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# **ARAMIS: An integrated risk assessment methodology for SEVESO Plants**

Olivier SALVI<sup>1</sup> Bruno DEBRAY<sup>1</sup>

INERIS, Direction des Risques Accidentels, F-60550 Verneuil-en-Halatte, France, Tel: +33 3 44 55 62 06, fax: +33 3 44 55 62 95, email: [bruno.debray@ineris.fr](mailto:bruno.debray@ineris.fr), Web-site: [www.ineris.fr](http://www.ineris.fr), <http://aramis.jrc.it>

This paper intends to give a very general description of the ARAMIS Methodology and to show how it answers the needs of various stakeholders concerned by the safety of industrial plants.

ARAMIS is divided into six major steps, which will be described shortly in this paper. The potential end users of ARAMIS are mainly the industry, the competent authorities and the local authorities. If all of them have an interest in the same risk management process, their needs are slightly different. Their expectations are detailed and the way ARAMIS brings an answer is explained in this paper.

*Keywords: Risk analysis, Risk assessment, SEVESO, land use planning, risk reduction, safety barriers, safety culture, safety management, vulnerability, risk severity*

## **1 Introduction**

ARAMIS overall objective was to build up a new Accidental Risk Assessment Methodology for Industries that combines the strengths of both deterministic and risk-based approaches. It was also to provide a way to reduce or at least explain the discrepancies of the results produced by different risk assessment approaches that were observed, for example in the ASSURANCE project [1]. Co-funded under the 5th EC Framework Programme, ARAMIS was a three-year project that started in January 2002. Four years later, the basic methodology is achieved and aims at becoming a supportive tool to speed up the harmonised implementation of SEVESO II Directive in Europe. This paper summarises the major features of the methodology and shows how the needs of ARAMIS potential users are addressed.

## **2 Needs of potential ARAMIS users**

The potential end users of ARAMIS are numerous but the most concerned are the industry, the competent authorities and the local authorities. If all of them have an interest in the same risk management process, their needs are slightly different. Plant operators need a method to identify, assess and reduce the risk. This method has to be

accepted by the competent authorities. This method also has to bring useful information about the ways to reduce the risk and to manage it daily.

The competent authorities need to be able to assess the safety level of the plant, particularly through the safety report. They need to know why scenarios have been kept for modelling of consequences. Both need to assess the influence of the management on the safety level.

The plant operator has to improve its management to reduce the risk and the competent authority to assess a true risk level which takes into account this major influencing factor. About 80% of the major accidents have causes related with human and organisational factors, which is a sufficient reason to take these aspects specifically into account.

The local authorities are interested in land use planning issues. They need a clear view about the risks or hazards the population actually faces. They also want to get information that can be used in decision processes, which now often involve the population. Basically, their capacity is about reducing vulnerability either by limiting the number of targets exposed to the risk or by introducing barriers between the source and these targets. They also need to trust the plant operator and competent authorities when they propose risk or consequence-based contours from scenarios.

The aim of ARAMIS is to answer all these needs. It is also to make the convergence between the deterministic and the probabilistic approaches and to resolve some difficulties inherent to each of them [2]. As far as the deterministic approach is concerned, the limit deals with the difficulty to justify the choices of the reference scenarios used for land-use planning decisions. For the probabilistic approach, the difficulty resides both in producing the probability data and in interpreting the results to take appropriate decisions. ARAMIS does not completely solve these difficulties but furnishes the tools and the structure to improve decision-making. It also provides a framework for the definition of further research programs as discussed in the last paragraph.

### **3 Main features of the ARAMIS methodology**

ARAMIS is divided into six major steps.

1. Identification of the major accident hazards (MIMAH)
2. Definition and evaluation of safety systems
3. Assessment of the management efficiency
4. Definition of the reference accident scenarios (MIRAS)
5. Risk severity mapping from the set of Reference Accident Scenarios
6. Vulnerability mapping of the plant surroundings

A last step involves the crossing of this information for decision making

#### **3.1 Identification of the major accident hazards (MIMAH)**

MIMAH [3] is the method for the identification of major accident hazards. It is based mainly on the use of bow-tie diagrams composed of a fault tree and an event tree. These turned out to be a very powerful tools to communicate on risks, in particular towards non-technicians (managers, politicians, etc.). The major input of ARAMIS was to define

a precise bow tie structure and to define precisely and exhaustively the list of equipment, potential critical events and their consequences. The critical events were defined to be either losses of containment for fluids or losses of physical integrity for solids. The complete list contains twelve critical events including breach, collapse, explosion, etc.

From a description of the plant including the chemical substances used, produced or stored, it is possible from MIMAH to list all the critical events susceptible to occur in the plant. For each of these critical events, MIMAH allows to identify all their consequences in terms of secondary events and dangerous phenomena.

Then, MIMAH provides the user with a set of generic fault trees, which are based on the most frequently observed causes. From these generic fault trees, the user will build specific fault trees that take into account the specificity of the studied plant: types of process used, presence of equipment, etc.

The specific fault trees are obtained mainly by the suppression of causes and consequences which are not relevant to the context without any consideration on probability at this stage. It is important to notice that both the fault and event trees are considered without safety barriers, which will be defined in the next step of the method. This has the advantage to make an explicit distinction between hazard and risk. This first step allows the identification of hazards. The next one aims at identifying the risks which result from the hazard scenarios and the failure of safety barriers.

### **3.2 An alternative to classical probabilistic approaches**

Classical risk analysis methods propose to assess the probability of major accident and to decide from this evaluation whether the risk is acceptable or not. But, during the ARAMIS project, this calculation of the probability was shown not to be an easy task. An inventory of the probabilistic data sources was carried out and showed that many of the available data are not adequate for the tools developed in the first steps of the methodology. Only very generic frequency ranges could be obtained for causes of the critical events, which hindered the possibility to rely solely on the probability of events. However, one main objective of ARAMIS was to valorise through contextual frequency data the efforts made by the operators both in prevention and mitigation.

An alternative method was developed, which focuses on generic values for safety systems and clear guidelines to lower the final frequency of identified scenarios. First, it aims at helping the user with the definition of the safety requirements applying to the plant. Then, the method helps the user to define the safety barriers [4] by promoting the concept of safety function and by providing different possible strategies of barrier implementation for a given safety function.

### **3.3 Defining the safety requirements**

As it can be understood from the previous paragraph, the definition of the safety requirements is a keystone of the ARAMIS methodology. The proposed method is inspired by the IEC 61508 standard [5]. The idea is to guide the user in the identification of the risk reduction goals that should be associated with different scenarios. This approach has a triple interest. It helps the user improving the management of risks by defining clear targets. It helps the competent authorities

checking the risk reduction measures. It provides an evaluation of the residual risks. The way it was built also reduces the stress put on the quality of probability values.

Once this work carried out in risk analysis, the resulting dangerous phenomena can be ranked according to their classes of probability and consequences in a Risk Matrix where acceptable risk levels are defined.

### **3.4 Assessing the influence of safety management and safety culture**

The safety management has a strong influence on the capacity to control the risk. Here again, the interest of ARAMIS is to provide tools to assess the safety management system (SMS) and the safety culture and to take them into account to help the operators identify the opportunities for improvement. The approach in ARAMIS [6] consists in devising a process-oriented audit protocol focusing on the activities relating to the life cycle of the safety barriers including design, installation, use, maintenance and improvement activities. For each, ten important structural elements are evaluated as requirements for the SMS. The outcomes of the audit are then combined with the results of a safety climate questionnaire collected from employees in order to get a contextual level of confidence, in particular regarding behavioural barriers. The questionnaire is made up of eight cultural factors that characterise a company's safety culture.

- learning and willingness to report
- safety prioritisation, rules and compliance
- leadership involvement and commitment
- risk and human performance limitation perception
- felt responsibility
- trust and fairness
- work team atmosphere and support
- motivation, influence and involvement

From the previous step, each type of barrier was given a generic level of confidence indexed on its probability of failure on demand. These indicative values require then to be adjusted from the local context where they are implemented and maintained. For instance for a behavioural barrier, the generic confidence in the barrier is adjusted depending on whether the operator knows the stakes of his actions, or his decisions require complex diagnosis, conflict with production. The aim of the project was also to aggregate the results from the auditing and questionnaires into a final score for adjusting –possibly lowering- the generic values into contextual ones.

This link and the whole scoring process was obviously an ambitious goal and still needs to be worked out. The case studies already helped getting some benchmark between different types of management and enabled eventually to propose a set of “minimum requirements” for both the culture and management system in order to anchor a first scoring scale. This remains however an important area of research.

### **3.5 Risk severity assessment and mapping**

Each reference accident scenario (RAS) is defined by an initiating event that leads to a critical event, which can potentially lead to different dangerous phenomena. For each

phenomenon, a severity index  $S_{DP}$  has been defined [7] in a single scale ranging from 0 to 100 according to its intensity which varies with the distance from the plant.

For each RAS the risk severity is defined for one scenario as the combination of the probability of the phenomena with their specific severity  $S_{DPi}$ . Risk severity can be represented for each scenario in a geographical way, as a function  $S_{RAS}(d)$  of the distance from the source term.

A final mapping of risk severity considering all RAS is then obtained by multiplying the frequency of each RAS with its specific risk severity index.

Risk severity mapping as it is defined provides an innovative way to aggregate the information for a decision-maker to elaborate relative priorities for land-use or emergency planning purposes. However, the range of values obtained with such an approach still requires to be interpreted and the decision making process to be adapted to this new approach.

### **3.6 Assessing the vulnerability**

The last innovative attempt from ARAMIS is to address the vulnerability of the environment independently of the hazardous site [8]. This has the fundamental interest of allowing the local authorities to take useful decisions to reduce the global risk level by reducing the vulnerability whereas the plant operator only can act on the potential hazard or risk of the installation.

The vulnerability is calculated on the basis of a multicriteria decision-aiding approach. With the development of new ways of governance involving local population in risk-informed decisions, the main interest of this approach is to base the vulnerability study on stakeholder risk perception through expert judgement elicitation. On a given spot of the environment, the vulnerability is thus characterised by the number of potential targets and their relative vulnerability to different phenomena. The global vulnerability is a linear combination of each target vulnerability to each type of effect for the various types of impacts.

## **4 Conclusion**

The ARAMIS methodology was briefly described in this paper. It aims at offering an alternative way to the traditional risk-based and consequence-based methodologies for risk analysis by providing a series of integrated tools. These were designed to answer the specific needs of potential ARAMIS users who are industry, competent authorities and the local authorities. They were also elaborated to solve some of the difficulties raised by the lack of reliable data, namely concerning the accident frequencies. By promoting the barrier approach, ARAMIS helps the users defining the safety requirements, which apply to a plant, and therefore helps the competent authorities verifying the explicit control of risk by the operator. This approach also enables an easy and explicit identification of the reference accident scenarios, making the communication between the stakeholders easier or at least more straightforward and structured. The same applies to the approaches of the severity and the vulnerability, which are exploited through a clearly understandable spatial representation.

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