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ARATech2013 – a Web-based Tool for Risk Assessment

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The risk assessment analysis is perceived as the most important stage in preparation of the major accident prevention documentation in accordance with the Directive 96/82/EC. The risk assessment alone is a complex process and several procedures and their modifications have been developed in practice, using various approaches to the task. ARAMIS (Accidental Risk Assessment Methodology for IndustrieS) methodology (Hourtlou, Salvi, 2003, ARAMIS, 2004) has been developed in order to unify the approach to risk assessment for major accidents and their impact on the environment.
Project ARATech2013 – a tool for major accidents risk analysis, has been established with the aim to transform ARAMIS complex procedures into a software tool, which will simplify and make the risk assessment techniques more readily accessible. It is the coherence of the ARATech2013 tool and the number of prearranged and recommended steps that provide the wider user base with a useful alternative to the commonly used and often technically and methodologically challenging deterministic and probabilistic approaches used for risk assessment.
ARATech2013 is a web-based modular tool, which enables to alternatively expand the functionality of the tool or gives its users the option to follow a simple pre-selected pathway without having to follow the entire major accidents risk assessment process. The tool is based on the following three core modules:
- risk source assessment module,
- representative scenarios determination module,
- accident impact assessment module.

The risk source assessment module presents the initial stage of the risk analysis process. The users use the module to establish the basic information about the facility, i.e. a list of all types of equipment containing hazardous substances, physical - chemical properties of hazardous substances, their physical state and amount. The application automatically identifies the potentially hazardous equipment to undergo further detailed analysis and matches this equipment with appropriate potential critical events. The user is provided with an ability to add supplementary information for determination of potential domino effects.
The representative scenarios determination module computes the frequency of various hazardous effects for the determined critical events. Each critical event is automatically assigned generic fault trees (Fault Tree Analysis - FTA) and event trees (Event Tree Analysis - ETA), which can be further modified by the user to match the real situation in the given establishment. The user has the option to use a generic frequency for each critical event or to determine the frequency using the in-built Fault Tree Analysis. The module offers a database of complex check lists of safety functions and barriers, which the user can assess and apply individually to each fault or event tree. This makes the tool highly valuable for assessing the effectiveness of risk management systems.
The accident impact assessment module is an independent module for modelling of the hazardous event and the spatio-temporal distribution of hazardous effects. The model distinguishes among the different types of release of the substance from the equipment, the consequent cloud formation and its dispersion with the toxic, radiative or pressure effects. The module is interlinked with a web mapping portal for a quick projection of the impact of the hazardous event.

1. The tool justification

The ever increasing use of hazardous chemical substances leads to an increased probability of major accidents with potentially serious and in some cases cross-border consequences. This intinsifies the need for

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establishment of suitable preventive measures that ensure high level of prevention and protection of humans, communities and environment in the Czech Republic and within the EU.

The fundamental requirements for major accidents preventions are defined by the “SEVESO” legislation, i.e. the directive 96/82/ES and more recently directive 2012/18/EU. The requirements have been implemented into the Czech legislation within a bill, legal regulations and several methodological guidelines. These documents follow current global trends toward safety improvements, especially in the risk analysis aspect.

The risk assessment alone is a complex process and several procedures and their modifications have been developed in practice, using various approaches to the task. Project ARATech2013 – a tool for major accidents risk analysis has been established with the aim to increase the hazard prevention effectiveness and to reduce the unnecessary administrative burden within. The project was co-funded by the 2007-2013 OPE (Operational Programme Environment), a useful alternative to the deterministic and probabilistic approaches used for risk assessment. The tool is derived from the widely accepted methodology ARAMIS, whose aim is to reduce the inconsistency and uncertainty and to include the assessment of management effectiveness in the risk analysis. The methodology, with modifications, complies with the requirements and methodologies within the Czech legislative framework.

Along with the relatively complex ARAMIS methodology, the tool developers used their own know-how acquired during long-term practice in major hazard prevention documentation, studies and related projects. Their main aims were to:

- Offer a harmonised methodology and thereby reduce the uncertainty in risk assessment,
- Provide an efficient compliance tool with SEVESO directive,
- Enhance the risk assessment by considering the existing safety measures and level of risk management,
- Assess the risks by integrating the severity of consequences, risk management effectiveness and vulnerability of the environment.

2. Interface selection

The project team decided to provide the software tool as a web-based application. This enables to use the tool without a need for software installation and also supports the developer’s ability to update the tool at any time. The users can access the tool via a web browser and internet connection. The software is currently provided in 3 languages (Czech, Slovak and English). The aim was to provide a modular tool that enables a simple intuitive operation as shown on Figure 1.

Figure 1: ARATech2013 homepage offers the users a choice of language and its simple structure enables easy navigation and access to the individual modules.

3. Logical framework of the ARATech2013 software tool

The following three main areas and their associated actions outline the logical procedure through the application ARATech2013.

- Consequence severity assessment (S – severity index),
- Risk management effectiveness assessment (M – management index),
- Environment vulnerability assessment (V – vulnerability index).

Each index can be assessed independently of the others, yet substantial interconnection can be found within the S and M index determination since both involve selection of reference scenarios and assessment of the consequence severity. In both cases, efficient risk management measures can influence the frequency of a potential accident or reduce the impact of its consequences. The interdependence is demonstrated in Figure 2.

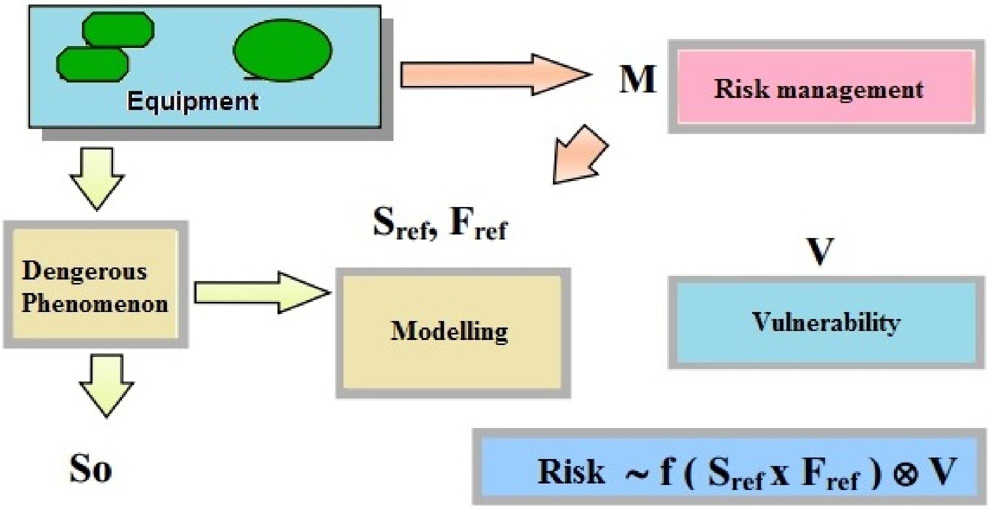


Figure 2: Outline of the logical procedure through the application ARATech2013.

3.1 Data collection about the organisation and facility containing a hazardous substance

Organization and their relevant facilities are identified in the first step, such as the company name and basic administrative information. ARATech2013 has been linked to an information system ARES (administrative register of economical subject in the Czech Republic) to simplify the company information data entry. Other important information is the identification of the type of facility/equipment containing a hazardous substance (e.g. storage or process unit, what kind of substance, its physical state and amount). This initial data creates a visual image of the real facility within the web-based application ARATech2013.

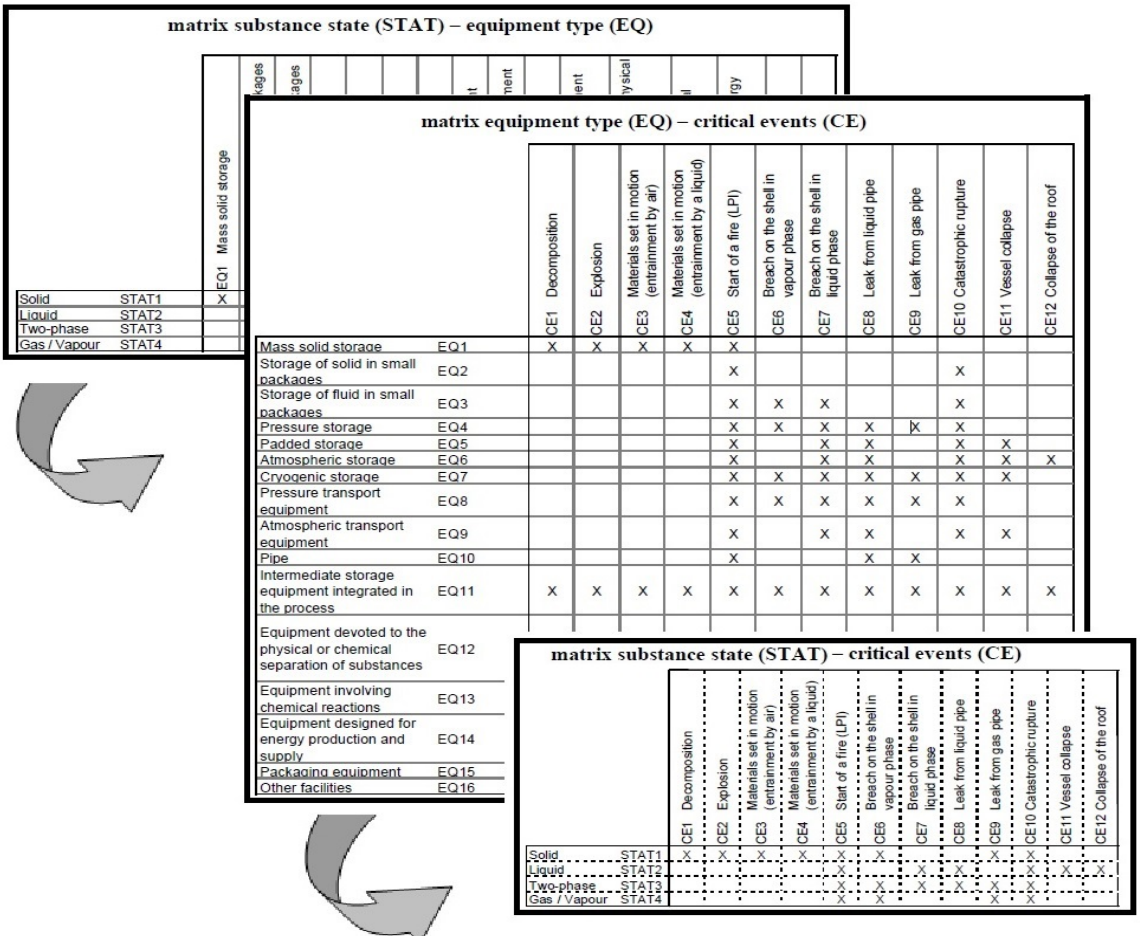
3.2 Identification of potentially hazardous equipment

Selection of hazardous equipment for detailed assessment is a fundamental step in any risk analysis. Here ARATech2013 uses a selection method derived from the Belgian “VADE MECUM” methodology (Vade Mecum, 2000), which is also used in the ARAMIS methodology. Based on a mass analysis the ARATech2013 application automatically identifies all potentially hazardous equipment. The methodology compares the quantity of a substance in the given equipment with threshold quantities determined based upon its hazardous properties, its physical state and locations with respect to other hazardous installations.

The ARATech2013 application enables the users to add supplementary information for further assessment in cases where the mass analysis classifies the facility as non-hazardous, yet it contains hazardous substances with a potential for domino effect.

3.3 Critical events determination

The hazardous equipment identified in the previous step is subjected to an assessment in accordance with the MIMAH methodology (Methodology for the Identification of Major Accident Hazards) (ARAMIS, 2004). This step provides the users with generic accident scenarios considered as the worst possible scenarios. This critical events determination is generated in ARATech2013 based on three generic matrices. These matrices are embedded in the application database and do not require any input from the user with regards to potential critical scenarios for the given equipment (illustrated in Figure 3).



matrix equipment type (EQ) – critical events (CE)

		CE1 Decomposition	CE2 Explosion	CE3 Materials set in motion (entrainment by air)	CE4 Materials set in motion (entrainment by a liquid)	CE5 Start of a fire (LPI)	CE6 Breach on the shell in vapour phase	CE7 Breach on the shell in liquid phase	CE8 Leak from liquid pipe	CE9 Leak from gas pipe	CE10 Catastrophic rupture	CE11 Vessel collapse	CE12 Collapse of the roof
Mass solid storage	EQ1	X	X	X	X	X							
Storage of solid in small packages	EQ2					X					X		
Storage of fluid in small packages	EQ3					X	X	X			X		
Pressure storage	EQ4					X	X	X	X	X	X		
Padded storage	EQ5					X		X	X		X	X	
Atmospheric storage	EQ6					X		X	X		X	X	X
Cryogenic storage	EQ7					X	X	X	X	X	X	X	
Pressure transport equipment	EQ8					X	X	X	X	X	X		
Atmospheric transport equipment	EQ9					X		X	X		X	X	
Pipe	EQ10					X			X	X			
Intermediate storage equipment integrated in the process	EQ11	X	X	X	X	X	X	X	X	X	X	X	X
Equipment devoted to the physical or chemical separation of substances	EQ12												
Equipment involving chemical reactions	EQ13												
Equipment designed for energy production and supply	EQ14												
Packaging equipment	EQ15												
Other facilities	EQ16												

matrix substance state (STAT) – critical events (CE)

		CE1 Decomposition	CE2 Explosion	CE3 Materials set in motion (entrainment by air)	CE4 Materials set in motion (entrainment by a liquid)	CE5 Start of a fire (LPI)	CE6 Breach on the shell in vapour phase	CE7 Breach on the shell in liquid phase	CE8 Leak from liquid pipe	CE9 Leak from gas pipe	CE10 Catastrophic rupture	CE11 Vessel collapse	CE12 Collapse of the roof
Solid	STAT1	X	X	X	X	X	X			X	X		
Liquid	STAT2					X		X	X		X	X	X
Two-phase	STAT3					X	X	X	X	X	X		
Gas / Vapour	STAT4					X	X			X	X		

Figure 3: Procedure for determination of critical events.

3.4 Butterfly diagram generation

ARATech2013 application database contains generic fault trees and event trees for the individual critical events identified using the MIMAH methodology. These can be modified by the user to reflect the real situation in the given facility. Just like in the actual FTA and ETA analysis, branches can be added, removed or modified based on the user's input, yet in already pre-edited clear graphic form. The logical gates OR and AND are incorporated in the generic trees in accordance with ARAMIS methodology (ARAMIS, 2004), which are further used for calculation of the hazardous event probability. These gates also serve as logic safeguards during modification of the generic butterfly trees so as to avoid omitting some simultaneously occurring events.

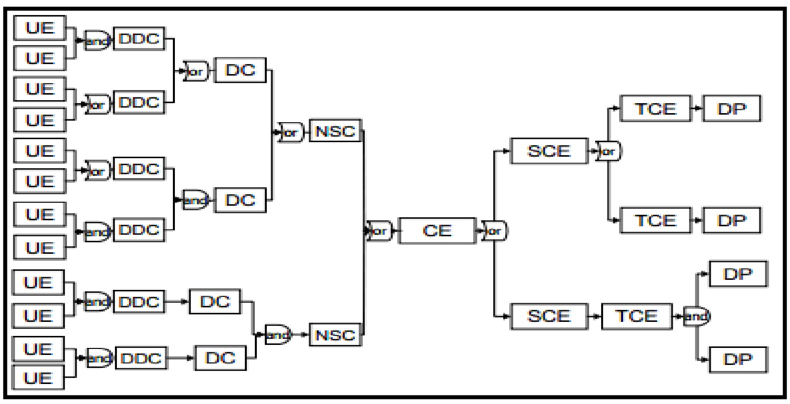


Figure 4: A typical result presented as a butterfly diagram.

3.5 Determination of probability of the critical events and their hazardous impacts

The probability of critical events, based on the generated butterfly diagrams, is calculated according to the MIRAS methodology (Methodology for the Identification of Reference Accident Scenarios) (ARAMIS, 2004), derived from previous risk assessment analyses. ARATech2013 users have two options for determination of critical event frequency. The first option is to use a generic critical event frequency included in the application's appendix, which contains values derived from a homogenous data set used in the ARAMIS methodology. Caution should be exercised when using these values and these should not be modified as the user "sees fit". The other alternative is to determine the frequency using the generated fault tree, where the user can take into account the actual safety system of the given facility. While more time-demanding, the latter provides more accurate and detailed assessment. The fact that the critical event frequency is mostly dependent on the user's expertise is an indisputable advantage of the ARATech2013 application.

3.6 Risk management assessment

The risk management efficiency can also be assessed using ARATech2013 application (M – management index). Risk reduction measures (barriers) are implemented into the butterfly diagrams, which further enables to remove the branches with insignificant impact or which are sufficiently protected by the barriers. The aim is to analyse and asses the efficiency of the safety barriers and their functionality within the given facility. In order to simplify the assessment process the ARATech2013 application contains comprehensive checklists of safety functions and barriers. The user selects a suitable safety measure and individually assesses its efficiency and reliability based on the real situation. Here ARATech2013 offers yet another tool in form of a methodological guide retrievable directly from the application.

The assessment of hazardous impacts frequency leads to a determination of real reference scenarios, which are further assessed from the environmental vulnerability perspective.

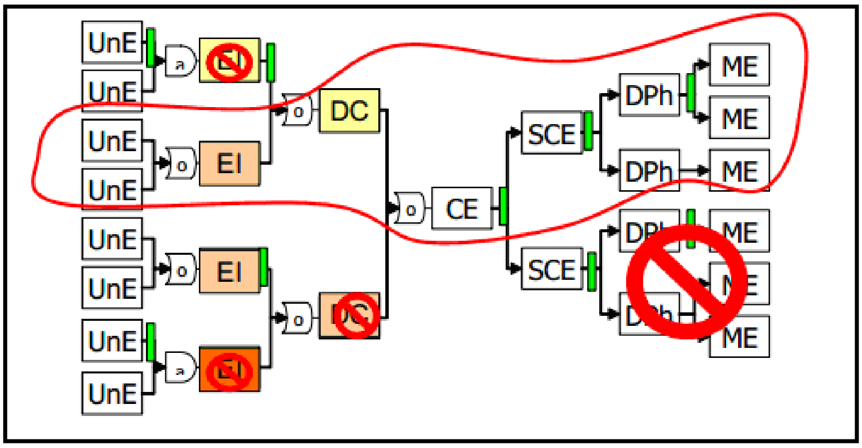


Figure 5: A modified butterfly diagram after the implementation of risk reduction measures.

3.7 Environmental vulnerability assessment

ARATech2013 provides ideal platform for classification of consequences of reference scenarios into the respective classes. The consequence classes are defined based on the impact on humans, animals, property, and environment and taking into account the possibility of domino effect. While the final classification ultimately relies on the user's expert judgement, ARATech2013 provides the user with a tool for more accurate classification using modelling of the extent of the accident scenarios. This step is not included in the ARAMIS methodology. Based on their own experience, the ARATech2013 developers' team decided to include this module as a suitable tool for obtaining more realistic data for risk assessment. The accident impact modelling is based on a mathematical apparatus, which provides complex description of the entire time course of a representative accident event and which enables to quantify the spatio-temporal distribution of its impacts. Using the physical-chemical properties of the hazardous substance (flammable, toxic, explosive), type of release (instantaneous, continuous), atmospheric conditions, topography and other parameters, the model distinguishes between various means of substance release, subsequent cloud formation and its dispersion with a resulting intoxication, explosion pressure wave impact or fire heat radiation. Toxic substance release is classified based on the extent of the toxic cloud of a selected concentration. Explosive substance releases are classified based on the extent of the pressure wave of a given pressure, or extent of the zone with danger to people in contact with the flame. Flammable substances are classified based on the effects of heat radiation on people and structural elements.

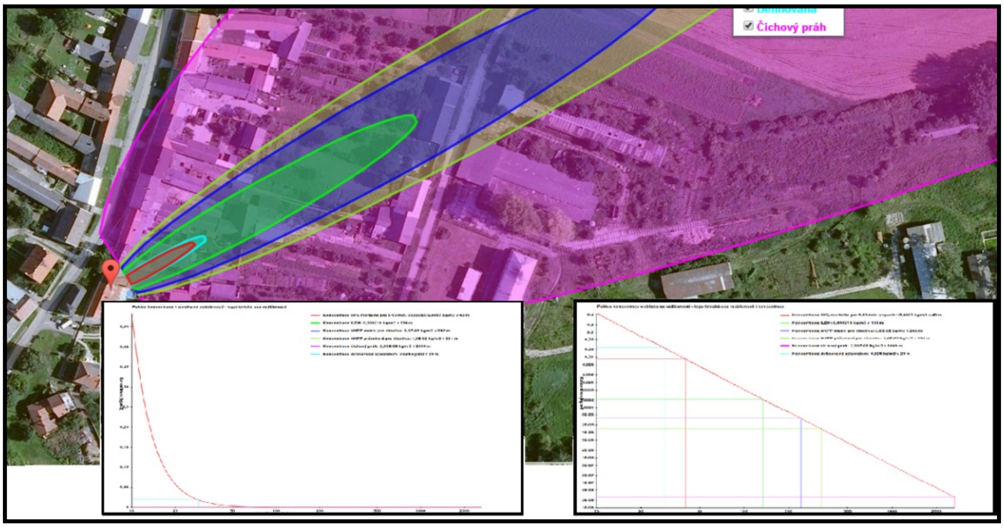


Figure 6: An example of graphical modelling of the impact of toxic substance release.

The acceptability of accident scenarios is assessed using the risk matrix, which compares the class of consequence on the x-axes with the frequency of occurrence of the hazardous phenomena taking into account the safety barriers on the y-axis. The matrix defines three risk zones – unacceptable, residual and negligible.

4. Conclusion

This paper provides a brief description of the main features of a new web-based application ARATech2013. The software has been developed to provide a tool for assessment of existing safety documentation by the Czech government authorities and for development of new safety documentation in facilities handling hazardous substances.

ARATech2013 is modularly structured software, which enables the developers to further expand the application with other modules related to the major accidents prevention topic. New projects are already undergoing approval process that will expand the application for mathematical modules that will facilitate the assessment of human reliability, improve the predictability of the environmental impact of major accidents or the economic impacts of industrial accidents. Regardless of the approval, the team is continuously expanding the database of physical-chemical parameters of hazardous substances within the existing tool.

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