ARAMIS Project : development of an integrated Accidental Risk Assessment Methology for IndustrieS in the framework of SEVESO II directive

David Hourtolou, Olivier Salvi

ARAMIS Project: development of an integrated Accidental Risk Assessment Methodology for IndustrieS in the framework of SEVESO II directive

D. Hourtolou, O. Salvi
INERIS, Verneuil-en-Halatte, France

ABSTRACT: The ESREL conference welcomes a special session on ARAMIS European project. This session represents halfway workshop of the project, which started in January 2002. The aim is to disseminate first results and collect comments from the public. This article is one of the five papers constituting the session and it presents the overall frame of ARAMIS project. ARAMIS objective is to build up a new integrated risk assessment method that will be used as a supportive tool to speed up the harmonized implementation of SEVESO II Directive. The proposed method results in an integrated risk index composed itself of three independent indexes. Index 1 assesses the consequence severity of first defined reference scenarios. Index 2 evaluates Safety Management effectiveness and accounts thus for the scenario probability. Index 3 estimates the environment vulnerability. Efforts have been made to disseminate work progress and results from the start. A dedicated web-site has been created and a review committee gathering industry risk experts and decision-makers from EU competent authorities periodically monitors the project.

1 INTRODUCTION

ARAMIS project was accepted for funding in February 2001 by the European Commission, in the 5th Framework Programme for Research and Technological Development, in the field of "Energy, Environment and Sustainable Development", chapter entitled "Fight against major natural and technological hazards". This three-year project started in January 2002. The project has been built in particular on the conclusions and results of ASSURANCE and I-RISK, two other European projects funded in the 4th Framework Programme.

ASSURANCE stands for ASSessment of the Uncertainties in Risk Analysis of Chemical Establishments. This project was a benchmark exercise, which aimed at improving the understanding of the sources and types of the uncertainties connected with risk analyses. As a rough conclusion, the project stated that the benchmark exercise revealed noteworthy variation in the final results. Discrepancies were present both in the assessment of frequencies and in the assessment of consequences. The different results would have obviously affected the relevant risk-informed decisions, mainly land use planning, emergency planning and acceptability of risk.

The initial statement of I-RISK project -I for integrated- was the idea that Quantitative Risk Assessments (QRA) and safety management audits were so far two separate tools and that would be valuable to integrate both to address major hazard management. In this respect, the main objective was first to develop a management model for risk control and monitoring, then to implement this model into a dynamic QRA tool. Conclusions of the project point out that the integrated technical and management model was very robust and helped audit organizations in a new way. However it also turned out that a full-scale site integrated QRA was too time and detail demanding, so not currently practical or relevant.

From both projects, but also from everyone's experience in his own country, it emerges the need for a methodology giving consistent rules to identify accident scenarios and taking into account both prevention and mitigation measures peculiar to each plant operator. Those safety measures are obviously controlled in a safety management system.

There is also an underlying need for a risk assessment method that could reach a consensus amongst risk experts from both Industry and Competent Authorities and then be used with reduced uncertainty to make risk-informed decisions. The ARAMIS project has been set up to propose solutions to both latter requirements.

The paper first recalls the context of major accident hazards prevention in the EU. ARAMIS overall objectives are then expressed and the work contents are described in details. As a conclusion, the expected impacts of such a methodology are addressed.

2 CONTEXT OF THE SEVESO II DIRECTIVE

The annual report from the European Environment Agency (1999) indicates, among others, that the trend in notified accidents has been constant over the last twenty years. This statement alone shows that many of the often seemingly simple "lessons learned" from accidents have not been yet enough implemented in industry's standards. There is unfortunately no doubt that disasters will continue to occur throughout the EU. Some will be due to technology, some to the hazards of nature. The problem of low-probability, high-consequence accidents is likely to remain a key issue in terms of risk management. Nevertheless, hazards have to be managed and risks can be reduced.

The most significant EU Directive to help protect people and the environment from major accident hazards is the SEVESO II Directive. This applies to industries that use "significant amounts of hazardous substances". Their operators must demonstrate in particular they apply a major accident prevention policy and they implemented appropriate prevention and mitigation measures controlled and monitored in a safety management system.

The SEVESO II Directive sets very clear objectives relating to major hazard management, but the remaining question is: how to reach them and to control they are reached? For instance, there is no harmonized definition of the scenarios to be considered for risk assessment. The ASSURANCE project showed in this way that the chosen scenarios (BLEVE, full bore rupture or small leakage, amount of substance caught in an explosion, etc.) are different according to the experts judgement and experience, and according to the deterministic or risk-based approach of the Member State applying the Directive. Moreover, constraints in land-use planning (Cassidy & Amendola, 1999) sometimes urge the operators to consider reduction of the safety zones by choosing "realistic" scenarios and accounting for the effectiveness of dedicated safety devices. Actually the lack of rules for identifying scenarios and carrying out risk assessment makes often the expert's job tricky and largely too subjective to base transparent risk-informed decisions on it.

In addition to uncertainties in risk analyses, differences of culture among the Member States result in a multiplicity of methods and approaches (Kirchsteiger, 1999). At a recent JRC International Workshop (Kirchsteiger & Cojazzi, 2000), most participants agreed that comparative risk assessment along harmonized procedures would significantly help the decision understanding. A harmonized risk assessment methodology would thus ensure that risk-based decision making provides the necessary transparency and the right balance between scientific understanding and principle of precaution.

Proposing a harmonized methodology for risk assessment is a tough and tricky task. However, deterministic and probabilistic approaches should not be opposed since they are often complementary (Libmann, 1996). From a historical point of view, deterministic methods first allow to check the safe design of an installation. Probabilistic methods help then evaluate the residual risk of the installation. Both approaches have their strengths and weaknesses (Hourtolou, 2002). A first basic idea of ARAMIS is to take advantage of each approach's strengths and to develop upon it an alternative semi-quantitative method based on the evaluation of the safety barriers –lines of defense- peculiar to each site.

3 OBJECTIVES

The main objective of the ARAMIS project is to create a new integrated risk assessment methodology by combining the strengths of different methods currently used in European Countries. Accordingly, the method should be flexible enough to account for different national cultures like deterministic or risk-based approaches, in order to become a recommended tool used by risk experts and endorsed by risk decision makers in the whole EU.

The proposed method in ARAMIS should allow to characterize an integrated risk index composed itself of three distinct and independent indexes. Index 1 is to assess the consequence severity of first defined reference scenarios. Index 2 is to evaluate prevention management effectiveness, which allows thus to account for the reference scenarios probability in a semi-quantitative manner. Index 3 is to estimate the environment vulnerability by evaluating the sensitivity of potential targets located in the vicinity of a SEVESO plant.

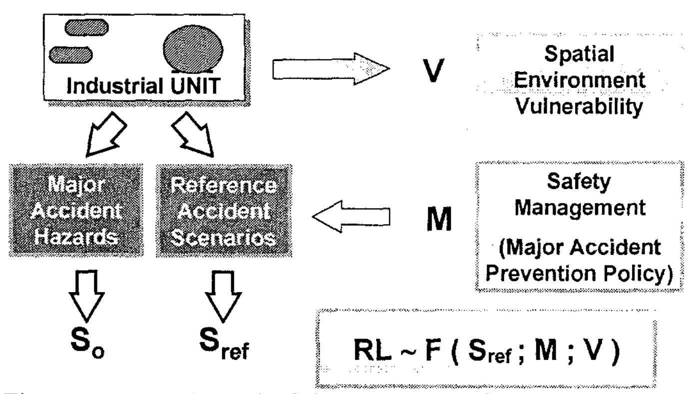

Figure 1. ARAMIS methodology representation

The project has been set up (Figure 1) to reflect the logical construction of the risk index and has been divided accordingly into work packages:

1 First goal is then to develop a method to identify "reference" accident scenarios. These scenarios are consensual "realistic" scenarios to be used in SEVESO II safety report and taking account of some prevention and mitigation measures of the site according to their effectiveness.

2 Second task is to build up the integrated risk index made up of the three distinct indexes, i.e.:
 - consequence severity evaluation,
 - prevention management effectiveness,
 - environment vulnerability estimation.

4 DESCRIPTION OF WORK

The work plan of the project has been built according to the logical construction of the final resulting risk index and it has been presented the same way in this article.

Halfway through the life of the project, the newly built methodology is to be tested on three SEVESO industrial sites in Europe. At this stage, two new partners from eastern-European countries will join the consortium and will also test the full method as totally unbiased end-users, each in one additional test site of their own country.

Moreover and since ARAMIS is intended to be a supportive tool to promote harmonized risk assessments throughout Europe, the project leaves from the start an extensive part to large exchanges with potential end-users of the method. Identified end-users are both industrial companies and Competent Authorities in charge of enforcing SEVESO II Directive. For that purpose, a dedicated Work Package deals with valorization and dissemination of project progress and results. Industrial partners have also been directly included in the consortium and a Parallel Review Team gathering potential end-users has been constituted.

4.1 *WP1 : Scenario identification*

Identification of the possible accident scenarios is a key-point in risk assessment (Amendola & al., 2002). However, especially in a deterministic approach, worst case scenarios are considered, often without taking into account existing safety devices and implemented safety policy. This approach can lead to an overestimation of the risk level and does not promote the implementation of safety systems.

The aim of this Work Package (Delvosalle & al., 2003) is first to identify major accidents without considering safety systems. A second step is then to study in depth safety device effectiveness and safety management efficiency, which will allow to assess -qualitative- probabilities, in order to identify finally Reference Accident Scenarios taking into account some of the implemented safety systems.

The first objective is to define a Methodology for the Identification of Major Accident Hazards (MIMAH). On the basis of considered equipment and properties of handled chemicals, the methodology must be able to predict which major accidents are likely to occur. Properties of substances are found out thanks to Directive 67/548/EEC (substance classification and labeling) and their own conditions of use (pressure, temperature, flow, etc.).

The work has been divided in several parts. Firstly, it was necessary to select a general approach. The bow-tie method was chosen (Bellamy & Van der Schaff, 1999) because it is a highly structured tool and it is considered as a very good way to establish links with other parts of the project and especially Management Efficiency (Figure 2). Secondly, a special effort was made to develop a common typology of equipment and hazardous substances. Thirdly, event trees and fault trees centered on critical events have been built, and above all a methodology able to build generic trees was created. Critical events are defined as "Loss of Containment" or "Loss of Physical Integrity" event.

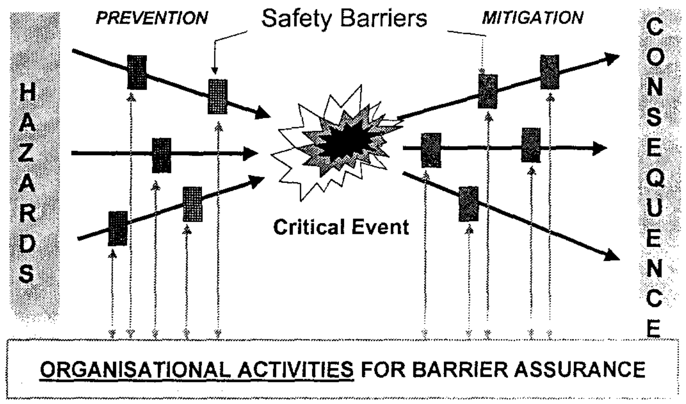

Figure 2. Bow-tie approach for scenario identification

At this stage, the MIMAH methodology is able to predict which major accidents are likely to occur on a given equipment. With the help of a deep study of safety systems, causes of accidents and a historical analysis of known accidents, the objective of the work to be done is now to place lines of defense - safety functions, safety barriers- on the different branches of the trees. This will lead to a second Methodology of Identification of Reference Accident Scenarios (MIRAS) which has to take into account some of the safety systems according to their effectiveness. Therefore, the Reference Accident Scenarios will use results from the work performed on the prevention management effectiveness (Figure 3). These scenarios are used afterwards as an input to evaluate the severity index, i.e. the hazard potential.

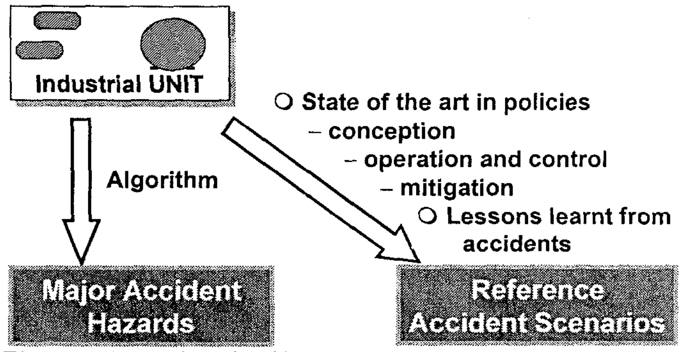

Figure 3. Scenarios identification process

4.2 *WP2 : Severity of the consequences*

The objective of this task is to define a severity index S characterizing the possible consequences of accident scenarios (Casal & al., 2003). In this respect, only the physical characteristics of the phenomena involved in accidents are studied in order to evaluate the severity of both major scenarios and reference scenarios identified in WP1.

First task of WP2 was the selection of the most suitable models for the calculation of the effects of the various dangerous accidental phenomena. Thus, a survey of the existing models for the calculation of the effects due to explosions (overpressure and missiles), fires (radiation), toxic clouds (concentration), BLEVE-Fireballs (overpressure, missiles and radiation), pollutant plumes into the water (concentration), soil pollution and domino effects is now available at this stage of the project.

The Severity Index must be independent of the other two indexes. It is thus constructed in such a way that every dangerous phenomenon has a corresponding specific sub-index. The contribution of each dangerous phenomenon to the global index S is strongly related to the probability of occurrence of the phenomenon associated to each critical event (e.g. probability of ignition) and identified in the WP1 event trees (Figure 2).

Each specific sub-index associated to the various physical phenomena takes into account in its construction the following parameters:

- the effect area concerned with the phenomenon, e.g. a disc in case of an explosion, a plume surface for gas dispersion ;
- the kinetic of the phenomenon: rapid for an explosion, much slower for a fire ;
- the potential of generating domino effect: fragment emission, delayed phenomena triggered off.

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

4.3 *WP3 : Prevention management effectiveness*

This work package deals with the assessment of safety management efficiency and its effect on the calculation of external risks for SEVESO plants (Duijm & al., 2003).

The methodology is based on the identification of initiating events and direct causes of the accident scenarios (bow-tie approach). Safety barriers are then related to generic fault and event trees representing all possible accident scenarios leading to critical events (Figure 2). The safety organization includes both the adequacy and completeness of technical and managerial barriers (lines of defense) that are implemented to prevent these accidents and the management system that ensures that these barriers are maintained and adjusted properly.

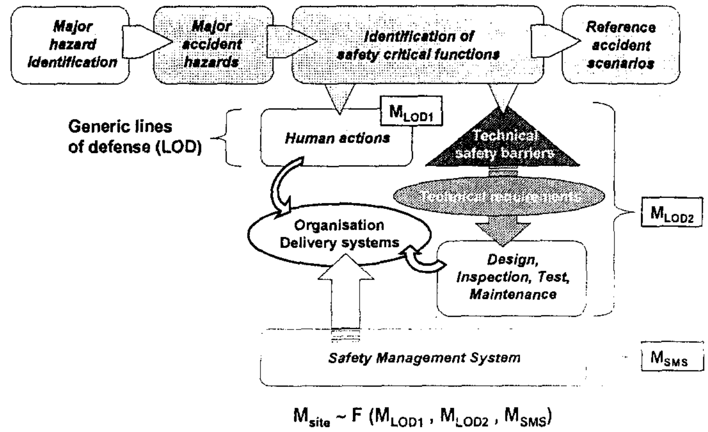

Figure 4. Structure of index M

The methodology recognizes a number of dimensions of safety management (delivery systems), derived from previous work on safety management modeling, notably the I-Risk (Hale, 1998) and MIRIAM (Plot, 2002) models. These are made explicit in specific functions that need to be executed to maintain a safety barrier. Examples of these delivery systems are: ensuring good competence and commitment of employees, manpower availability, communication, procedures, plans, hardware and human-machine interfaces.

Currently, the focus is on developing instruments to measure the set of dimensions, using a combination of audit, questionnaire, interview and observation techniques. The combination of measurements ensures that not only the implementation of functions, but also its conditions and outcome (e.g. good safety commitment of the employees) are taken into account.

The measurement techniques address in particular the specific safety functions (M_{LOD1} and M_{LOD2}, Figure 4) found in a given establishment. However measurement will also be carried out in a generic way onsite (M_{SMS}, Figure 4), assuming then the quality of the dimensions represents a common mode for the quality of safety barriers maintenance. The efficiency of the barriers can then be adjusted according to the measurement scores to select the final set of Reference Accident Scenarios.

The assessment of technical barriers effectiveness follows the principles described in the norms IEC61508 and IEC61511 (Functional safety : safety instrumented systems for the process sector). Among these principles, effectiveness is analyzed through the definition of "Safety Integrity Levels" linked to device characteristics (design, reliability, maintainability, testability…) and also through criteria upon the activities in charge to maintain them.

Challenges in the development of the methodology include the need to calibrate the scores in the measurement of dimensions, as well as the need to determine the efficiency of technical barriers as a function of these scores.

4.4 *WP4 : Environment vulnerability*

An installation handling dangerous substances is hazardous only according to the potential of vulnerable targets liable to be affected. In assessing the overall risk level of a plant, it is therefore quite relevant to characterize the spatial vulnerability of the environment surrounding the plant. Such is the aim of this work package (Tixier, 2003).

Vulnerability of the surroundings depends on the features of the environment that are potential targets (human, environmental and material) and on the type of impact due to hazards (fire, explosion, and toxic release). It also strongly depends on the considered target area.

To address this issue, the area of interest in the vicinity of a plant has been first divided into meshes and the potential targets have been identified and localized with the support of Geographic Information Systems (GIS). The major difficulty is then to rank and prioritize the various sensitivities of the targets according to the various expected impacts.

A suitable solution has been found out by applying a multi-criteria ranking approach, such as SAATY methodology which allows to define priorities from complex situations. At this stage of the project, SAATY method has been extensively applied to the concern of vulnerability estimation.

First step was to describe and classify potential targets, hazards and impacts in adequate typologies. Following step involved expert judgement. Through experts' answers to specific questionnaires, SAATY method helped build up mathematically the generic coefficients of target vulnerability.

Final step will be to test and validate the calculated coefficients and resulting index through full-scale case studies.

Thanks to the combined use of SAATY method and GIS, index V should be represented as vulnerability maps of a plant surroundings, and should become in this way a powerful tool for risk-informed decision making.

4.5 *WP5: Risk level integration and validation*

4.5.1 *Characterization of final Risk Level RL*

The risk level RL of an installation in its environment is a function depending on the severity index S, the vulnerability index V and management effectiveness index M:

$$RL = \lambda \times \frac{S^{\alpha} \times V^{\beta}}{M^{\chi}} \tag{1}$$

The objective of this phase is to study the relation between S, M and V to characterize final risk level.

It will be decided at this stage whether the risk level should remain characterized by 3 separate indexes or whether the 3 indexes could be aggregated into one single index.

4.5.2 *Case studies*

Halfway through the life of the project, five case studies will be carried out with the collaboration of five different SEVESO establishments throughout Europe in order to test and validate or improve the new methodology.

To select the test sites, it has been assured that both countries with consequence-based and probabilistic approaches would be represented. Moreover two case studies out of five will take place in Slovenia and Czech Republic. Two institutes from these countries will indeed join the consortium at this stage and test the full method with the test sites. Both of them will thus act as totally unbiased end-users since they were not involved in the method development.

After these full-scale exercises, the ARAMIS methodology will be improved again and give rise to its last version in the project.

5 WP6-7: VALORIZATION, DISSEMINATION

Since ARAMIS is intended to be a supportive tool to promote harmonized risk assessments throughout Europe, the project leaves from the start an extensive part to large exchanges with potential end-users. Identified end-users are both industrial companies and Competent Authorities in charge of enforcing SEVESO II Directive.

In the valorization process, industrial end-users are directly represented in the consortium through an association of European industrial companies. This helps the consortium to relay information about the project progress and results, and to convince plants for the case studies.

A Parallel Review Team gathering risk experts from industry and EU competent authorities has also been constituted. This review team gathers every six months to monitor the project and thus to ensure needs from end-users are indeed fulfilled and the final approach will be widely accepted. In this respect their main comments concern the applicability and usefulness of achieved results.

In the dissemination process, a dedicated web site has been set up first: please visit http://aramis.jrc.it. The web-site aims at promoting the project towards the public and also works as a quick communication tool among the partners. An electronic newsletter is also released every six month on the web-site, in order to get the public informed of work progress.

Two workshops were also planned during the project. This article is part of the halfway workshop held at the ESREL conference. A final workshop will also take place at the end of the project to disseminate main achievements to all relevant stakeholders. Proceedings of the workshop will be made available on the web-site.

6 CONSORTIUM DESCRIPTION AND INVOLVEMENT

The consortium consists of twelve organizations expert in the field of risk analysis (Table 1). Nine partners represent mostly research centers throughout Europe. The last three institutes represent Newly Associates States from Eastern Europe.

Table 1. Description of partner organization

Organization full 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	France
6. Risø National Laboratory System Analysis Department	RISØ	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	Netherlands
10. Institution of Chemical Engineers European Process Safety Centre	IChemE-EPSC	U.K.
11. Jozef Stefan Institute - Department of Inorganic Chemistry and Technology	IJS	Slovenia
12. Technical University of Ostrava – Energy Research Centre	VSB-TUO	Czech Republic

INERIS is the coordinator of the project. It has a European expertise in the field of major accident prevention. It works as technical support for the French Ministry of Ecology in charge of SEVESO II Directive application. In particular, it manages with a steering committee the risk index aggregation and validation phase. INERIS is also deeply involved in the valorization and dissemination process.

EC-JRC-IPSC and especially MAHB has a recognized international expertise in the field of major accident prevention. It animated EU Working Groups dealing with the application of SEVESO Directives and is also experienced with accident databases and GIS tools at a European level. MAHB is WP leader of the dissemination activities and also coordinates the Parallel Review Team.

FPMs-MRRC has a great experience in the application of SEVESO Directives, and already developed methodologies and tools in the field of domino effects and source term / consequence modeling. MRRC is WP1 leader concerning scenario identification and also brings its experience to WP2.

UPC-CERTEC has a recognized expertise in the evaluation of accident consequences: dispersion, explosion, fire modeling. UPC is WP2 leader.

ARMINES is a consortium of research centers from French school of mines. Three different research teams take part in the ARAMIS project.

"Pôle Cindyniques" from Mines de Paris has built up a debriefing and interview methodology to learn better from both technical and organizational incidents. By this means, Mines de Paris contributes to develop ARAMIS organization model and management effectiveness index.

"SITE" Center from Mines de Saint-Etienne has a long experience in risk analysis and environmental management system. In ARAMIS, this team mainly focuses on developing generic "bow-ties" and an assessment method for technical barrier effectiveness.

"LGEI" Laboratory from Mines d'Alès has developed a methodology based on GIS and multi-criteria SAATY approach to study risks in transportation of hazardous substances. This partner is WP4 leader concerning environment vulnerability estimation, which intends to use the same competence.

RISØ is experienced with both SEVESO Directives. It also coordinated the ASSURANCE project. Furthermore, it is experienced in applying function-oriented modeling to analyze the effectiveness of an organization and its safety culture. RISØ is WP3 leader dealing with Prevention management.

UROM is experienced in risk analyses and area risk studies, linked in particular with the use of GIS. Its activities in ARAMIS mainly concern the interfaces to build up between the model developed for V index and the use of GIS to represent this index.

CMI has a long experience both in fire and explosion modeling and in the use of safety management standards. In this respect, CMI works in WP2 to list and select appropriate models for consequence modeling, and in WP3 to analyze how the common management standards fit in the ARAMIS model.

TUD was a major partner of I-RISK project. It brings its expertise to the project in safety management modeling and auditing, and also in scenario identification with the use of bow-tie approach.

IChemE-EPSC only participates in the dissemination process to other member companies or associates from EPSC. It also cares about Industry participation into the Parallel Review Team.

IJS is the largest Slovenian research organization. VSB-TUO has been involved for long in Industrial Environment Research, and has enlarged since 1995 its focus towards technological and natural risks. Both institutes have been chosen to test the full ARAMIS method in companies of their own country and also to compare it to commonly used approaches in their respective country.

7 CONCLUSIONS

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

The resulting method should indeed be proposed as a recommended and harmonized tool used by risk experts and recognized by risk-informed decision-makers of EU competent authorities. Harmonizing industrial risk assessment in Europe would significantly contribute to the European Commission's overall efforts to establish harmonized policies following the SEVESO II Directive.

For both Competent Authorities and Industry, such a harmonized risk assessment procedure would constitute first a useful comparison tool for industrial sites, which integrates the strengths of both probabilistic and deterministic approaches. The risk assessment procedure would at last be linked to the setup of progress plans within the framework of a safety management system. It would also allow to reach a consensus in the selection of accident scenarios that takes into account plant-specific safety devices and safety management effectiveness, i.e. suitable frequencies for the scenarios as required in a safety report for risk control demonstration.

The participation of potential end-users in the project from the start, in particular through the Parallel Review Team ensures that the ARAMIS project will contribute on a very practical level to EC research objectives and to consistent implementation of European policies in major hazard prevention.

8 ACKNOWLEDGEMENTS

The ideas presented in this publication are developed in the frame of EU project ARAMIS "Accidental Risk Assessment Methodology for IndustrieS", contract n°EVG1-CT-2001-00036 funded by the Energy, Environment and Sustainable Development Program in the 5th Framework Programme for Science Research and Technological Development of the European Commission.

The project is coordinated by INERIS but also includes a consortium of fifteen efficient institutions representing ten countries which all contributed to the results presented during this workshop.

The Parallel Review Team represents also fifteen organizations either from Industry or from EU competent authorities, which are also kindly acknowledged for their advice and contribution during the periodic reviews.

9 REFERENCES

Bellamy, L. & Van der Schaff, J. 1999. Major Hazard Management : Technical-Management Links and the AVRIM2 Method, in Seveso 2000 – Risk Management in the European Union of 2000 : The Challenge of Implementing Council Directive Seveso II. *Edited by EC-JRC-MAHB. Athens, Greece. 10-12 November 1999.*

Casal Fàbrega, J., Planas, E., Delvosalle, C., Fiévez, C., Pipart, A. 2003. ARAMIS project: the severity index. *Proc. ESREL, Maastricht, Netherlands, 16-18 June 2003.*

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.

Delvosalle, C., Fiévez, C., Pipart A., Casal Fàbrega J., Planas, E., Christou, M., Mushtaq, F. 2003. ARAMIS Project: Identification of Reference Accident Scenarios in SEVESO establishments. *Proc. ESREL, Maastricht, Netherlands, 16-18 June 2003.*

Duijm, N.J., Madsen, M., Andersen, H.B., Goossens, L., Hale, A. 2003. ARAMIS project : Assessing the effect of safety management efficiency on industrial risk. *Proc. ESREL, Maastricht, Netherlands, 16-18 June 2003.*

European Environment Agency. 1999. Environment in the European Union at the turn of the century, Chapter 3.8. Copenhagen, Denmark.

Hale, A.R., Guldenmund, F. & Bellamy, L. 1998. An audit method for the modification of technical risk assessment with management weighting factors. *Probability and Safety Assessment and Management. Springer. London. 2093-2098.*

Hourtolou, D. 2002. ASSURANCE – Assessment of the Uncertainties in Risk ANalysis of Chemical Establishments. U.E. Project U.E. ENV4-CT97-0627. Rapport final opération a DRA-07. *Ref. INERIS-DHo- 2002-26824*

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 N°1. Elsevier Science.

Kirchsteiger, C. & Cojazzi, G. (ed.). 2000. Promotion of technical harmonization on risk-based decision-making, *Proc. intern. workshop, Stresa, Italy, 22-24 May 2000.*

Lauridsen K., Kozine, I., Markert, F., Amendola, A., Christou, M. & Fiori M. 2002. The ASSURANCE project. Final summary report.

Libmann, J. 1996. Eléments de sûreté nucléaire. Institut de Protection et de Sûreté Nucléaire

Plot, E. & Lecoze J.C. 2002. MIRIAM: an integrated approach to organize major risk control in hazardous chemical establishments. *ESREDA 23rd Seminar, Delft, Netherlands, 18-20 November 2002.*

Tixier, J., Dusserre, G., Dandrieux, A., Bubbico, R., Luccone, L.G., Mazzarotta, B., Silvetti B., Hubert, E. 2003. ARAMIS project : Assessment of the environment vulnerability in the surroundings of an industrial site. *Proc. ESREL, Maastricht, Netherlands, 16-18 June 2003.*