for the hazard zoning by installation (Figure 3).

The selected scenarios by group of effects are retranscribed in the form of a zoning (cartography) in four levels of hazard: very high, high, medium and low (Figure 4).The limits between these four levels of hazard are represented respectively by the three distances which come to characterise each scenario of accident: the insulating distance with a lethality threshold of 5% (In1), the distance with a lethality threshold of 1% (In2), and outdistance with the irreversible effects (In3).

The result of ranking is translated to a hazard-zoning map for each installation and for each effect (Figure 5 and 6).

At the end of this procedure, information are presented to the decision:

- A total pre-order (ranking of all the scenarios) ;
- ELECTRE III graph;

- a visualisation of the scenarios that present the highest level of hazard according to each effect and to each installation using a geographic information system (GIS).

Conclusion

To improve risk management process and reduce the number of major accidents, new approaches are urged to address the complexity of the issue in a context where industrial systems are evolving and where the civil society expectations become more difficult to satisfy in terms of consistency and transparency.

In France, the Toulouse disaster has initiated a deep reflection in the society and at the political level, and finally a new law was adopted. This law mainly clarifies the way the procedure to determine the safety distances for land-use planning, increases the participation of the employees in the risk prevention and enables the involvement of stakeholders in the decision-making process. The global approach advocated by the law, that address both scientific aspects and societal issues, has taken advantage of the preparatory work carried out by INERIS in several projects based on a systemic view of risk management. Moreover, a specific methodology to establish a hazard zoning was developed to take into account the complexity of the criteria contributing to define the hazardous zones.

As a matter of fact, because of its characteristics (contextual, wholeness, multidimensional and complexity), the risk management process needs to be carried out by specialists and generalists. The role of the specialists is to provide in depth-information, data, analyses to know where are the hazards related to the products, the processes, to quantify or estimate the damage and the probability of possible accident, and of course to assess the performance of the safety measures implemented. To sum up, technical specialists are needed for the risk assessment step and in the risk reduction step. Specialists are also needed in economy, in communication … for the other dimensions of risk management. The role of the generalists could be seen as collecting and integrating the information provided by the specialists that the generalists would have identified as relevant to solve the risk-related problem. The generalists have also to overcome the interface difficulties generated by the selected views given by the specialists from the engineering side but as well as from the social side, where psychologist, sociologist… who bring their specific insights to

relevant issues that need to be addressed. This mutation urges multi-disciplinary expertise from engineering sciences, social sciences and management and the development of the use of multiple-criteria analysis.

Therefore, considering the evolutions mentioned above, the risk regulation systems should also evolve with the increasing participation of the stakeholders and in particular of the industry in the risk control requirements. Since the industry has the best knowledge to control risk on site, regulations should move from prescription to goal-oriented one. It will enable the development of pro-active solutions to improve risk management. It seems to be the only way to build a sustainable and consistent risk management policy.

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Table 1 : Set of criteria which characterises the hazard

Id.	Designation	Nature	Unit	Evolution of increasing hazard	Value of the criteria	Weight
Probability of occurrence of the scenario of accident						
Pr_1	Probability of the scenario	Qualitative	-	↘	1 : Class 1 (Highest level of probability) 2 : Class 2 3 : Class 3 4 : Class 4 *5 :* Class 5 6 : Class *6* *7 :* Class *7* (the lowest level of probability)	35
Kinetic of the scenario of accident						
C_1	Post-accidental kinetic	Qualitative	-	↗	(5) Very fast. (4) Fast. (3) Fast but backward. (2) Fast but highly backward. (1) Long but immediate.	6
Intensity of the effects of the accident scenario						
In_1	Insulating distance (with the threshold of 5% lethality)	Quantitative	m	↗	According to a formula	25
In_2	Outdistance with the threshold of 1%lethality	Quantitative	m	↗	According to a formula	21
In_3	Outdistance with the irreversible effects.	Quantitative	m	↗	According to a formula	13

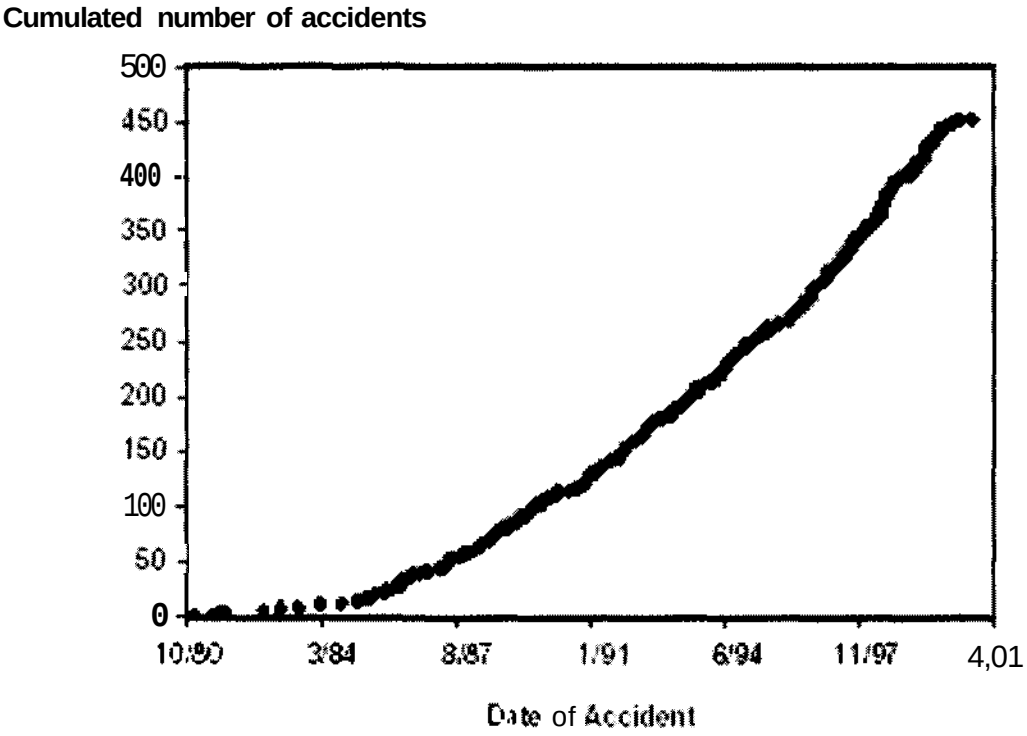

Figure 1 : Extract from the Report on the application in the Member States of Directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities for the period 1997-1999 (2002/C 28/01) : cumulated number of accidents in the MARS database versus time

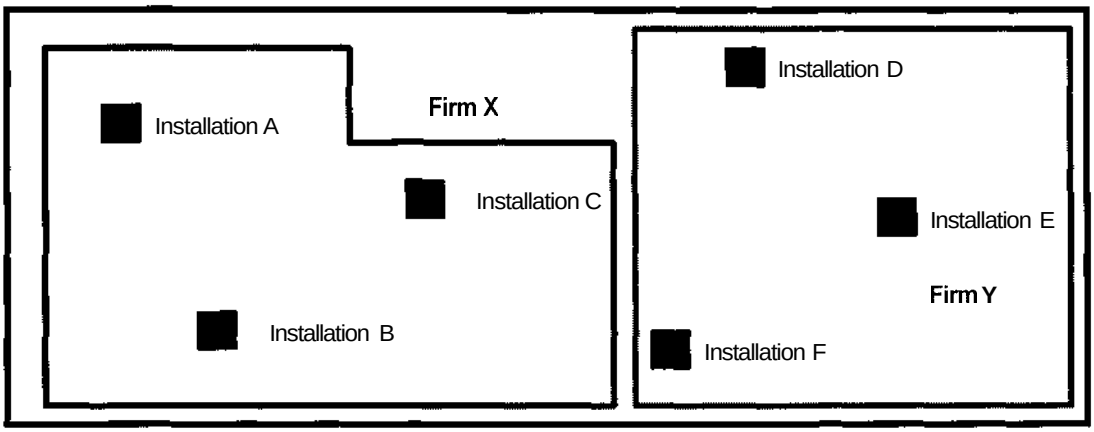

Figure 2 : A factory site as several companies (firms) and several installations

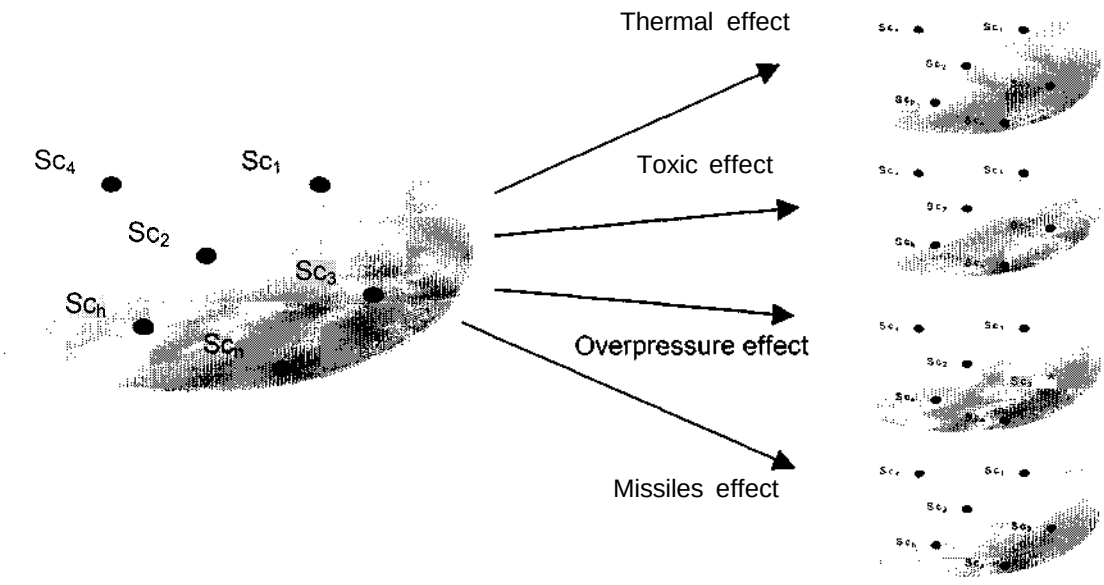

Figure 3 : Gathering of scenarios by effects (Thermal, toxic, overpressure, missiles)

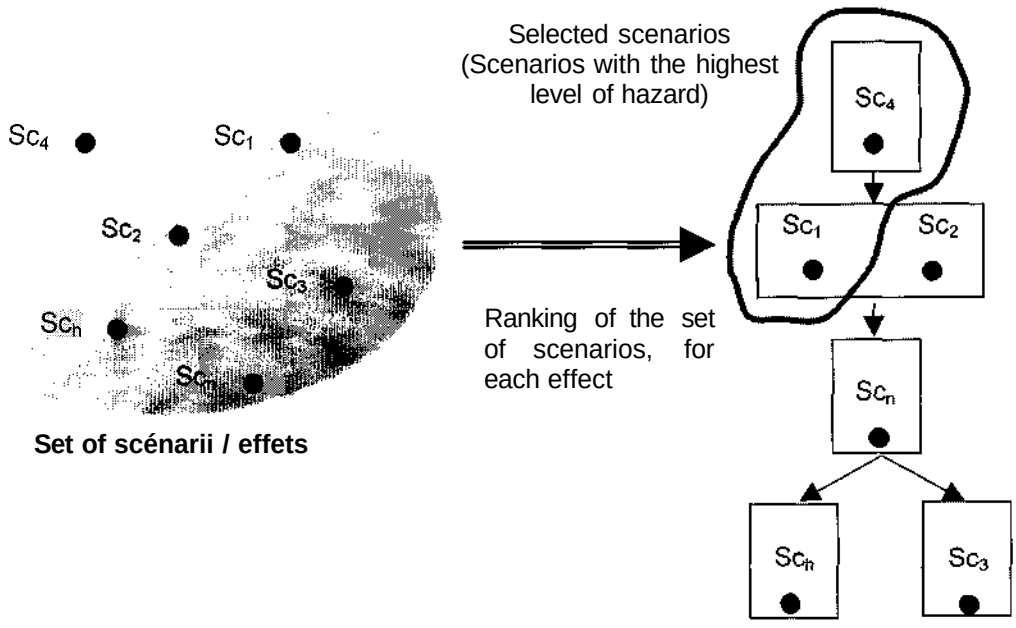

Figure 4 :The problems of hazard zoning consist in choosing the relevant group of scenarios by group of effects

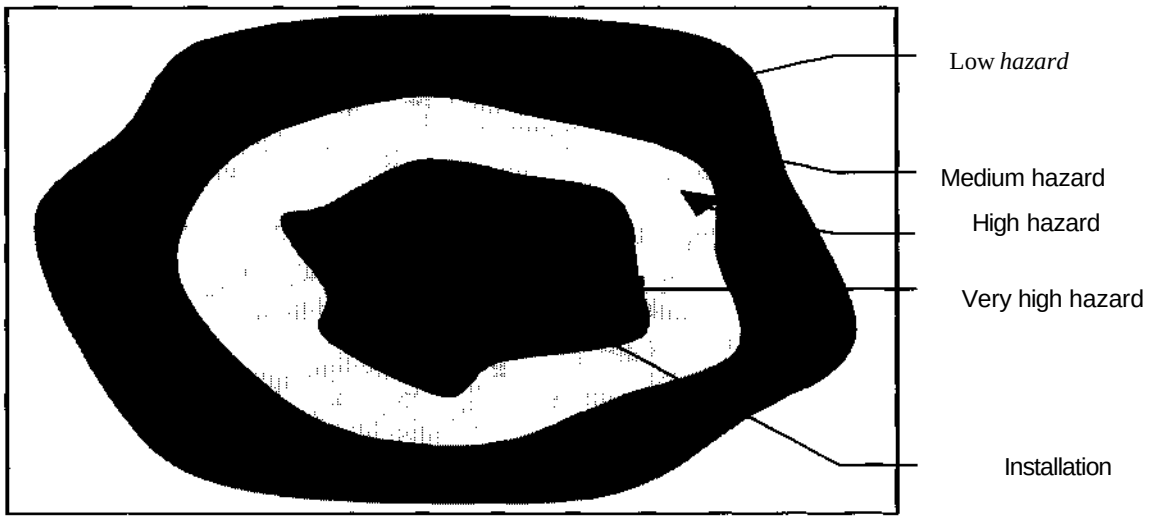

Figure 5 : Hazard zoning map for each effect and for each installation

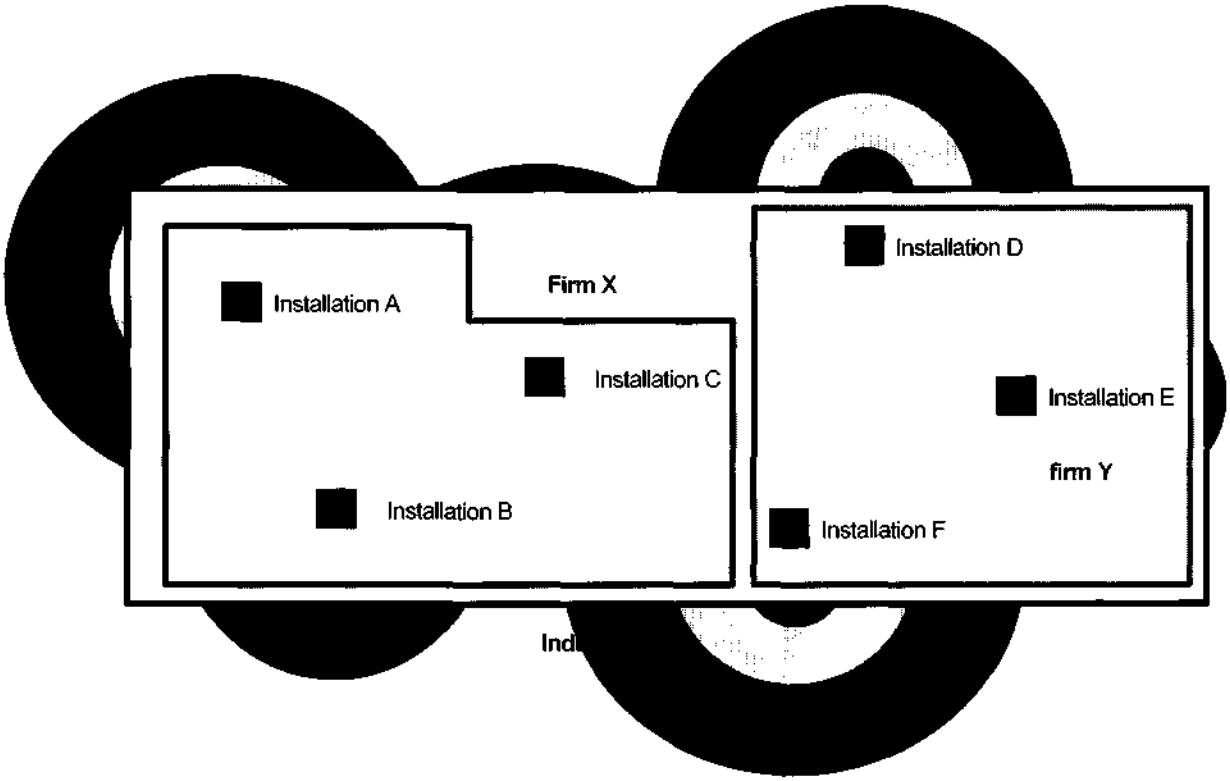

Figure 6. Hazard map for each effect