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RISK ASSESSMENT AND TREATMENT IN ACCIDENTS PREVENTION

Abstract: This education material is determined for those students and employees who deal with security and safety engineering and crisis management, but especially with the prevention of industrial accidents. It can furthermore be utilized in companies which aim at risk assessment for fulfilling regulation requirements, risks in managing the continuity of operational processes or detecting security at the workplace from the point of view of safety and protection of health at work.

Key words: risk assessement, risk treatment, industrial accident, prevention, hazardous substance, Seveso

1. RISK ASSESSMENT AND INDUSTRIAL PROCESSES

1.1. Introduction

Every manufacturing enterprise, service company, or transporter wants to be successful. Their goal is to increase prosperity through production or services. Industrial risks are very closely linked with the technological processes and equipment which have become the subject of assessment and solution as well as permanent monitoring from the side of the companies and selected bodies of the state administration. Perceiving and being aware of the need for prevention against the rise of crisis phenomena is very important for society as well as for the legal entities and natural persons. Ignoring and/or paying insufficient attention to the risks could bring negative consequences for all participating parties.

Technological progress brings mankind face to face with sophisticated and dangerous technologies which can be a source of dangerous situations or industrial calamities. The tragic disasters of Chernobyl, Seveso, Flixborough, Bhopal and many others prove the failure or incorrect usage of technological processes or their elements. Although the probability of the rise of these events was very low, their real consequences were huge.

The manufacturing enterprises working with risk technologies have to deal with systematic and complex risk management. Its part is the risk assessment which this studying material is dealing with. The preparedness of companies for the prevention of industrial disasters in the European Union, as well as abroad, cannot be achieved without a high level of expertise in the people making decisions and the analysts assessing the risks. At present there are several possible approaches to risk assessment which differ, not only from the point of view of the terminological terms of the individual phases, the sequence of steps, but also from the point of view of the content itself.

1.1.1 Industrial Accidents prevention in European Union

The European Union has been solving the society-wide area of preventing the major industrial accident which can threaten the environment and life, health and the property of the EU citizens through its centres Join Research Centre and Major Accident Hazards Bureau as well as selected institutions of the EU member states and belongs to one of the public security research. For carrying out these regulations and rules which adapt the area of the major industrial accident prevention in the individual EU states, the SEVESO directive was issued in 1982 and it has been amended for several times since then (1996 and 2003). Due to the changes during the first five years the responsible bodies in this area decided about amending this directive also in 2012 and directive SEVESO III was adopted in all EU Member states in 2015. [1]

This problem is being solved by the EU by creating the databases (MARS and SPIRS) and from this fact resulting lessons learned and corresponding legal environment in the framework of the SEVESO directives.

All major industrial accidents are thus recorded in the database eMARS. This Major Accident Reporting System (MARS) was established to handle the information on 'major accidents' submitted by Member States of the European Union to the European Commission in accordance with the provisions of the 'Seveso Directive'. Currently, MARS holds data on more than 450 major accident events. [1]

The figure 1 shows a ten-year overview according to the classification type of events that has happened in European union and are recorded in eMARS database.

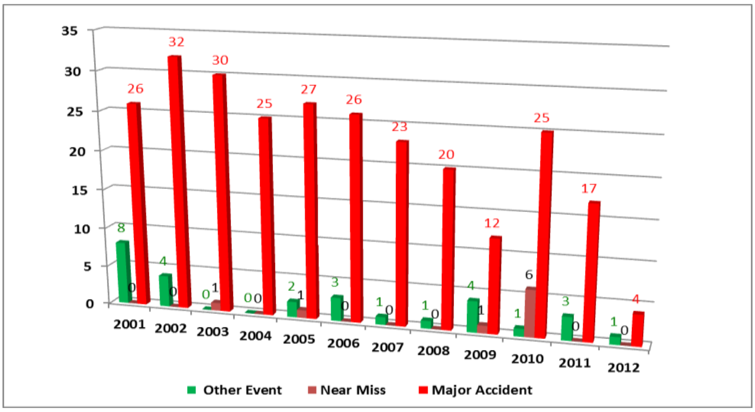

Figure1 Events types in eMARS 2001-2012 [2] [4]

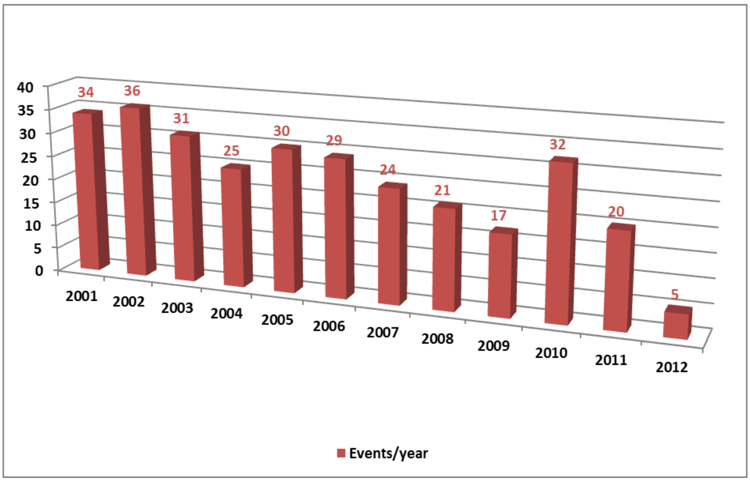

Figure 2 No. of events 2001- 2012 [2] [4]

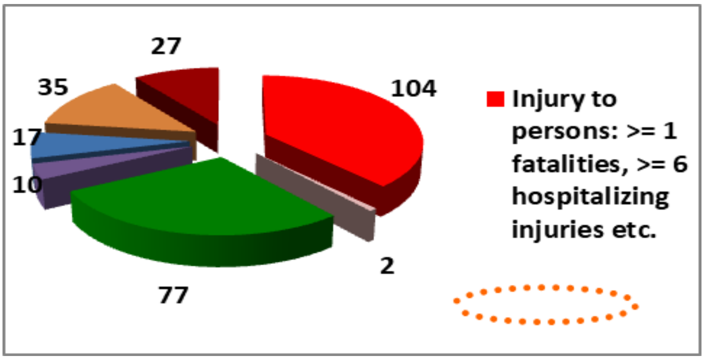

Figure 3 Reasons for reporting [2] [4]

Based on the figures 1, 2 and 3 it is impossible to estimate the development of the rise of major industrial accidents in the next time period. The main reason is especially the fact that the rise of this kind of crisis phenomenon is not easy to foresee especially because the basic cause of the rise of major industrial accidents is the element that is very difficult to anticipate – human factor.

In spite of the maximal effort exerted for prevention, the major industrial accidents still occur. It is always necessary to take lessons from this accident. As to the system MARS new lessons learned from recent industrial accidents in this database have been as follows:

- explosion in an ammunition dismantling facility (Production and storage of explosives),
- release of toxic substance - Mining activities (tailings & physicochemical processes),
- fire at a dry-goods warehouse (Wholesale and retail storage and distribution),
- mobile vacuum tank explosion Petrochemical / Oil Refineries,
- accident in an oil refinery Petrochemical / Oil Refineries. [3]

We can mention one example of fatal Accident 15th of March in2012 in Mining Company in Finland: a worker died after breathing in hydrogen sulphide while working in the yard.

Figure 4 Finland Mining company

This company has ore mining activities and started in October 2008 and is mining nickel, zinc, cobalt and copper**.** Enrichment method used in this Upper tier establishment is bioheap leaching (first time in use in Finland on this scale)**.** The resulting solution treated by hydrogen sulphide at the metals recovery plant**.**

The accident happened in this SEVESO establishment and one worker died when collecting samples. The big problem was that worker had not used a gas meter or a gas mask and high concentrations of hydrogen sulphide (50 – 300 ppm) were detected in the area before and after the accident. There was also established an accident investigation group and realized that the company has had environmental problems okrem iného. During the investigation process there were a huge interest from the media and Tukes had to prohibit the re-starting of the process.

The main causes of the accident including deficiencies in process safety management were:

- technical reason: A valve in sample collection had been left open,
- overuse of hydrogen sulphide because they wanted a pure end product,
- maintenance was not preventative monitoring the use of hydrogen sulphide was difficult because current measurements and automatic valves did not function,
- all possible leaking points for hydrogen sulphide were not identified,
- reaction to earlier hazards and high concentrations was not adequate,
- gas sensors were inside even though higher concentrations had been noted outside.

European tools

The basic starting point for protecting the interest values of the EU is to ensure the effective prevention in the framework of which the EU creates and utilises:

- the institutional tools,
- the legislative tools.

In the framework of the institutional tools the European Commission created in – house science service called **Joint Research Centre (JRC)** and the part of this centre is **The Major Accident Hazards Bureau (MAHB)**[1] what is a special Unit within the Joint Research Centre's Institute for the Protection and Security of the Citizen, Hazard Assessment Unit, dedicated to scientific and technical support for the actions of the European Commission in the area of the control of Major Industrial Hazards.

2. RISK ASSESSMENT OF INDUSTRIAL PROCESSES

2.1 Risk Assessment in general

Realising the risk assessment requires the presence of at least two persons, i.e. the decision-maker and the analyst. The following questions are to be answered in the phase of planning the analysis:

- What do you want to know (to what questions do you want to get an answer) and why?
- What assumptions (estimations) are acceptable?
- What is the time framework for realising the risk assessment?
- Who will join the process? [1,5]

The main objective of the risk assessment or analysis is to provide the decision-maker with information for a correct decision in an environment full of indeterminateness. In cooperation with the analyst they have to create clearly defined questions which the analysis and risk assessment are to answer. In the introduction it is necessary to aim at the following tasks:

- divide the questions you need to gain the answer to into groups and order them in the sequence from critical to interesting,
- agree on the form of answers with the analyst,
- explain what arguments (decisions) will be based on these outputs,
- check if the analysis of the risks complies with the time schedule and the schedules in the enterprise,

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[1] http://ec.europa.eu/dgs/jrc/index.cfm?id=1450

- check the target group of the analysis – the object of the analysis,
- analyse various negative reactions and circumstances which can be assumed,
- create a time schedule of fulfilling the tasks,
- state priorities,
- determine how often the decision-maker and analysts will meet. [1,5]

It is difficult to characterise the person of the analyst who should assess and analyse. Several character properties and professional qualities are introduced in the text which continues. His/her person should fulfil these attributes:

- creative thinking,
- reliability,
- deliberation,
- the ability to communicate,
- partial mathematical thinking,
- a team spirit,
- impartiality.

The risk assessment is affected by several factors which determine the quality of its realisation. Overpriced and lengthy analyses with a needlessly high number of participants can cause a negative final effect and a devaluation of their results. There are several reasons for which a risk analysis can be wrong and insufficient.

In the book Foundation of Risk Analysis it is said that particularly insufficient data which serves as the input to the analysis and its uncertain character belong among the factors which can threaten the analysis results. The results were summarised based on research from among 39 analysts and introduced in the book Foundation of Risk Analysis. Secondly, it is the insufficient time for carrying out the analysis or the effort to accelerate its execution. Thirdly, according to the research it is the insufficient professional erudition in the area investigated and finally, the insufficient human resources for carrying out the analysis. [7]

Another issue investigated was what threatens the implementation of putting the decisions into practice. Firstly, it was the politics and political decisions. Secondly, it was lack of time for studying the results and correct decision-making. The complexity of the analysis carried out was the third factor and is connected especially with the fact that the responsible decision-maker is not able to make any corresponding decision based on his/her interpretation. Furthermore there were reasons such as a lack of resources for implementing the decisions, the results of the analysis were not acknowledged as being justified, etc. [7]

The mistake of the decision-makers who order the analysis is, according to the research, in particular the fact that they expect too much from it, however, their expectations may not be fulfilled. On the other hand they create sufficiently good conditions for the analysis to be realised, but in the case that the results do not confirm the goal stated they are not willing to also make them accessible for other purposes.

The results could be summarised into a few key areas when we can assume that the analysis will not fulfil the expectations of the decision-maker and analyst:

- if it cannot give answers to all the key questions,
- if too many assumptions (estimations) are in the analysis,
- if not enough data or experts are not available for realising the analysis.

A few assumptions and estimations are stated in every analysis. We estimate the values of the input quantities, the computation models and due to these facts it is possible to confirm that each analysis output is similarly only the most precise estimation which is possible. The goal of development and advance in this area is to provide precision to these estimations permanently, and in this way to increase the probability of correct decisions.

If one or more irresolvable assumptions occur in the analysis and we do not possess sufficient capability for creating only one analysis model, we can create two or three accurate models according to other assumptions. Subsequently these models can be assessed in an effort to state unified assumptions.

Another problem is when the analyst who makes the preliminary estimation is sure at the beginning that the data is accessible. However, over the course of time he/she can discover that the data is not available or it is incorrect and insufficient (this happens frequently), or it is delivered with a delay or it has to be adjusted laboriously for realising the analysis. Based on these circumstances the realisation of the analysis can be prolonged or its results need not be relevant.

2.2 Uncertainty in Risk Assessment

Uncertainty in the area of the decision-making processes is not a new phenomenon. In the conditions of risk management it is connected with the analysis and risk assessment. When we adopt a risk assessment we have to count on the uncertainty as part of the process, both in the qualitative and quantitative phase. *The benchmark studies* showed the increase of uncertainty in the individual phases of risk assessment and also showed the sources and reasons for its rise. The legal framework of crisis management in some countries concerns this area only marginally. It would therefore be necessary to introduce the impacts of uncertainty in the framework of the risk analysis to a greater extent into the legal standards. The sources of uncertainty have been investigated by comparison studies. Their coordinator was JRC in Ispra through three security projects which were created for the conditions of two chemical plants and one nuclear power station. [8]

The JRC in Ispra and the Risq National Laboratory were the coordinators of the projects which showed the acute presence of uncertainty when carrying out the risk analysis, the sources of uncertainty, as well as the fact of how it can affect the final result of the analysis. In the first comparison study seven teams analysed the risk in a chemical plant located at a non-determined place in Europe. Their results, in spite of having the same input data, differed which was caused especially by using various methods and approaches. When identifying the risk sources resulting from realising the analysis, it was discovered that the assessment of the scenarios by the probabilistic and deterministic approach can lead to completely different conclusions.

The comparison study consisted of five main phases: the documentation phase, three working phases and the assessing (enlarging) phase. The working phases included the qualitative and quantitative part – a detailed study of mechanisms of the technological process by case studies. The uncertainty is in this case linked to multiple components, the inspection mechanisms used in the technological process and the interaction between them and the human factor. On the other hand we also consider the uncertainty which is connected with the meteorological and environmental conditions.

In the framework of the aforementioned project the uncertainty was divided into three groups:

- the parametric uncertainty,
- the model uncertainty,
- the overall uncertainty.

The parametric uncertainty results from the variability of the input data for the same event and exponents. **The model uncertainty** can be considered the assignment of uncertainty to a suitable structure or mathematical form of the model. **The overall uncertainty** is a special category of the model uncertainty connected with phenomena determining the method the model was created by.

The results of the risk assessment are sensitive especially to the parameters used in the model as introduced in the previous text. In the case of checking or auditing the analysis realised, most ordering parties of the audit are surprised at the fact that especially the mathematical models and statistical analyses are not subordinate to the check, but those questions are assessed which were asked at the beginning of the analysis (by the decision-maker). It is important to determine if the structure and the object of the analysis are in compliance. The greatest uncertainty of the analysis results from the question of whether we are analysing the right thing and in the correct way.

3. RISK ASSESSMENT IN INDUSTRIAL ACCIDENTS PREVENTION

There are several approaches to the risk management in the industrial environment. This process can be perceived as part of the security and safety analysis which is generally understood as studying the system, identifying the risk sources and dangerous situations in the whole system and their reduction and control. It is a formal title for understandable and systematic investigation of the engineering systems (especially the industrial processes) which can cause injuries of persons, depreciate the property or damage the environment if the stability is lost.

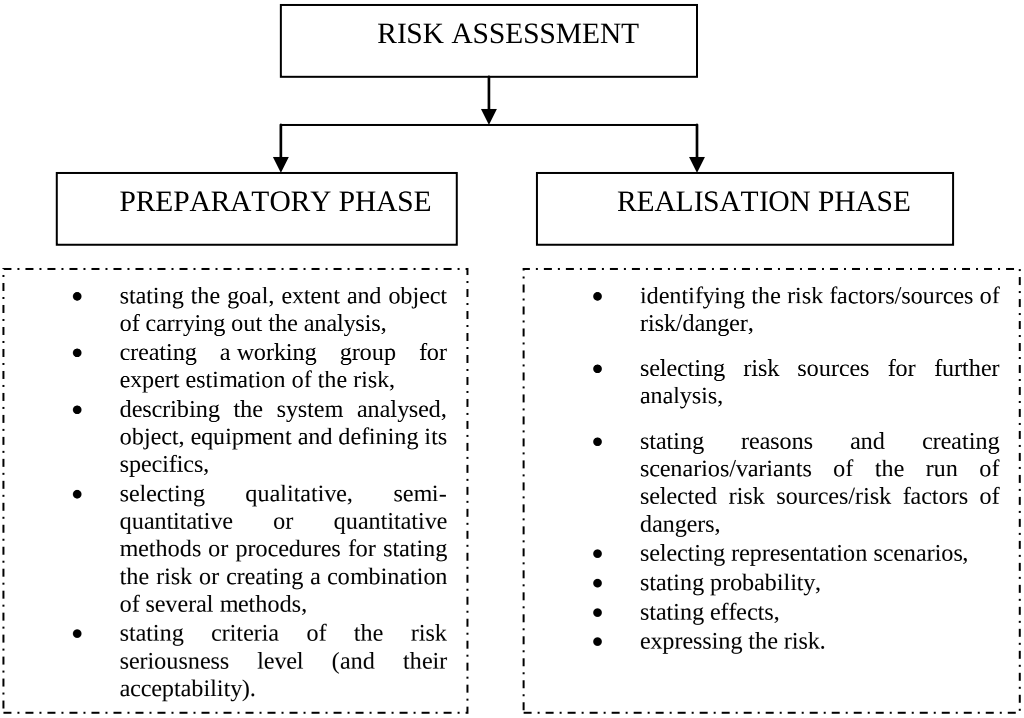
One of the areas utilising the security and safety engineering analyses is also the major industrial accident prevention which is managed by the directive SEVESO III in the EU and the main tool in the prevention framework in this area is the risk assessment. The basic aim is to prevent the rise of a major industrial accident and to assess the risks resulting from utilisation of hazardous substances in the industrial processes. Every member country transposes the directive SEVESO III in its legal environment and in the Slovak Republic the most important guideline is the law No 128/2015 Coll. about prevention of major industrial accidents. Currently there are several systematic approaches which the experts implement into practice, e.g.:

- Probability approach PRA, PSA,
- Quantitative approach QRA, CPQRA (Stoffen, G, 2005),
- Complex approach MOSAR, (Izvercian, K. et al., 2012),
- Complex approach ARAMIS, (Volek, I, 2008), (Hourtolou, D. and Salvi O., 2002),
- QRA and risk analysis software - Phast and Safeti. [1,8]

In the framework of the aforementioned approaches the individual steps make use of the principles of the following selected methods:

- FTA,
- ETA,
- Bow-tie diagram,
- HAZOP, HAZAN,
- What if analysis, Ishikaw diagram,
- FMEA,Check-list analysis,
- PHA. [1,8]

In the further text we will describe a simplified approach to implementing the model which complies with the routine procedures in this area.



- stating the goal, extent and object of carrying out the analysis,
- creating a working group for expert estimation of the risk,
- describing the system analysed, object, equipment and defining its specifics,
- selecting qualitative, semi-quantitative or quantitative methods or procedures for stating the risk or creating a combination of several methods,
- stating criteria of the risk seriousness level (and their acceptability).

- identifying the risk factors/sources of risk/danger,
- selecting risk sources for further analysis,
- stating reasons and creating scenarios/variants of the run of selected risk sources/risk factors of dangers,
- selecting representation scenarios,
- stating probability,
- stating effects,
- expressing the risk.

Figure 5 Simplified approach to risk assessment [1]

The individual phases together with recommended utilisation of the methods and techniques in the individual steps will be explained in the text to come.

Identifying the risk factors/ the risk source/the danger. This phase consists of identifying the following risk factors:

- the list of selected hazardous substances (SHS) (comparison with reference values),
- identifying dangerous devices.

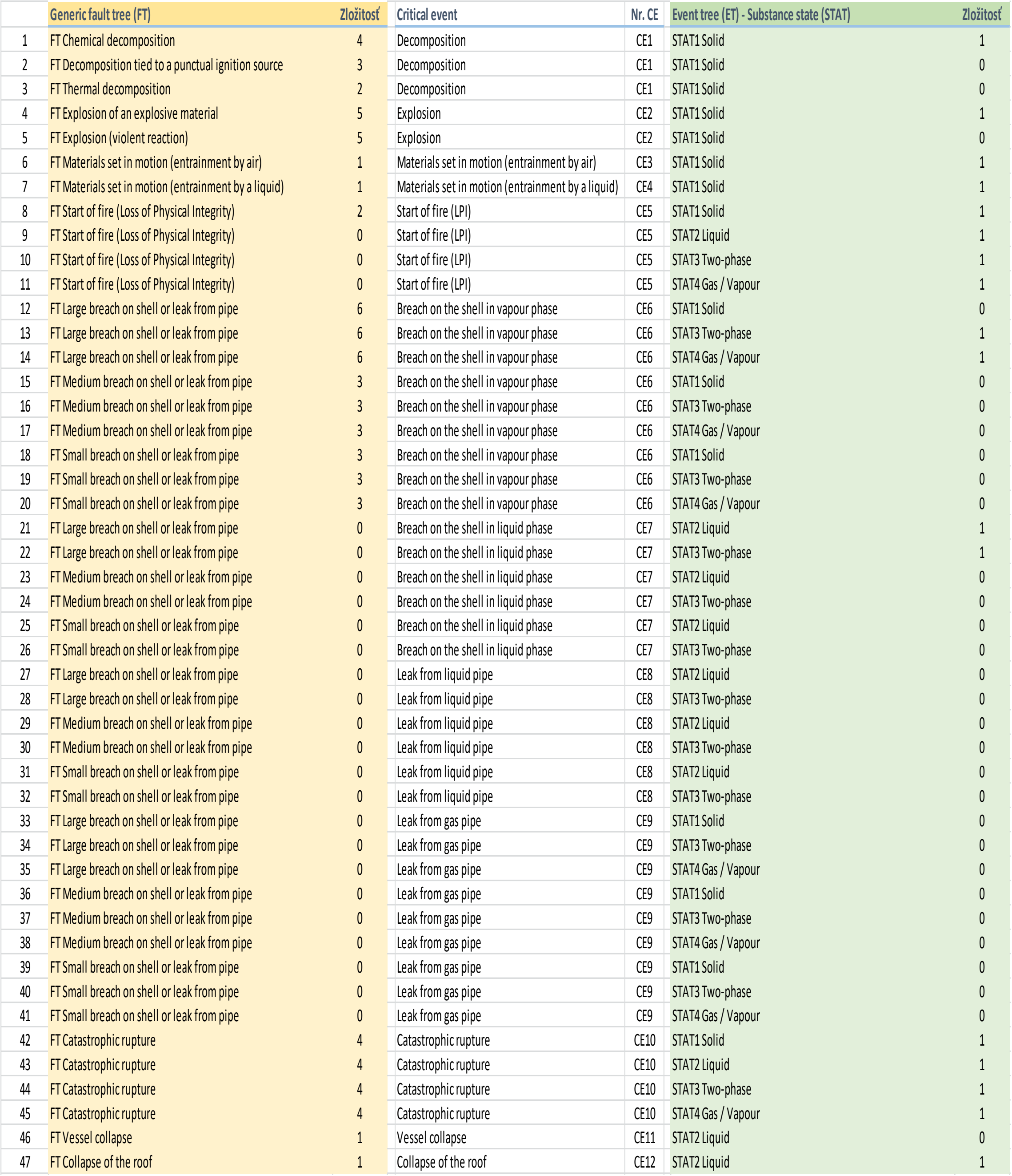
First of all it is necessary to choose those hazardous substances (based on the cards with the security and safety data from the preparatory phase) which can be designated as selected/specified. The SHS are then compared with the existing list of the selected hazardous substances listed by the SEVESO II or SEVESO III Directive. If the selected hazardous substance (according to the corresponding legal regulation) exceeds the reference value introduced in the tables of the law about major industrial accident prevention and shows a dangerous property, the company is categorised into the class A and B.

The list of SHS, which are bound to a particular device, should be the output of this step. The devices are introduced in the table – List of Dangerous Devices – in the ARAMIS methodology and the individual devices are designated from EQ1 to EQ16.

Stating the causes and creating the scenarios/variants of the selected risk sources/ risk factors and dangers. The identified SHS and devices are subsequently attached to critical events:

- Decomposition (CE1),
- Explosion (CE2),
- Materials set in motion – entrainment by air (CE3),
- Materials set in motion – entrainment by liquid (CE4),
- Start of fire (LPI) (CE5),
- Crack of casing in vapour phase (CE6),
- Crack of casing in liquid phase (CE7),
- Leak from liquid pipe (CE8),
- Leak from gas pipe (CE9),
- Catastrophic crack (CE 10),
- Vessel collapse (CE11),
- Roof collapse (CE12). [9]

Subsequently, based on the identified critical events in connection with the SHS and devices, there were created the bow-tie diagrams which are a principal contribution in the area of the major industrial accidents prevention. In the framework of the project solved at the University of Žilina in Žilina there was created software means in the user environment Excel. The basic tree structure was taken over from the ARAMIS and the calculation rules were adapted to the currently used approaches in the Slovak Republic. The selection for implementing barriers to the individual trees was left open; the investigators themselves enter their name as well as the success level. On Figure 6 there are presented created bow – ties within software tool.



	Generic fault tree (FT)	Zložitosť	Critical event	Nr. CE	Event tree (ET) - Substance state (STAT)	Zložitosť
1	FT Chemical decomposition	4	Decomposition	CE1	STAT1 Solid	1
2	FT Decomposition tied to a punctual ignition source	3	Decomposition	CE1	STAT1 Solid	0
3	FT Thermal decomposition	2	Decomposition	CE1	STAT1 Solid	0
4	FT Explosion of an explosive material	5	Explosion	CE2	STAT1 Solid	1
5	FT Explosion (violent reaction)	5	Explosion	CE2	STAT1 Solid	0
6	FT Materials set in motion (entrainment by air)	1	Materials set in motion (entrainment by air)	CE3	STAT1 Solid	1
7	FT Materials set in motion (entrainment by a liquid)	1	Materials set in motion (entrainment by a liquid)	CE4	STAT1 Solid	1
8	FT Start of fire (Loss of Physical Integrity)	2	Start of fire (LPI)	CE5	STAT1 Solid	1
9	FT Start of fire (Loss of Physical Integrity)	0	Start of fire (LPI)	CE5	STAT2 Liquid	1
10	FT Start of fire (Loss of Physical Integrity)	0	Start of fire (LPI)	CE5	STAT3 Two-phase	1
11	FT Start of fire (Loss of Physical Integrity)	0	Start of fire (LPI)	CE5	STAT4 Gas / Vapour	1
12	FT Large breach on shell or leak from pipe	6	Breach on the shell in vapour phase	CE6	STAT1 Solid	0
13	FT Large breach on shell or leak from pipe	6	Breach on the shell in vapour phase	CE6	STAT3 Two-phase	1
14	FT Large breach on shell or leak from pipe	6	Breach on the shell in vapour phase	CE6	STAT4 Gas / Vapour	1
15	FT Medium breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT1 Solid	0
16	FT Medium breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT3 Two-phase	0
17	FT Medium breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT4 Gas / Vapour	0
18	FT Small breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT1 Solid	0
19	FT Small breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT3 Two-phase	0
20	FT Small breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT4 Gas / Vapour	0
21	FT Large breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT2 Liquid	1
22	FT Large breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT3 Two-phase	1
23	FT Medium breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT2 Liquid	0
24	FT Medium breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT3 Two-phase	0
25	FT Small breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT2 Liquid	0
26	FT Small breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT3 Two-phase	0
27	FT Large breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT2 Liquid	0
28	FT Large breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT3 Two-phase	0
29	FT Medium breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT2 Liquid	0
30	FT Medium breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT3 Two-phase	0
31	FT Small breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT2 Liquid	0
32	FT Small breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT3 Two-phase	0
33	FT Large breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT1 Solid	0
34	FT Large breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT3 Two-phase	0
35	FT Large breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT4 Gas / Vapour	0
36	FT Medium breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT1 Solid	0
37	FT Medium breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT3 Two-phase	0
38	FT Medium breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT4 Gas / Vapour	0
39	FT Small breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT1 Solid	0
40	FT Small breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT3 Two-phase	0
41	FT Small breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT4 Gas / Vapour	0
42	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT1 Solid	1
43	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT2 Liquid	1
44	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT3 Two-phase	1
45	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT4 Gas / Vapour	1
46	FT Vessel collapse	1	Vessel collapse	CE11	STAT2 Liquid	0
47	FT Collapse of the roof	1	Collapse of the roof	CE12	STAT2 Liquid	1

Figure 6 List of bow-ties created within Software tool and adapted to Slovak republic conditions [10, 11]

Stating the probability. Based on the created bow-ties for the stated critical event it is necessary to determine the probability/frequency of the causalities which are on the FTA side. The partial frequencies/probabilities of causes are written directly into the created software and relations according to the Boolean algebra re-calculate the frequencies which enter other knots. Also the probability/frequency and barriers in every branch are mutually in an interaction.

According to ARAMIS the frequency of the critical event moves in the range of F0 to F4 – the F0 is attached to the event with the highest frequency and F4 with the lowest one.

Stating the consequences and impacts. In the end, the impacts of an accident are determined (based on the created bow-ties). Before we define them, it is necessary to simulate the development of the crisis phenomenon by appropriate software for us to find out the extent of the hit area. Based on this simulation we subsequently determine the impacts on life, property and environment through the C1 – C4 indicators. [9]

The impact classification is based on the assessment of the effects on human targets and effects on the environment.

Expressing the risk (stating the risk and determining the risk perception acceptability). In the end it is necessary to identify if the stated risk value is acceptable or not. In the Slovak Republic we stated these values as the individual and social risks. [9]

4. CONCLUSION

The risk assessment of the technological processes in the industrial environment, i.e. the subject of this educational paper is an area which is highly actual nowadays both from the point of view of the scientific knowledge and the social practice. The technological processes having at disposal hazardous substances are potential threats for the employees, the public, environment and property. Therefore it is inevitable to pay increased attention to their prevention.

During increasing demands on the security of the technological processes the prevention whose part is the risk assessment is becoming a priority. The process of the risk assessment requires adequate personnel as well financial background.

The systematic procedure which was described includes a sequence of phases for the risk assessment in the industrial processes and explains the content of fulfilling the single steps of the individual phases which is, undoubtedly, a benefit for the person who assesses the risks but especially the students in the corresponding or similar field of study. The model created is in compliance with the currently valid legal regulations in the area of prevention of industrial accidents and in balance with the utilised procedures for the risk assessment in its practical understanding in Slovakia and the EU as well.

It can be utilised by a manufacturing enterprise, providers of services, carriers and other subjects which use the dangerous technological processes in the industrial environment. In the context of the risk assessment it can be used for fulfilling the regulation requirements in the Slovak Republic in compliance with the laws introduced in the chapter 1 in the process of managing continuity of the operating processes and securing the workplace in compliance with the security and protection of health at work.

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5. REFERENCES

[1] Hollá, K., Kampová, K., Šimák, L., Šimonová, M., Míka, V. 2013. *Major Industrial Accident Prevention*.Žilina. Žilinská univerzita, 2013. 147 s. ISBN 978-80-554-0786-9.

[2] Hollá, K. et al. 2013. *Statistical Survey of SEVESO Establishments in Slovak Republic: project APVV-0043-10 Complex model for risk assessment and treatment in industrial processes*, Žilina : Faculty of Special Engineering – University of Žilina, 2013. - 22 s.

[3] Salvi, O a kol.: F – SEVESO, 2008. *Study of the effectiveness of the Seveso II directive*. Brusel: EU – Vri, 2008.

[4] MARS & SPIRS. Joint research centre [online]. [cit. 4.5.2012]. Dostupné na: http://mahb.jrc.it/index.php?id=39 .

[5] Paleček, M. a kol.: *Procedures and Methodologies Of Analyses and Risk Assessments for Purpose of Law No 353/1999 Coll., on Prevention of Serious Accidents*. Praha: VÚBP.

[6] The Framework Programme Accidental Risk Assessment Methodology For Industries in the Context of the Seveso II Directive [online]. 2004. [cit. 25.6.2012]. Dostupné na: http://mahb.jrc.it/fileadmin/ARAMIS/downloads/ARAMIS_FINAL_USER_GUIDE.pdf

[7] Aven, T.: *Foundations of Risk Analysis*. New York: John Wiley & Sons, 2005. ISBN 0- 471 – 49548 – 4

[8] Bedford, T. - Cooke, R.: *Probabilistic Risk Analysis (Foundations and Methods*). Cambridge university press 2001. ISBN 978 – 0 – 521 – 77320- 1. p.373.

[9] Delvosalle Ch. Et al.: ARAMIS project: A comprehensive methodology for the identification of reference accident scenarios in process industries. 2006. [online]. [cit. 11.2.2014]. Available on: http://www.sciencedirect.com/science/article/pii/S0304389405003742

[10] VOSESOFTWARE – Risk Analysis Software – ModelRisk, [on line].[cit. 2010–04-12]. Accessible at: http://www.vosesoftware.com/ .

[11] Hollá K. et al..: Complex Model of Risk Assessment in Industrial Processes. APVV 0043-10 MOPORI. University of Žilina in Žilina. 2014.