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How powerful is ARAMIS methodology in solving land-use issues associated with industry based environmental and health risks?

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Abstract

The first experience on how a part of the ARAMIS methodology has contributed to demonstration of safety in the licensing process in Slovenia for a new Seveso II plant is described. There are two foci of this description: first, trustworthy of the methodology for evaluating safety, and second, the role of a land-use plan in issuing a construction permit for the new plant. In the context of the first focus, we present why has been safety report first rejected by the regulator, and later-on accepted after applying components of the ARAMIS methodology in its revised version. In the context of the second focus, we discuss a relationship between the land-use plan and the licensing process for the new plant. The outcomes of this Seveso II plant licensing case are that the ARAMIS approach, in spite it was still under development when applied, is more transparent and credible comparing to the others, which have also been applied. This is related to the demonstration of how safety management system and general safety behaviour is integrated into the overall management policy. The conclusions take into account regulator's response in the licensing process.

Keywords: Risk assessment; Seveso II establishments; Land-use planning; Licensing process

1. Introduction

The objective of the paper is to show how the ARAMIS methodology has contributed to build trust into risk assessment and related safety management system in a Seveso II plant in Slovenia. The context is licensing process in a situation where no quantitative safety standards are available on which the authority can rely while making decisions. Background information is as follows.

A chemical industry Nafta Petrochem d.o.o. (PetroChem), 1 of 23 Seveso II upper tier establishments in Slovenia, started licensing process in 2003 for the purpose of getting a construction permit for a new plant for annual production of 40,000 tonnes of 36 formaline (a formaldehyde solution in water). According to Slovenian regulation, which covers Seveso II issues and approval of new industrial installations, applicants need to demonstrate safety and environmental acceptability of new plants by environmental impact report (EIA), which includes risk assessment. For this assessment, regulation provides general guidance on the items of safety reporting, however no specific methodology on how to perform risk assessment is prescribed. Consequently, applicants are free to choose any of the methodologies to demonstrate safety as long as it covers the required topics. A format of safety report is also not prescribed.

In such circumstances the PetroChem decided to combine different methods in the evaluation of safety for the new plant. The HAZOP, "What-if", Fault/Event Tree Analysis and expert opinion combined with technology assessment were the methods to identify and describe hazards, develop accidental scenarios, calculate the likelihood of occurrence and specific incident outcomes, and for the evaluation of the scope and seriousness of consequences, respectively. The results were in final instance qualitative and semi-quantitative.

After reviewing the submitted EIA and safety report for the new plant the regulator required a number of additions and justifications as a condition for issuing operational permit [1,2]. Basically, the required additions and justifications relate to:

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Table 1
Summary of risk assessment results

Scenario, description of an incident	Frequency/probability of the incident	Safe distance (m)	People at risk	
			Employees[a]	Others
A: leakage of the synthesis gas after reforming, unconfined explosion	$f = 1.22 \times 10^{-2}$ year^{-1}	40	1–2	–
B: explosion in the reformer	$f = 0.033$ year^{-1}	20	1–2	–
C: explosion of the methanol vapours in the reactor (synthesis)	$p = 4.4 \times 10^{-5}$	5	1–2	–
D: spill of methanol during loading	$p = 0.01$	50	2	–
E: spill of formaline during loading	$p = 0.01$	800	2[b]	1000[c]

[a] Process control and maintenance workers.
[b] Respiratory disorders and/or acute poisoning of loading operators which intervene without personal protective equipment.
[c] Number of those in the surroundings who may experience smell of formaldehyde and irritation of eyes and respiratory organs. The assessment took into account wind rose in summer (expected intensified volatilisation of formaline compared to winter temperatures), night time when most people are expected to be at home, wind velocity of 2 m s^{-1}, number of people living in radius of 1200 m (in two closest villages), emergency response with complete control of the incident – stop of emission of formaldehyde – is expected in 15 min after its occurrence.

- Accident scenarios and their consequences (the core of the regulator's requirements is a need for systematic and transparent explanation on how was a set of major accident scenarios developed and why was each of them chosen for detailed analysis; a concern was about a possibility that there exist other major scenarios which were excluded from the analysis).
- Description of the Safety Management System (SMS) and Major Accident Prevention Policy (MAPP) (the regulator wanted stronger proofs of the implementation of preventative and mitigation measures against potential accidents).

It is important to note that the additions have been required in two phases. In the first phase stress was on determining major accident hazards, possible accident scenarios with the evaluation of their consequences and likelihood of occurrence. In the second phase, the focus was on SMS and MAPP, i.e., measures on preventing initial events leading to accidents, mitigation if an accident occurs, and organisational aspects of the system aimed at preventing major accidents. According to this the applicant provided two revisions of the safety report. In Section 2, we present key components of these revisions, while in Section 3, we discuss them in the context of the land-use planning and related licensing.

2. Review of the improvements of safety report

The improvements regarding accident scenarios followed results of the comprehensive HAZOP study, which covered all activities at the new plant and systematically identified possible faults and undesirable deviations in operation. This study has been made as an addition to the first HAZOP study which was rather limited in scope since it covered only storage and loading of the two main products: methanol and formaline. Major accident scenarios and possible outcomes treated in the first safety report were consequently associated with major spills from the storage tanks and at the loading facility. The regulator's requirement for justification and additions associated with major accident scenarios was in these circumstances justified.

After performing the comprehensive HAZOP study, a major accident hazard screening matrix has been applied to sort out hazards, which have potential for major risk [3–5]. This served as a basis for developing major accident scenarios to be further evaluated in terms of their likelihood of occurrence and the scope and intensity of consequences. The results of the overall exercise are summarised in Table 1. For modelling scenarios' outcomes, we used PHAST 6.1 [6], for fault and event trees analysis we used the "FaultTree+" software and the "Red Book" [7,8], for evaluating potential consequences in the surroundings of the new plant we used *Risk*Assistant* [9]. Detailed presentation of assumptions, basic data and procedures of calculation and assessment is beyond the scope of this paper; its primary aim is to show the power of the ARAMIS methodology in solving land-use issues associated with industry based environmental and health risk.

Improvements regarding demonstration of the SMS and MAPP were based on the concept of the *M* index of the ARAMIS methodology and related audit protocol [10]. It has been shown in the revised safety report that PetroChem's managers require that safety engineers and operators follow the safety barrier's life cycle loop as presented below when developing concrete SMS:

Incident ⇒ risk assessment

⇒ evaluation of adequacy of SMS/safety barriers

⇒ elimination of incidents

It has also been shown that the concept of linking risk analysis and SMS as presented in [11] is what the PetroChem is planning to apply in the near future.

3. Discussion on risk assessment, demonstration of safety and land-use issues

Issuance of the construction permit for the PetroChem's new plant have not solved a tangible link among the risk assessment, demonstration of safety, land-use planning and licensing so as to be applied in similar future cases. Remaining discussion aims at presenting where the problems still exist and what are the targets of future research.

The Seveso II Directive requires from the Member States that they "... prohibit the use or bringing into use of any establishment, installation or storage facility, or any part thereof where the measures taken by the operator for the prevention and mitigation of major accidents are seriously deficient ..." (Article 17). The weak point of this formulation is that it is insufficient in specifying what exactly means "seriously deficient" and how should it be understood/measured/evaluated/applied when it comes to issuing permits. As such, the formulation transposes importance of accurate and credible assessing of risks to value judgements and subjective evaluation of general trustworthy of the SMS and MAPP. Taking into account uncertainty of any risk assessment this opens room for further discussion on how capable is science in supporting decisions; the issue has been widely discussed by a number of authors, a condensed overview is in [12]. We believe that the *M* index of the ARAMIS methodology together with the audit protocol maintains science as a real problem solver even in the presence of uncertainty; evaluations of the deficiency of prevention and mitigation measures based on this tool are more credible than an opinion of a regulator who acts without systematic tools and information systems [13]. In this sense, we recommend modification and additions to the text of the Article 17 of the Directive by which an audit trial will be introduced as a system for controlling regulator's decisions against justifiable evaluation of a "serious deficiency".

Land-use planning in Slovenia, like elsewhere, focuses on zoning policy, i.e., dedication of a particular piece of territory to a certain purpose/use. Licensing relates to the implementation of a plan and is not, strictly speaking, a component of the planning activities. Licensing basically consists of two stages: (i) checking whether the location of a proposed development project is in accordance with the zoning plan and (ii) checking whether environmental acceptability standards will be met during operation of the proposed activity (emission and imission standards, nature protection policy, etc.). Both are to be demonstrated by an EIA. It is important to note that no specific quantitative safety standards are available for stage two in Slovenia. Therefore, the PetroChem did not expect obstacles and delays in getting construction permit for the new plant since its location is in chemical park (industrial zone) and the project was about extension of the existing installation, which has proper safety record, clearly supportive in terms of the credibility of the applicant. However, due to the authority's standpoint that no construction permit will be issued before the applicant revises safety report and proves that prevention and mitigation of major accidents are not seriously deficient, it was necessary to explore this modified understanding of the general licensing procedure. Namely, solely in terms of a concrete land-use plan and Seveso II related regulation the authority had no legal basis for not issuing requested permit to PetroChem. Exploration of the

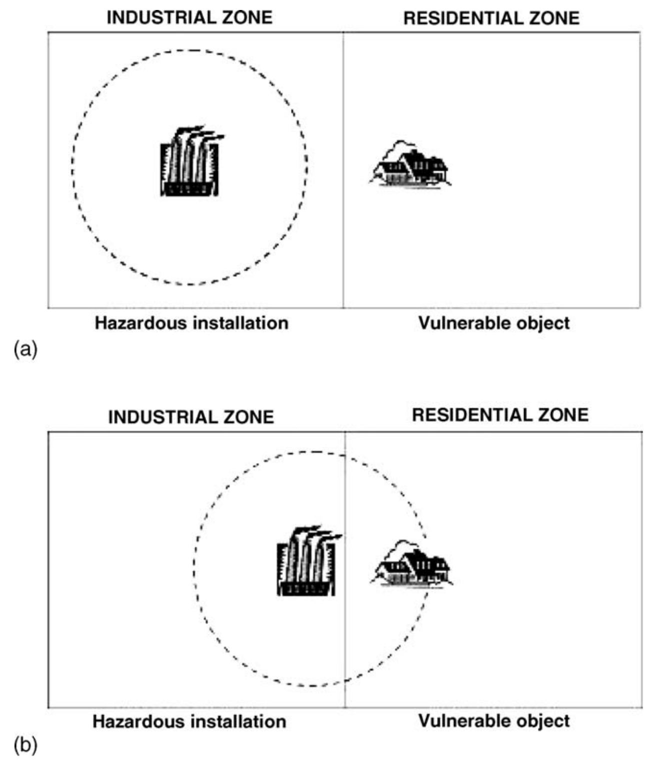

Fig. 1. Illustration of a common conflicting situation, which occurs due to isolated licensing processes; the source of a problem is not a land-use zoning policy: (a) no conflict and (b) conflicting situation.

issue revealed that the authority uses generally prescribed content of the safety report as the main and only criteria for evaluating safety compliance. Since this is clearly a vague approach it has been concluded that the authority acts semi-legally. In spite of that recognition, the PetroChem decided to meet regulator's requirements as defined in [1,2].

The problem of inconsistent understanding of the land-use planning around hazardous installations and related licensing remains. One of the reasons seems to be that implementation of a plan is interchanged with planning. Such a conclusion stems from a number of suggestions, proposals, models on how to solve existing or potential conflicting situations as illustrated in Fig. 1 [12,14–21]. Namely, the cited cases treat the problem of precise land-use planning related to hazardous installations after zoning is already established, i.e., after the general land-use plan has already been approved. Basically, the proposals provide ideas on micro-siting inside the zones. Such an approach, especially if associated with the licensing process, should not be treated as a component of the land-use planning process, but as its implementation stage. On the other hand, it is clear that there exists a strong need for additional hierarchical step in land-use planning associated with hazardous installations, which would serve as intermediate control and guidance in terms of reducing risk from existing installations. The main reasons why licensing should not be treated as a part of the land-use planning process are the following:

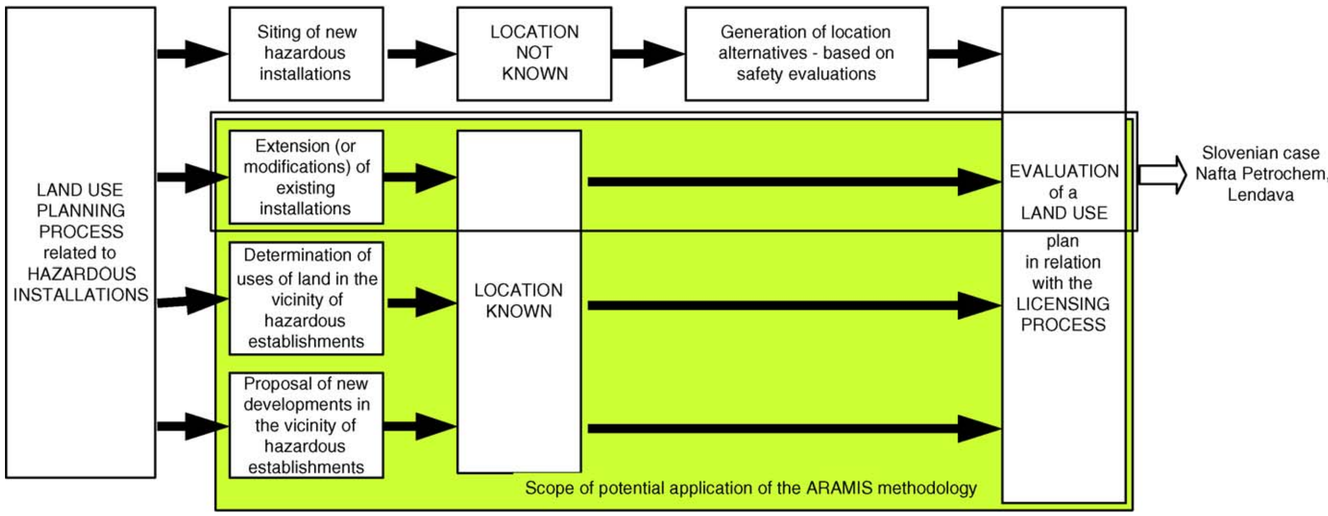

Fig. 2. Illustration of the applicability of the ARAMIS methodology in solving licensing and land-use issues of hazardous installations.

- Licensing means that a development project is in its final stage. No investor would start the licensing process during preparation of a new land-use plan, i.e., without assuring that proposed location for the project is in accordance with the approved land-use plan.
- Implementation of the concept of proper safe distances is possible only if a hazardous installation is specified, i.e., if impact/risk area can be determined. This works only for existing installations and those for which licensing process is taking place. Namely, at the level of preparing new zoning (land-use) plan precise information on new hazardous occupants of the zones are not available so the concept of proper distances based on accurate risk assessment is not possible at this stage. However, certain modifications of the existing land-use plans in terms of changing dimensions of the zones due to existing or new installations are theoretically possible; one should be aware that this is difficult to achieve in practice due to different interests of the neighbouring users of land, which makes negotiation process exhausting.

Potential of the ARAMIS methodology to support solving of these issues is depicted in Fig. 2. The PetroChem case serves as the first experience related to extension of the existing establishment. Others are still to be checked. The illustration takes into account relevant guidance of the Seveso II Directive and [22,23].

As regards the siting of new installations we believe that environmental vulnerability feature of the ARAMIS methodology could be successfully combined with the wider concept of strategic environmental assessment described in [24,25]. The core of this approach is optimisation of siting through generation of zoning and specific site alternatives at the level of land-use planning. The idea has been briefly presented in [14] in association with natural hazards and sustainable urban development in northern Italy; further efforts are needed to make the concept fully transparent and operational.

At the end, it seems worthwhile to mention that an additional exercise has been done in the context of presenting transparency of the ARAMIS methodology. Comparison was made among the QRA, Rapid Risk Assessment (RRA) [26] and SPIRS. These have been selected based on a study, which has been commissioned by the Slovenian authority responsible for the implementation of the Seveso II Directive in 2002. The aim of the study was to get answer to the question "Which risk assessment method among the following three is the most appropriate for Slovenian Seveso II establishments: QRA, RRA or SPIRS?" The results of the study are available in [27,28]. They show that RRA is proper method for risk screening purposes only and is not well informative in terms of consequences and frequencies of an accident. Similarly, SPIRS is aimed for comparing purposes among Seveso establishments at the EU level and does not serve well as a self-explaining methodology for a single installation. QRA reveals as the most suitable method among the three for the above stated purpose and as the only method, which provides inputs for defining risk reduction measures.

Finally, it can be concluded that the ARAMIS methodology is more transparent compared to the QRA in the component of the evaluation of Safety Management System, since it explicitly takes into account safety behaviour. This is important in the view of expressing trust into a particular SMS in an auditable way. In addition, the ARAMIS methodology uses environmental vulnerability in a traceable manner, which contributes to clear interpretation of final risk evaluation results.

4. Conclusion

The paper exposed a problem of issuing construction permit for a Seveso II plant in the situation where no quantitative safety standards are available. We demonstrated effectiveness of the ARAMIS methodology in building trust into

SMS and MAPP in such a licensing situation. The approach proved beneficial—the ARAMIS methodology obviously has potential for assisting in solving issues of trustworthy of risk assessment. Since land-use planning and licensing process are interrelated it remains to be checked whether the ARAMIS methodology is also powerful in supporting risk informed land-use planning on strategic, i.e., zoning level. For existing installations *M* index coupled with auditing of safety barriers in a life cycle approach, and environmental vulnerability, both integral features of the ARAMIS methodology, are supportive in the context of micro-siting inside the land-use zones.

Acknowledgments

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References

[1] Letter by the Ministry of the Environment, Spatial Planning and Energy sent to Nafta Petrochem d.o.o., 20 June 2003.

[2] Letter by the Ministry of the Environment, Spatial Planning and Energy sent to Nafta Petrochem d.o.o., 2 February 2004.

[3] F.I. Khan, T. Husain, S.A. Abbasi, Safety Weighted Hazard Index, Trans. IChemE Part B Inst. Chem. Eng. 79 (2001) 65.

[4] F. Lees, Loss Prevention in the Process Industries, Hazard Identification, Assessment and Control, vol. 2, second ed., 1996.

[5] Guidelines for Major-Accident Hazard Identification and Risk Assessment, Project: Planning for Emergencies Involving Dangerous Substances for Slovenia, 360006-23-RP-101, 2001.

[6] DNV PHAST, Version 6.1, Det Norske Veritas, http://www2.dnv.com/software/.

[7] FaultTree+, Version 10.1, Isograph Software, www.isograph-software.com.

[8] J.C.H. Schueller, Methods for Determining and Processing Probabilities "Red Book", CPR 12E, second ed., Committee for Prevention of Disasters, 1997, ISBN 90-12-08543-8.

[9] Risk*Assistant for Windows, Version 1.1, The Hampshire Research Institute, Inc., Alexandria, VA, USA, 1995.

[10] Refer to ARAMIS project web site http://aramis.jrc.it.

[11] M. Demichela, N. Piccinini, A. Romano, Risk analysis as a basis for safety management system, J. Loss Prevent. Process Ind. 17 (2004) 179–185.

[12] H.C. van Latesteijn, A policy perspective on land use changes and risk assessment, Agric. Ecosyst. Environ. 67 (1998) 289–297.

[13] SHAPERISK WP3 Discussion Document on Available ToPSIS, http://shaperisk.jrc.it.

[14] G. Spadoni, D. Egidi, S. Contini, Through ARIPAR-GIS the quantified area risk analysis supports land-use planning activities, J. Hazard. Mater. 71 (2000) 423–437.

[15] M. Besio, A. Ramella, A. Bobbe, A. Colombo, C. Olivieri, M. Persano, Risk maps: theoretical concepts and techniques, J. Hazard. Mater. 61 (1998) 299–304.

[16] I.A. Papazoglou, Z.S. Nivolianitou, G.S. Bonanos, Land use planning policies stemming from the implementation of the SEVESO-II Directive in the EU, J. Hazard. Mater. 61 (1998) 345–353.

[17] S. Batterman, E. Kovacs, Threshold quantity criteria for risk management programs: recommendations for toxic releases, J. Hazard. Mater. A105 (2003) 39–60.

[18] G.M.H. Laheij, J.G. Post, B.J.M. Ale, Standard methods for land-use planning to determine the effects on societal risk, J. Hazard. Mater. 71 (2000) 269–282.

[19] I.A. Papazoglou, G.S. Bonanos, Z.S. Nivolianitou, N.J. Duijm, B. Rasmussen, Supporting decision makers in land use planning around chemical sites. Case study: expansion of an oil refinery, J. Hazard. Mater. 71 (2000) 343–373.

[20] O. Salvi, N. Rodrigues, S. Descourriere, D. Gaston, Risk assessment and decision making related to land-use planning in France, loss prevention and safety promotion in the process industry, in: 11th International Symposium Loss Prevention, Praha Congress Center, 31 May–3 June, 2004.

[21] B. Rasmussen, I. Bertelsen, V. Burchard, P. Christensen, N.J. Duijm, C.D. Groenberg, F. Markert, Multi-Objective Decisions in Land Use Planning Involving Chemical Sites, Risoe National Laboratory, Rorkilde, Denmark, 1999.

[22] M.D. Christou, M. Mattarelli, Land-use planning in the vicinity of chemical sites: risk-informed decision making at a local community level, J. Hazard. Mater. 78 (2000) 191–222.

[23] M.D. Christou, A. Amendola, M. Smeder, The control of major accident hazards: the land-use planning issue, J. Hazard. Mater. 65 (1999) 151–178.

[24] R. Therivel, et al., Strategic Environmental Assessment, Earthscan, London, 1992.

[25] B. Sadler, A framework for environmental sustainability assessment and assurance, in: J. Petts (Ed.), Handbook of Environmental Impact Assessment, vol. 1, Blackwell, Oxford, 1999.

[26] Manual for the classification and prioritisation of risks due to major accidents in process and related industries, Inter-Agency Programme on the Assessment and Management of Health and Environmental Risks from Energy and Other Complex Industrial Systems, IAEA-TECDOC-727, Rev 1, 1996.

[27] Ministry of the Environment, Spatial Planning and Energy, web address with reports in Slovene only: http://www.sigov.si/mop/podrocja/uradzaokolje_sektorokolje/nevarnosti_velikihnesrec/studije/primerjalna.htm.

[28] M. Gerbec, B. Kontić, D. Kontić, How much are SPIRS, IAEA's RRA and common QRA complementary in the context of Seveso II directive? in: 11th International Symposium Loss Prevention and Safety Promotion in the Process Industries, Loss Prevention Praha, Czech Society of Chemical Engineering, 2004, pp. 1449–1456.