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ARAMIS
Accidental Risk Assessment Methodology for Industries in the framework of SEVESO II directive

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Abstract

This paper presents the ARAMIS project accepted for funding in the 5th Framework Programme of the European Commission, which should start end 2001.
ARAMIS project aims at developing a new risk assessment methodology which allows to evaluate the risk level of an industrial plant by taking into account prevention measures against major accidents. The methodology will support the harmonised implementation of the SEVESO II Directive.
The project is built to result in the composition of an integrated risk index based on the definition of Reference Scenarios and combining : 1. Scenario consequence severity 2. Safety management effectiveness affecting the probability of occurrence of major accidents 3. Environment vulnerability. The methodology will be validated with case studies. Efforts are given to disseminate the methodology to decision-makers in charge of the control of major accident hazards. Thus the project development will be continuously monitored by a review team gathering risk experts from industry and EU competent authorities in order to ensure the widest acceptance of the approach.

1. Introduction

The ARAMIS project was submitted for funding in the 5th Framework Programme of the European Commission in February 2001 under the programme ENVIRONMENT AND SUSTAINABLE DEVELOPMENT, in the chapter untitled "The fight against major natural and technological hazards" of the Work Programme. This 3-years project should start at the end of year 2001.
The ARAMIS methodology builds further on methods studied in the 4th Framework Programme such as in ASSURANCE[b] project, a benchmark exercise on the uncertainties in risk analysis, and developed in I-RISK project[c], 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 is 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.

[a] Paper written on behalf the consortium described in chapter 5 and including the contribution of the organisation mentioned.
[b] ASSessment of the Uncertainties in Risk ANalysis of Chemical Establishments, n°ENV4970627
[c] 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 is an 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 propose 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 SEVESO II 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 paper starts with the presentation of the general and operational objectives of the project, and a recall of the context of the major-accident hazards control and prevention in the EU. Then, the project and especially the work contents and the consortium are described in details. And finally, the expected impacts of such a methodology are addressed.

2. Objectives

The objective of ARAMIS project is to create a new integrated risk assessment methodology by combining the strong points from the different methods currently used in risk assessment in European Countries.
The methodology will be used as a supportive tool to promote safety in the process industry. In particular, it will contribute to speed-up the harmonised implementation of the Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances known as SEVESO II Directive. Accordingly, this tool should be flexible enough to take into account the different national cultures in industrial risk assessment like deterministic or risk-based approaches, so that the new methodology could become a recommended tool used by risk experts and endorsed by the risk decision-makers in the whole EU.

In technical terms, ARAMIS project aims at :

1. Establishing a methodology for accident scenarios identification taking into account the prevention process carried out by the operators of SEVESO establishments, and endorsed by the Competent Authorities and the decision-makers in charge of risk control,
2. Composing an integrated risk index which takes into account:
   - Consequence severity evaluation of scenarios,
   - Prevention management effectiveness (preventative, protective and mitigation measures) on initiating and aggravating events, thereby reducing the probability of occurrence of major accidents,
   - Environment vulnerability estimation.

3. Context of major-accident hazards control and prevention

The 1999 annual report from the European Environment Agency [1] indicates that the trend in accidents shows that many of the often seemingly simple 'lessons learned' from accidents have not yet been sufficiently implemented in industry's standards. There is no doubt that disasters will continue to occur throughout the EU. Some of these will be due to technology, some to the forces of nature. Inevitably there will be loss of life and environmental damage. However, hazards can be managed to reduce risks. The problem of low-probability, high-consequence events is likely to remain a key issue in terms of risk management.
The most significant EU Directive to help protect people and the environment from major accident hazards is the SEVESO II Directive. This Directive applies to those industries that use significant amounts of hazardous substances. Their operators must demonstrate that they apply a policy for the prevention of major accidents using appropriate measures related to both "hardware" and "software" aspects, such as safety management systems. This is likely to reduce risk levels, not only from high-probability, low-consequence accidents, but also from low-probability, high-consequence events, although these are by nature difficult to address.

In the SEVESO II Directive, the objectives in terms of risk management are very clear, but the remaining question is : How to reach them ? For example, there is no harmonised definition of the scenarios that have to be considered for risk assessment. Typically, the chosen scenarios (BLEVE, total loss of containment, fire in the largest tank, explosion of the largest mass of explosive, etc.) can be different according to the specific risk analysts and according to the deterministic or risk-based approach of the country applying the Directive. This situation is confirmed by the results of the EC project ASSURANCE, in which 6 European organisations perform a benchmark exercise for the risk analysis of a specific plant. The partners use various hazard analysis techniques and arrive at quite different conclusions with respect to the scenarios that are relevant for the safety assessment. Moreover, sometimes, according to reference [2], land-use planning constraints urge the operators to consider reduction of the safety distances. Then, it may be proposed to choose 'realistic' scenarios by taking account of the effectiveness of mitigation devices. In fact, because of the lack of rules for identifying scenarios including safety measure effectiveness, the expert's job is tricky and often involves large subjective elements.

Not only risk assessment experts, but also decision makers are confronted with a variety of approaches to assess and manage industrial risk. The difference of cultures in the Member States results in a multiplicity of methods for the evaluation of major accident hazards [3]. This fact makes the comparison of risk studies performed by different analysts a difficult task and has significantly hampered the widespread use of risk assessment for decision making purposes. At the recent EC-JRC International Workshop on Promotion of Technical Harmonisation on Risk-Based Decision Making, held in Italy in May 2000 [4], most participants agreed that comparative risk assessment along harmonised procedures would significantly help the decision understanding. A harmonised risk assessment methodology would thus ensure that risk-based decision making provides the necessary transparency and strikes the right balance between scientific understanding and precaution.

To propose a harmonised methodology for risk assessment is difficult. However, some aspects of the different approaches can be put in common such as scenario identification, severity evaluation and the integration of the effectiveness of the safety management that affects the major accident probability of occurrence. Because of these reasons there is a real need to establish common rules to identify scenarios integrating the prevention management achieved by the operator and to propose a harmonised method for their evaluation [5].

4. Project work plan

4.1 Introduction

The objective of ARAMIS is to develop a risk assessment methodology to evaluate the risk level of installations by taking into account the prevention measures implemented by the operators.
The project work plan is built to result in the characterisation of the risk level which is based on the determination of Reference Accident Scenarios and integrates :

- Consequence severity evaluation of scenarios,
- Prevention management effectiveness,
- Environment vulnerability estimation.

The end-users of the methodology are both the industrial companies and the Competent Authorities in charge of the application of the SEVESO II Directive. Thus, the valorisation and dissemination plan start at the beginning of the project with large exchanges with the end-users partners in the consortium and in a Review Team.

4.2 Project description

This paragraph describes the three main phases of the project which are :

1. Development of the methodology ;
2. Finalising and testing the methodology ;
3. Valorisation and dissemination plan.

4.2.1 Development of the methodology

The development of the methodology starts with the identification of reference scenarios, that are evaluated. Then the prevention management effectiveness and the environment vulnerability of the establishment are characterised. All these results are integrated to assess the risk level of a given establishment. The various phases of the methodology are described in details hereunder.

- Scenarios identification

The objective of this phase is to propose a methodology for the identification of Accident Scenarios.
For industrial installations, the Major Accident Hazards will be first identified with an algorithm based on the labelling of the substances (Directive 67/548/EEC) and the conditions of their use (pressure, temperature, flow, etc.). Then, the Reference Accident Scenarios will be determined from the Major Accident Hazards and from the review of accidents which occurred on similar units. The Reference Accident Scenarios will take into account the current practices (state of the art) mentioned in the legal requirements with regard to design, operation and control, and mitigation.

Therefore, the Reference Accident Scenarios will use results from the work on the prevention management effectiveness as described in Figure 1.
Reference Accident Scenarios define realistic scenarios, considering an installation operated today. They will be used to evaluate the effects (severity) of the major accident and describe the hazard potential.

- Evaluation of consequence severity of scenarios

The objective of this task is to define a severity index S depending only on physical parameters. It is intended to study the physical characteristics of the phenomena involved in accidents (dispersion, explosion, fire), and to take them into account to evaluate the consequence severity of the scenarios. The parameters to be considered are :

- the effect area A concerned with the phenomenon : for instance, a disc in case of an explosion, the projection of a plume for gas dispersion ;
- the phenomenon kinetics K : rapid for explosions, slower for dispersion and fires ;
- the capability of intervention I to mitigate the disaster : possible for fire and gas dispersion, but possible only at the design step for explosion ;
- the potential of domino effects D : fragment emission, interlocking of delayed phenomena.

A severity index S is therefore a function of parameters only associated with physical phenomena. All scenarios identified can then be evaluated and ranked with this severity index according to the calculation of S_0 for the Major Accident Hazards and S_{ref} for the Reference Accident Scenarios.

- Prevention management effectiveness

The objective of this task is to define an index M characterising the prevention management effectiveness.
Because technical and organisational factors are key issues to prevent major accident, this task consists in developing a methodology to evaluate the management effectiveness. Safety management applied in a Major Accident Prevention Policy leads to define actions to manage technical, human and organisational factors. The operational goal of safety management is to strengthen the barriers and lines of defence against accidents (safety equipment or human operation). Safety management contains a large number of responsibilities, tasks and functions that are difficult to disentangle. A way of discriminating different levels in safety management is as follows :

- Policy : The implicit or explicit statement of a company's intentions with respect to plant safety, the objectives and goals for safety management and the way safety is prioritised and incorporated in the company's daily management.
- Organisation : Organisation of safety management requires allocation of resources, definition of tasks, and scheduling activities.
- Operation and maintenance : An important part of safety management is maintaining the reliability of the safety-critical technical, human and organisational components. This activity/responsibility includes :
  - training, education and competence of personnel,
  - maintenance of technical systems and introduction of new safety devices,
  - maintenance of procedures,
  - keeping up hazard awareness, e.g. by updating risk assessments.

- Leadership : Implementation of safety management requires leadership, showing consistency between stated policies, intentions and objectives and decision-making in daily plant management, setting examples, creating common values and attitudes. Leadership has important impact on safety culture, safety awareness and prevention of "unsafe acts".

The evaluation methodology will be built on the use of several research approaches :

- Analysis of the effectiveness of safety devices providing physical safety barriers and lines of defence according to their characteristics (nature, availability, reliability, maintainability, testability...). This analysis follow the principle of the norms IEC61508 and draft IEC61511 (Functional safety : safety instrumented systems for the process sector) and lead to general methods to improve safety barriers and some results will be used for the scenario identification.
- Analysis and comparison of specific safety management systems (e.g. application of standards) and analysis of how safety policies are embedded in the company's overall management system.
- Development and use of theoretical modelling of management tasks, with Structured Analysis and Design Techniques (SADT) or function oriented modelling. This will be built on the work carried out in earlier EU projects, like I-RISK which established different ways of linking technical risk analyses with organisational influences.
- Expert judgement, in particular to prioritise the management factors for assessment purposes.
- Identification of safety performance indicators using audit techniques, questionnaire techniques and analysis of incident reports.
- Development and validation of audit techniques.

Safety management affects the probability of occurrence of the scenarios. Therefore the objective of this work will be :

- To assess the effectiveness of various forms and aspects of safety management in preventing accidents.
- To develop reliable indicators that are a good measure of the effectiveness of a plant safety management.

This information will be used to define a multidimensional index *M* characterising the prevention management effectiveness.

- Environment vulnerability estimation

This phase aim at defining an index *V* characterising the spatial vulnerability of the environment of an hazardous establishment by characterising potential targets (population, natural and man-made environment) and to estimate their sensitivity.
To reach this objective, the area of interest in the vicinity of a plant will be divided into meshes : the potential targets belonging to each class (population, natural and man-made environment) will be identified and localised with the support of Geographic Information Systems (GIS). The sensitivity of the targets (workers of the plant, residents, surface and underground waters, public buildings...) will be characterised and ranked, using a multi-criteria ranking method (SAATY), determining a scale of vulnerability levels. Vulnerability maps will be obtained by calculating and combining the vulnerability of all the targets falling in the same mesh.

4.2.2 Finalising and testing the methodology

- Characterisation of the Risk Level *RL*

The severity index *S* can be combined with the management effectiveness index *M* and the vulnerability index *V* to define a risk level *RL* index of an installation in its environment (See Figure 2). The objective of this phase is to study the relation between *S*, *M* and *V* to characterise the risk level. It will be studied whether the risk level should remain characterised by the 3 indexes or whether the 3 indexes could be aggregated to form a multidimensional index.
The ARAMIS method enables ranking the hazards only in terms of severity with the calculation of the severity index *S* for each scenario. Then the scenarios identified in several units are comparable. It also enables taking into account the efforts (preventive measures) made by the company with the estimation of the prevention management effectiveness *M*.
The result also makes it possible to compare the risk level between two or more units of an industrial group to define the priorities for the investment for safety.

- Case studies

To validate and to improve the ARAMIS methodology, case studies will be carried out with the collaboration of industrialists and Competent Authorities in several SEVESO establishments in Europe. For the selection of the test sites, it will be assured that countries with a consequence-based and probabilistic approaches are represented. After this exercise, the definition of the indexes will be modulated to improve applicability and validity of the procedure.

4.2.3 Valorisation and dissemination

In the valorisation and dissemination plan, efforts will be made to transfer the methodology to risk assessors and decision-makers, who are the end-users of the methodology.
Industrial end-users are represented in the consortium through an association of European industrial companies. It will help the consortium to relay information about the project and its progress, to find plants for case studies and to disseminate the methodology at the end of the project.
For dissemination, a web site will be built aiming at promoting the project and disseminating the public results. An electronic newsletter will also be released by the project management on the web site, after the progress meetings.
Moreover, a intermediate workshop is set to provide the end-users with some partial results of the project and to collect comments to improve the relevancy of the further work. And a final workshop is also planned at the end of the project to disseminate the main results to all relevant stakeholders. The two workshops will be open to third-parties not involved in the consortium and workshop proceedings will be issued and made available on the web-site. Besides, in connection with the workshops, to ensure the widest possible dissemination of the results during the project, the participants will publish papers in scientific international journals and conferences.

5. Consortium description and involvement

The consortium consists of ten organisations involved in the risk analysis of major accidents. They are presented in Table 1.

Table 1: Description of partner organisation

Organisation name	Short name	Country
1. Institut National de l'Environnement Industriel et des Risques Accidental Risk Division	INERIS	FRANCE
2. European Commission - Joint Research Centre - Institute for the Protection and Security of the Citizen- Major Accident Hazard Bureau	EC-JRC-IPSC-MAHB	ITALY
3. Faculté Polytechnique de Mons Major Risk Research Center	FPMs-MRRC	BELGIUM
4. Universitat Politecnica de Catalunya Centre for Studies on Technological Risk (CERTEC)	UPC	SPAIN
5. Association pour la Recherche et le Développement des Méthodes et Processus Industriels - ARMINES	ARMINES	FRANCE
6. Risø National Laboratory System Analysis Department	RISOE	DENMARK
7. Universita di Roma Dipartimento Ingegneria Chimica	UROM	ITALY
8. Central Mining Institute Safety Management and Technical Hazards	CMI	POLAND
9. Delft University of Technology Safety Science Group	TUD	THE NETHERLANDS
10. Institution of Chemical Engineers European Process Safety Centre	IChemE-EPSC	UNITED KINGDOM

INERIS, the co-ordinator of the project, has an international expertise in the field of major accident prevention. It works as technical support for the national Competent Authority in charge of the application of the SEVESO II Directive. INERIS will lead with the steering committee the aggregation of the works for the risk level index composition and validation. INERIS will also provide support for valorisation and dissemination and for the Parallel Review.

EC-JRC-IPSC and especially MAHB has a recognised international expertise in the field of major accident prevention. It has animated EU Working Groups dealing with the application of the SEVESO I and II Directives and is also experienced in the development and use of accident databases and GIS tools at European level. MAHB acts as leader of the activities related to valorisation and dissemination of the results as well as leader of the parallel Review Team.

FPMs-MRRC has a great experience in the application of the SEVESO II Directive, and already developed methodologies on the choice of accident scenarios to study domino effects. It acts as the leader of work on Scenario Identification. In addition, the MRRC also brings its experience about domino effects and accident consequences modelling in the Severity Evaluation.

UPC (through CERTEC) has a recognised expertise in the evaluation of the accident consequences for SEVESO plants (dispersion, explosion, fire modelling). UPC will develop research on the Severity Evaluation as task leader.

The Pôle Cindyniques of ARMINES has built a methodology to formalise the development of accidents as a series of "particles of experience" which are collected and documented from the analysis of reports, debriefing sessions and interviews. Using this methodology, it will contribute to the scenario identification and the work related to the prevention management effectiveness.

The SITE department of ARMINES has a long experience in environmental system management characterisation. It will mainly focus on the prevention management effectiveness and environment vulnerability characterisation.
The LGEI of ARMINES has competencies in using both multi-criteria ranking methods (SAATY) and GIS. It has developed a methodology based on these two aspects for studying risks in transportation of hazardous substances., and will contribute to provide a methodology to rank the vulnerability of targets (human, environmental, equipment) in the vicinity of plants to obtain a vulnerability cartography used to characterise the spatial vulnerability.

RISOE is experienced with drawing up and evaluating safety reports for hazardous installations. It has special experience with applying function-oriented modelling to analyse the effectiveness of the organisation of safety procedures and using questionnaire techniques for assessment of safety culture. RISOE will be leader of the work on the Prevention management effectiveness.

UROM is experienced in methodologies and software tools, including GIS systems, to carry out risk analysis and area risk studies. Its activities will be mainly devoted to the development of the methodology for characterising the potential targets and their vulnerability. It will prepare a software tool for determining the environmental vulnerability index basing on GIS information.

Due to its experience, on one hand in fire and explosion, and, on the other hand in safety management and risk assessment, CMI will carry out research respectively for work related to the Severity evaluation and the Management effectiveness by analysing the implementation of management standards and guidelines.

Bringing its expertise in safety management modelling and risk assessment, TUD will carry out a major effort in the ARAMIS research project in work on Prevention management effectiveness with expert judgement and audit tools developed at TUD.

IChemE-EPSC will participate in the dissemination of the results to the industrial companies which are members or associates of the EPSC. It is important to notice that a lot of EPSC members are end-users of the ARAMIS methodology. In the project, EPSC will circulate to the members information related to the project and its results, and care about the Review Team participation.

In addition to the consortium, a Review Team is indeed built up. It has an essential role for the dissemination of the results through decision-makers involved in the control of major accidents. The Review Team has a role in the management and will comment on the applicability and usefulness of the results achieved. The involvement in the methodology development of risk experts both from the Competent Authorities and industrial companies will ensure that the methodology will be known and recognised at a European level.

6. Contribution to the implementation of the SEVESO Directive

The project supports the European Research Area concerning the improvement of the knowledge, encouragement of the Science-Industry dialogue and harmonisation in decision-making process related to hazardous establishments.

The ARAMIS method will indeed be proposed as a recommended and harmonised tool used by risk experts and recognised by the risk decision-makers in the EU. Harmonising industrial risk assessments in Europe would significantly contribute to the European Commission's overall efforts to establish harmonised policies following the SEVESO II Directive. Such a harmonised risk assessment procedure would be of significant interest for both Competent Authorities and Industry :

- It would constitute a risk evaluation and comparison tool for industrial sites, which integrates the strengths of probabilistic and deterministic approaches.
- The procedure would enable definition of progress plans within the framework of a safety management system.
- It would enable to moderate the selection of scenarios by taking into account realistic data and preventive measures.
- It will enable the evaluation and consideration of plant-specific safety devices and safety management effectiveness, as required in the Safety Reports.

The partnership in the consortium and in the Review Team ensures that the ARAMIS project will contribute on a very practical level to the EC research objectives built to support the further development and consistent implementation of European policies.

7. Acknowledgement

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The programme is organised within the Energy, Environment and Sustainable Development Programme in the 5th Framework Programme for Science Research and Technological Development of the European Commission

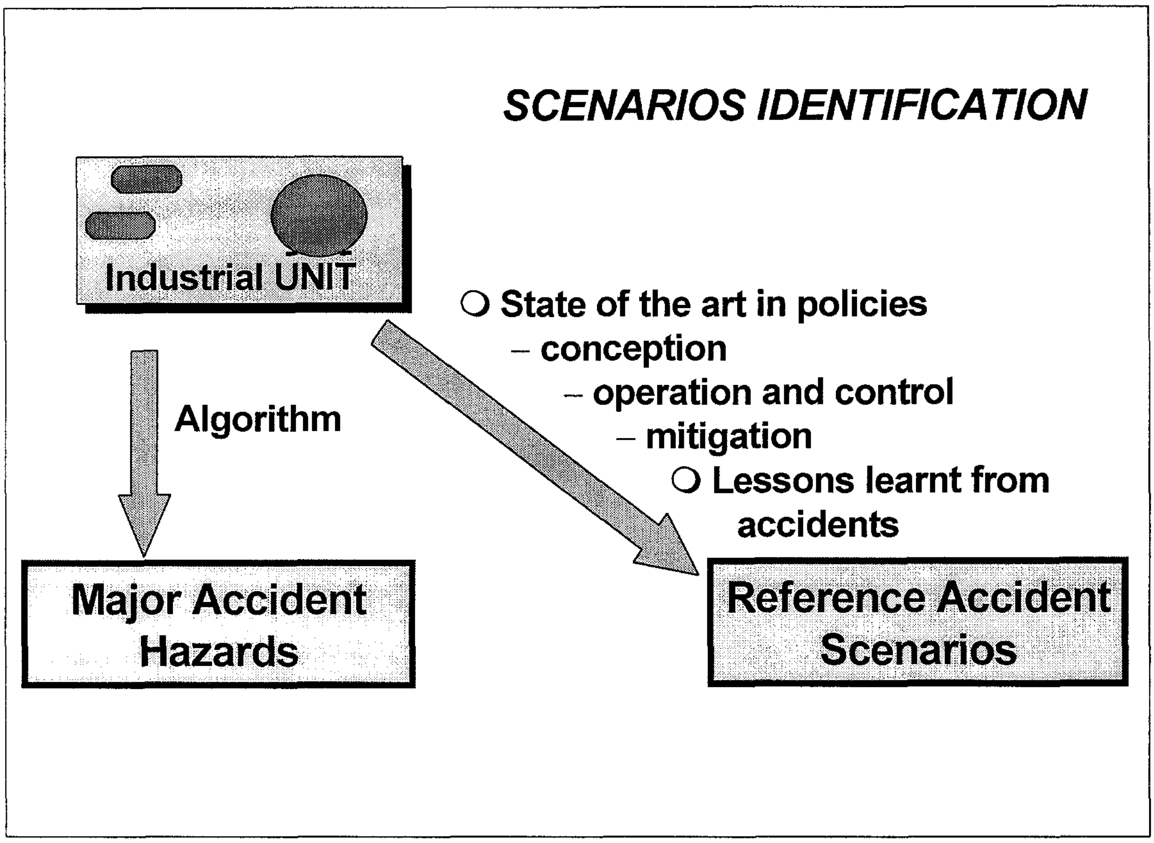

Figure 1 : Scenarios identification procedure

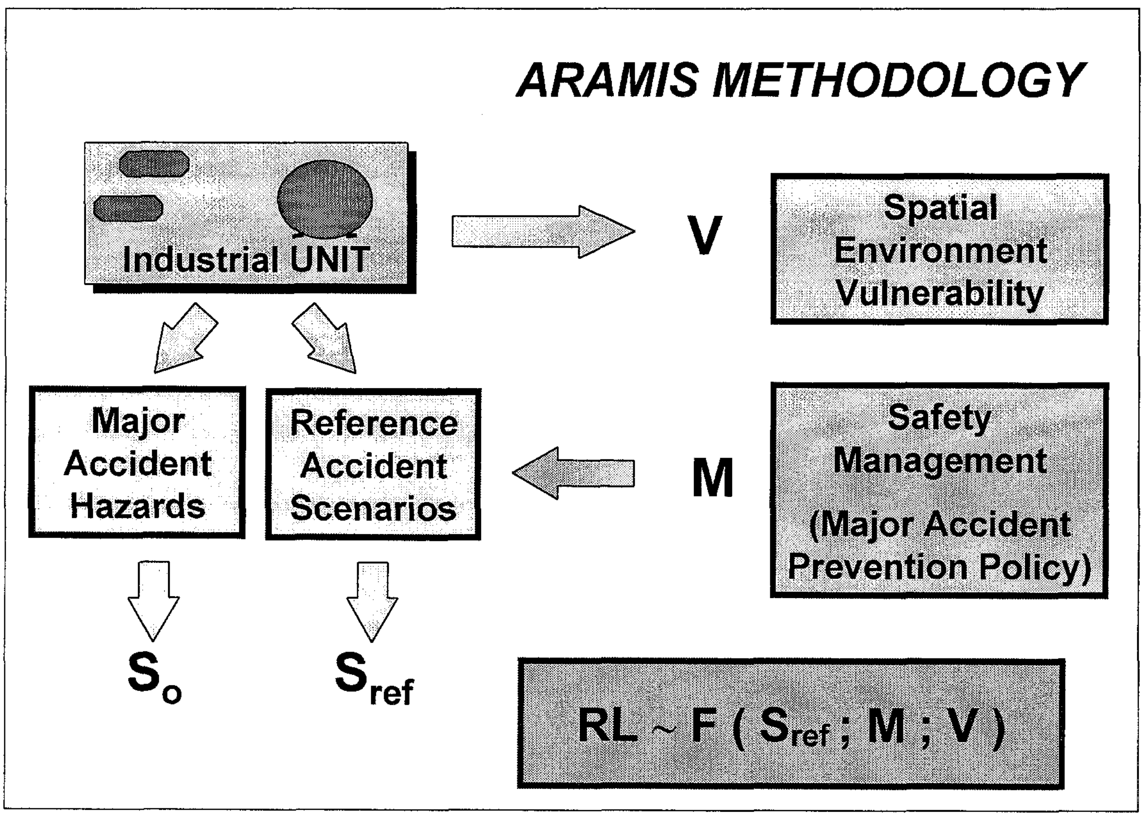

Figure 2 : ARAMIS methodology representation

8. References

[1] European Environment Agency (1999). Environment in the European Union at the turn of the century, Copenhagen, Denmark.

[2] Cassidy K., Amendola A. (1999), Special issue : The SEVESO II Directive (96/82/EC) on the control of major accident hazards involving dangerous substances, Journal of Hazardous Materials, Vol. 65, n°1-2, Elsevier Science.

[3] Kirchsteiger C. (1999), Special Issue on International Trends in Major Accidents and Activities by the European Commission towards Accident Prevention, Journal of Loss Prevention in the Process Industries, Vol. 12 No 1, Elsevier Science.

[4] Kirchsteiger C., G. Cojazzi (editors), Promotion of technical harmonization on risk-based decision-making, Proceedings of a Workshop held on 22-24 May, 2000 at Grand Hotel Bristol, Stresa, Italy, Organised by the European Commission, DG JRC, Institute for Systems, Informatics & Safety, S.P.I.00.63, Ispra, 2000.

[5] Salvi O. and Gaston D. (1999), Why changing the way to measure the risk ? Proceedings 9th Annual Conference Risk Analysis : Facing the New Millennium Rotterdam, 10-13 October 1999, The Netherlands. Edited by L.H.J. Goossens. Delft University Press, 1999 (pp 263-267).