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Dear reader,

crisis events and their solution are part of our everyday life. Terms such as sustainable development, climate changes, natural disasters, critical infrastructure and many more have become an integral part of casual conversation. At the beginning of the new millennium new global risks and threats emerged, endangering society and fulfillment of its goals. This is why it is necessary to continually improve preventive measures and to create forces, resources and means for effective removal of crisis event consequences.

In last century the attention was centered mostly on solving military crisis events but recently in a relatively stable global security environment, the attention has been focused more on prevention of non-military crisis events. Natural disasters that man can neither foresee nor can he at least reduce their negative impacts on society, are getting more and more into the spotlight. These are mostly earthquakes and tsunami associated with them, whose destructive power we are unable to prevent. An example of this kind of natural catastrophe was the earthquake in Japan on 12 March, 2011, which also caused subsequent industrial accidents. Human beings try to adapt natural conditions according to their needs but against many meteorological, topological, telluric and other crisis events affecting human lives, health, property and environment in a significant way, they are powerless.

On the other hand there is a substantial problem presented by increase in industrial accidents. Human efforts to achieve still a higher level of living are reflected in the dynamic development of technologies, which are becoming more and more complex and can possibly result in endangering human life, property and environment. Examples include not only such industrial accidents as explosions in Flixborough, Seveso or in Union Carbide Company in Bhopal, but also accidents in nuclear power engineering, petrochemical industry, mining accidents which are regularly recurring particularly in China, traffic accidents, airplane crashes and many others.

Safety of citizens is not only endangered by natural disasters and technological accidents but also by intentional human activity. It is for the sake of citizens, social groups, states and international communities to prevent national conflicts, to solve economic disagreements between countries, remove oppression and other forms of undemocratic acts including organized crime and terrorism. The efforts to raise the level of security in society and to ensure a desired level of human rights and freedom get often into mutual conflict. Personal safety is connected with material provisioning of a given person and it is influenced mostly by social risks. This creates preconditions for providing physical protection of persons and property, which represents the individual level of security.

Above stated facts and specific crisis events create space for scientific and research activities. Their results are published in this thematic issue of the scientific journal of the University of Zilina which is oriented to the solution of topical security questions.

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NANOMATERIALS: PROS AND CONTRAS

In its first part the contribution presents basic characteristics of nanoparticles, their history, reason of their different behavior, classification of nanoparticles into natural, man-made and engineered nanoparticles. The article highlights potential risks of nanoparticles and the observation of the precautionary principle in contact with them. There is a special risk present in nanoparticles in the form of aerosols. Inhalation of aerosols consisting of nanoparticles leads to their deposition in the respiratory tract and due to their size they are expected to be further transported in the organism.

The contribution presents and discusses results of pilot experiments with the use of modern measuring devices, specifically determination of the quantity and distribution of nanoparticles in the air in an underground carriage during the regular operation, in a city transportation bus, in the working environment of an office building, during fires and their extinguishing, effects of the type of Diesel engine, lighting up of entertainment pyrotechnics and during welding. The last part of the contribution presents experiments demonstrating utilization of some properties of nanoparticles of C60 carbon – fullerene.

Key words: nanoparticles, classification of nanoparticles, toxicity of nanoparticles, working environment, precautionary principle, fullerene, radioprotective, nanocomposite

1. Introduction

Nanomaterials are solid particles with at least one dimension smaller than 100 nm [1]. Nanomaterials may be isometric (nanoparticles with all the three dimensions under 100 nm), they may be in form of fibers (two dimensions smaller than 100 nm) or layers (one dimensions smaller than 100 nm).

The different behavior of nanomaterials can be explained in a simplified manner by the fact that physicochemical properties of solid substances are not the same inside the material and on its surface. When particles of a given material are smaller than 100 nm then physicochemical properties of the surface start to dominate over properties of the given material and the particles start behaving as if they consisted only of the surface. One of the most distinct demonstrations of this phenomenon is a significant increase of chemical reactivity, which may also result in a change of the toxicity.

Nanoparticles were used already in the past, despite the fact that their users were not familiar with their essential properties (in glassmaking, ceramics – glazes, chemical catalysis, metallurgy, production of soot, etc.) Nanoparticles have been surrounding us in real life since the time immemorial. They are generated during fires, volcano eruptions, erosions, chemical decomposition of organic matters by anthropogenic activity, i.e. e.g. by burning of fossil fuels (thermal power plants, combustion engines, etc.) and recently also engineered nanoparticles have been made in laboratories and in industrial plants. An overview of various sources of nanoparticles, both natural and man-made, is shown in a graphic form in Fig. 1.

Two principle processes may be used to produce nanoparticles. The process "TOP-DOWN" represents disintegration of big pieces of material while the process "BOTTOM-UP" means association of individual atoms and molecules into bigger nanostructures. There are three ways to do this: chemical (e.g. reduction), physical (e.g. pyrolysis with the use of laser) and mechanical (e.g. high-energy crushing).

Due to the fact that dimensions of nanoparticles are below the detection limit of optical methods, new technologies have been an important factor which has contributed to the development of nanotechnologies. Critically important was the invention of an electron microscope which enables to see and identify a three-dimensional structure of nanoparticles. The scientific discipline which deals with investigation of nanomaterials (nanoparticles), including development of materials and equipment of nano dimensions, is called nanotechnology. The current nanotechnology represents an interdisciplinary scientific discipline, which includes classical fields of science, such as physics, quantum mechanics, chemistry, biochemistry, electronics etc. Nanotechnologies are considered to be the phenomenon of the late 20th and early 21st centuries. In conformity

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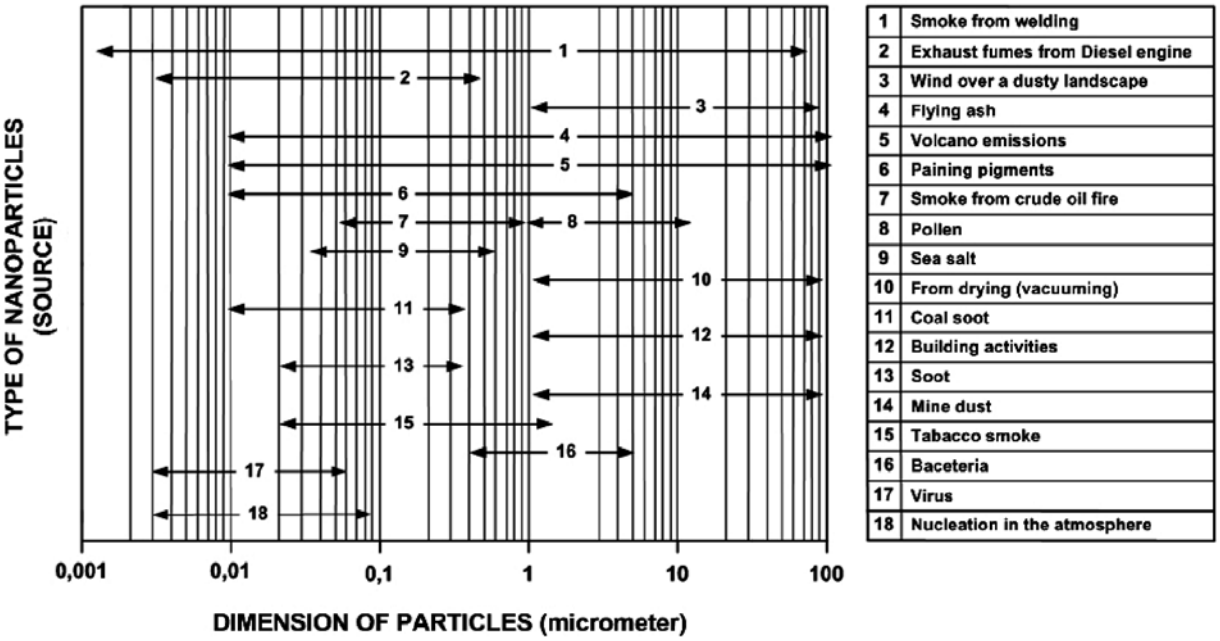

Fig. 1 Sources of nanoparticles and their dimension range

with this fact is the huge increase of support provided to the research in the concerned area. The development of nanotechnologies cannot be stopped.

2. What are the potential risks posed by nanomaterials?

After the negative experience with certain substances (e.g. DDT, PCB, dioxins etc.) the worldwide public now requests the research centers and producers dealing with nanomaterials and nano-technologies to observe the so-called precautionary principle. Recommendations have been made for regulation, registration, determination of risk assessment methods and monitoring of nano-compounds [1] (COM 1 2000, COM 243 2005, COM 338 2004, COM 345 2008), policy framework for California to deal with nanosubstances [2], prohibition to use nano-compounds in foodstuffs without execution of risk assessment (European Parliament, March 2009) etc. In terms of the potential risks posed by nanomaterials the following classification may be used:

- dangerous for health (toxicity),
- dangerous for the environment (ecotoxicity),
- physicochemical risks, i.e. they may cause fire, explosion, uncontrolled and undesired reactions,
- in the future it is impossible to exclude an unethical use of nanotechnologies and nanoparticles by a third party (criminal or terrorist act, war conflict).

The first two potential sources of danger are mutually very closely interconnected as the occurrence of nanoparticles in the elements of the environment enables their contact with living organisms. The presence of nanoparticles in a living organism results in a number of interactions between their surfaces and biological systems. The interactions may lead to formation of protein coronas, wrapping of particles, intracellular absorption and biocatalytic processes, which may have positive and negative results in terms of the toxicity. The organic world intertwines with the synthetic world of man-made nanomaterials. The nano-bio interfaces are created, associated with dynamic physicochemical interactions, kinetic and thermodynamic exchanges between surfaces of nanomaterials and surfaces of biological components (proteins, membranes, lipids, DNA, biological liquids etc.). A background research [3] has shown that only very little is known about what happens with nanoparticles inside a cell. Nanoparticles may cause a wide range of intracellular reactions which depend on their physicochemical properties, intracellular concentration, duration of contact etc.

There is a general agreement among authors [3] dealing with toxicity of nanomaterials that the primary driving force behind the bioactivity of nanoparticles is the size of their surface. A surface coat on nanoparticles (e.g. hydrophobic polymer) increases the safety of nanoparticles and reduces their bioreactivity. The biggest problem is that the information we have gathered about one specific nanomaterial may not be applicable for the same particles if they are made synthetically or slightly modified. Another problem is the characterization of the surfaces with simple and available measuring equipment. It is also assumed that natural nanoparticles will behave differently from the so-called "engineered nanoparticles" – i.e. nanoparticles made in industrial plants or in laboratories [4, 5].

Physicochemical risks are present particularly in the production of nanoparticles using the "TOP-DOWN" system, where nanoparticles are created by a mechanical method i.e. e.g. grinding, cutting, supermilling etc. It should be noted and stressed here, that nanopar-

ticles are present essentially in all dusty operations which include e.g. metal machining, woodworking, milling, grinding, welding, etc. Their numbers and reactivity are influenced by the degree of their mutual aggregation or agglomeration. In general, it is typical for dust-air mixtures not to be stable in terms of place and time, they are not homogenous. The explosiveness of dust is strongly influenced by the size of particles. The general risk of explosion increases with the reducing size of the particles. This statement has been verified experimentally for microparticles and one can assume that the trend will continue to apply also to particles of nanometric size. Many nanoparticles e.g. Fe, Ni, Al, Mn, Co are prone to self-ignition and thanks to their large surface they operate as active catalysts and thus may initiate an uncontrolled exothermic reaction. Nanoparticles as such are more reactive than their "macro versions" with the same chemical composition. A special risk is posed by nanoparticles in form of aerosols, i.e. particles suspended in the air. Inhalation of aerosols consisting of nanoparticles leads to their deposition in the respiratory tract and they are expected, depending on their diameter, area and surface etc., to be further transported in the organism into other peripheral organs. There are a number of epidemiological studies which have identified the negative effect of nanoparticles on respiratory and cardiovascular systems in susceptible groups of population. It has been discovered that exceptionally serious is the cardiovascular effect of inhaled ultrafine (nano) particles [6]. Those particles come mostly from anthropogenic sources (road traffic, combustion products, forest fires, fires of organic matters and crude oil products etc.) and they occur in urban agglomerations.

This was one of the reasons to perform the measurements of nanoparticles in transportation means in Prague, in an office building in the city center and at different types of Diesel engine, to identify the quantity of nanoparticles released into the atmosphere and to check the level of risk caused by nanoparticles to fire fighters during an intervention against fire. We also measured production of nanoparticles during welding and lighting up of entertainment pyrotechnics. We also selected one chemically non-active nanoparticle of carbon – fullerene – which occurs in soot from burning wood, soot from fire of organic and crude oil products, in emissions from coal power plants, car exhaust fumes, in municipal emissions etc. [7–13]. With those nanoparticles we focused on their potential "favorable" use as a radioprotective, radical-based extinguishing agent and nanocomposite.

3. Pilot measurement of quantities and distribution of nanoparticles from various anthropogenic sources

Measuring points:

I. Prague underground carriage, under operating conditions, line C,
II. City transportation bus (MHD) in Prague No. 189, under operating conditions
III. Car driving on the same route as the bus No. 189,
IV. Office building in the center of Prague, Senovážné nám. – Dlážděná street,
V. At fires with various composition of burning materials,
VI. At exhaust pipes of a regular Diesel engine and of a modern environment-friendly engine,
VII. Simulation of lighting up of entertainment pyrotechnics,
VIII. Welding in a maintenance workshop.

The following conclusions may be drawn from the results:

- It is impossible to positively define a small increase in the quantity of nanoparticles depending of the occupation rate in the underground carriage. Other involved factors may include the ground-level location of the stations and the routes which are close to the extremely busy arterial road (ventilation shafts).
- The concentration of nanoparticles which affects passengers in the city transportation bus No. 189 is by one order of magnitude higher than in the underground on the line C (max. 36.7.103 N/cm^3 in the underground carriage, 260.103 N/cm^3 in the bus). Even in this case it is impossible to demonstrate a positive effect of the number of passengers on the concentration of nanoparticles but it is rather the effect of intensity and composition of the traffic.
- The effect of intensity of the surrounding traffic was demonstrated by measurements in a driving car: the quantity of particles increased in the proximity of a slip road to the Prague ring road and D1 motorway (location Kačerov).
- A certain protection of persons against nanoparticles in a driving car may be provided by lower ventilation intensity and pollen filter.
- Probably the most risky particles are those smaller than 50 nm due to their potential ability to penetrate cellular protective barriers. Particles of that size were primarily identified in the proximity of Kačerov, which is again the location close to a slip road to the Prague ring road and D1 motorway. In the underground it was the section (although with a much lower value than in the bus) that passes through the center of Prague near the arterial road (Pankrác – Florenc).
- Alarming was the finding that particles smaller than 40 nm were those measured most frequently in the city bus.
- The number of nanoparticles in the office building used by non-smokers for regular office activities was slightly lower than in the proximity of the building (ca. units .103 N/cm^3).
- When measuring nanoparticles on individual floors in the building wing in the Dlážděná street no relation was found between the quantity of nanoparticles and the floor level.
- An extreme increase of the number of nanoparticles was found in an office where people regularly smoked. When three people were smoking at the same time in the office the number of nanoparticles increased by up to two orders of magnitude (their values were comparable with those for traveling in the city traffic).
- An increased number of nanoparticles was also found in a regular maintenance workshop.
- During fires and during their extinguishing there is a high increase of aerosol nanoparticles, depending on the composition of burning components (the measuring devices got congested with products of combustion of mostly crude oil-based materials).
- An increase of the total amount of aerosol nanoparticles was found for the classical Diesel engines but in the case of a modern Diesel engine we found an increased number nanoparticles whose

size makes them more risky for human health and for the environment (for comparison see Figs. 2 and 3).
- It was demonstrated that the concentration and size of nanoparticles changes depending on the distance from the source (see Fig. 3). This is caused by dispersion and mainly by coagulation of the particles (aggregation, agglomeration, adsorption of nanoparticles on microparticles, etc.).
- The risk area of that size of nanoparticles was also found in the case of the regular engine, before it was heated to the operating temperature (see Fig. 2).
- Apart from particles generated by the fire and its extinguishing, firefighters are also exposed to nanoparticles that may be produced by their own firefighting technology, i.e. by fire-fighting trucks, Diesel aggregates, etc. (see Fig. 4).

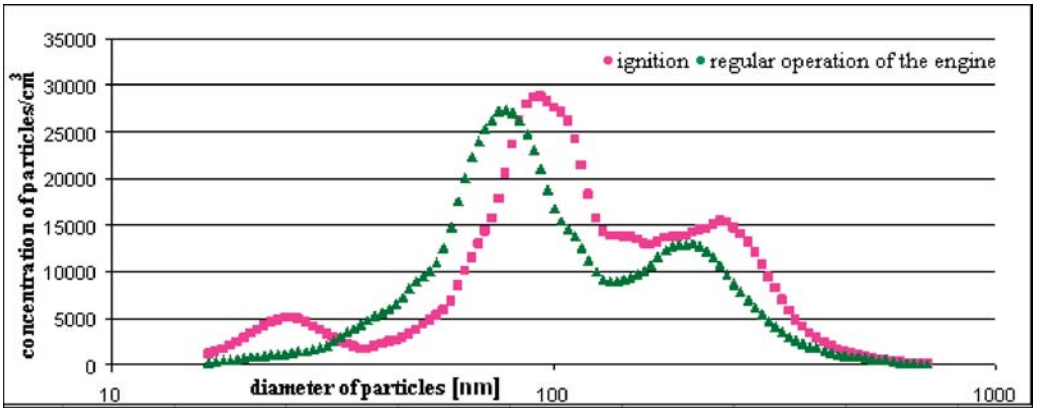

Fig. 2 Distribution of particles measured at a Diesel engine made by Zetor, exp. VI.a)

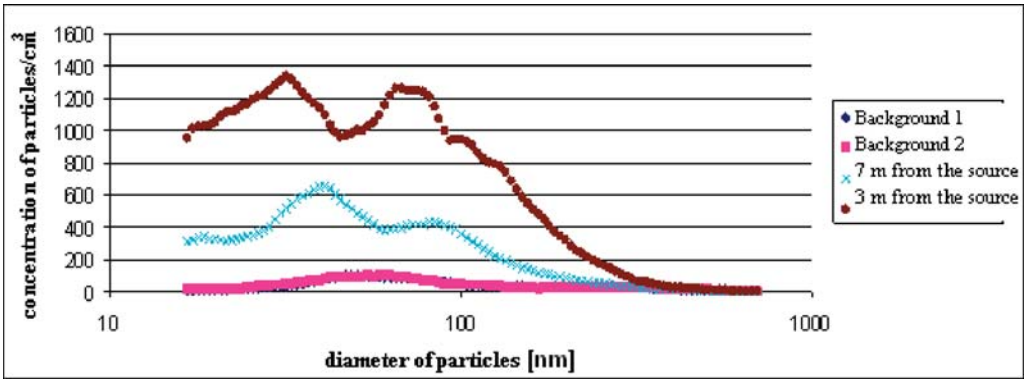

Fig. 3 Distribution of aerosol particles measured at the exhaust pipe of Ford Transit exp. VI.b)

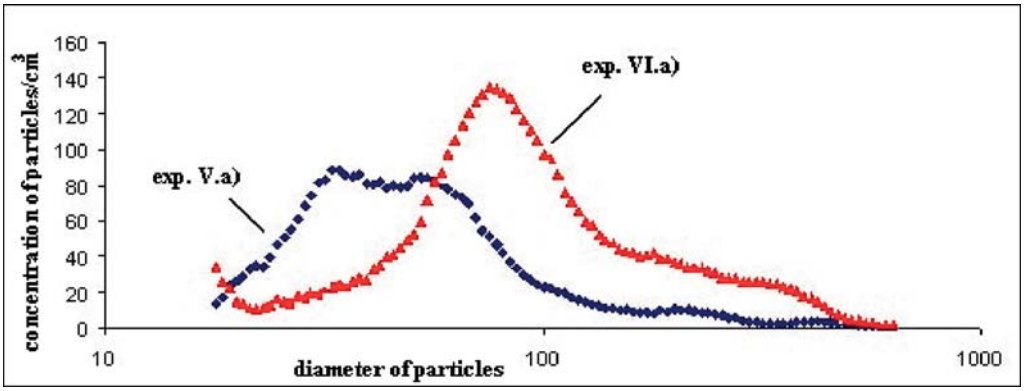

Fig. 4 Distribution of particles exp. V.a) - fire, exp. VI.a) - Diesel engine type Zetor

- The increase in the number of nanoparticles after lighting up of entertainment pyrotechnics is two orders of magnitude in comparison with the background levels.
- The size of nanoparticles produced by the lighting up of entertainment pyrotechnics is greater than 100 nm – as measured in a relatively big distance from the source. Also in this case we could observe the time dependence of coagulation.
- Dangerous nanoparticles smaller than 100 nm are generated immediately in the course of welding and they subsequently coagulate.

The presented results of the performed experiments have the character of only basic measurements. It is very difficult to measure the number of nanoparticles and the results are influenced by many factors (e.g. air flow, temperature, humidity, distance from the source etc.). It is nearly impossible to get reproducible results of measurements and it is one of the biggest problems of standardization of nanoparticles in respect to their impact on human health (toxicity) and the environment. For this reason the published conclusions shall be applicable only for the specific situation [14].

Alarming was the finding that particles smaller than 50 nm were essentially most frequently present during fires, fire extinguishing, welding and at exhaust pipes of a modern Diesel engine and of a cold classical Diesel engine. This corresponds to the discussion and statement [15] that improved combustion in modern Diesel engines extremely reduces the ratio of big particles, however, at the expense of increased emissions of extremely small particles. As the authors say: "The fact that you see no smoke coming out from the exhaust pipe is reassuring for the eye but the problem is actually in something that cannot be seen." We dare say that the same applies for fires.

4. Fullerene – carbon nanoparticles

Carbon is the basic element which forms organic compounds and it has two allotropic forms – graphite and diamond. The third carbon modification was discovered in 1985 (R. E. Smalley and R. F. Curl – American professors and British professor H. W. Kroto, they received the Nobel prize for chemistry in 1996), which are giant molecules made of more than twenty atoms of carbon situated in the corners of various polyhedrons, including more or less spherical shapes. Those molecular formations were called fullerenes in remembrance of the renowned American architect R. B. Fuller (they are similar to a skeleton of the geodesic dome designed on the occasion of the World Exhibition in Montreal in 1967).

The best known and, by its properties, the most interesting molecule from among fullerenes is the molecule C_{60}. In comparison with other fullerene molecules it has the most perfect spherical shape and the structure of truncated icosahedrons, whose surface is made up of twenty hexagons and twelve pentagons (analogy to a football), see Fig. 5.

The basic difference from graphite and diamond is the solubility of C_{60} in non-polar organic solvents, such as THF, toluene, benzene, 1, 2 dichlorobenzene, xylene, carbon disulphide etc. Colors of such solutions are varied, e.g. brown-yellow, violet, red-violet and they are symptomatic for the transition of π – π electrons.

Fig. 5 Structural molecule C_{60}

Reactivity of fullerene is associated with the internal tension in the molecule, which is caused by non-planar arrangement of hybrid sp^2 orbitals of the carbon atom. Therefore it typically features reactions associated with transformation into sp^3 configuration which leads to a reduction of the internal tension in the molecule. Moreover, the C60 molecule is electropositive, which means preference of nucleophilic or radical addition to form multiple bonds.

The solubility of fullerene C_{60} in organic solvents is the first precondition for a number of syntheses [16]. Results of available studies that are based on the effects of fullerenes on living organisms are in many respects mutually contradictory [15]. The experiments that we have performed focused on utilization of the ability of the fullerene molecule to catch radicals and to use is as a radioprotective, radical extinguishing agent or nanocomposite in organic polymers.

5. Radioprotective properties of C_{60} fullerene derivative

Effects of ionizing radiation on organisms and post-irradiation changes at the molecular level are associated particularly with mechanisms related to the formation of reactive water metabolites. The probability of a direct hitting of an organic molecule (its excitation and ionization) is relatively small in comparison with a cascade of degradation radical reactions, which are caused by reactive metabolites generated by radiolysis of water. Hydrogen atoms and electrons are immediately caught by molecular oxygen to form superoxide. Extremely reactive is the hydroxyl radical, which immediately, at the place of its formation, reacts with all biomolecules (saccharides, aminoacids, phospholipids, nucleotides and organic acids) and strips them of hydrogen. This launches other radical reactions with the resulting damage of membranes. The radical reacts in the same manner with deoxyribose in DNA. It is also capable of an addition reaction with aromatic rings of purine and pyrimidine bases, which are a part of DNA and RNA. The reason of the limited development of C_{60} alone in biological applications is its minimum solubility in the water environment. But thanks to its reactivity it is possible to perform its organic functionalization with hydrophilic groups, which increases its solubility in water.

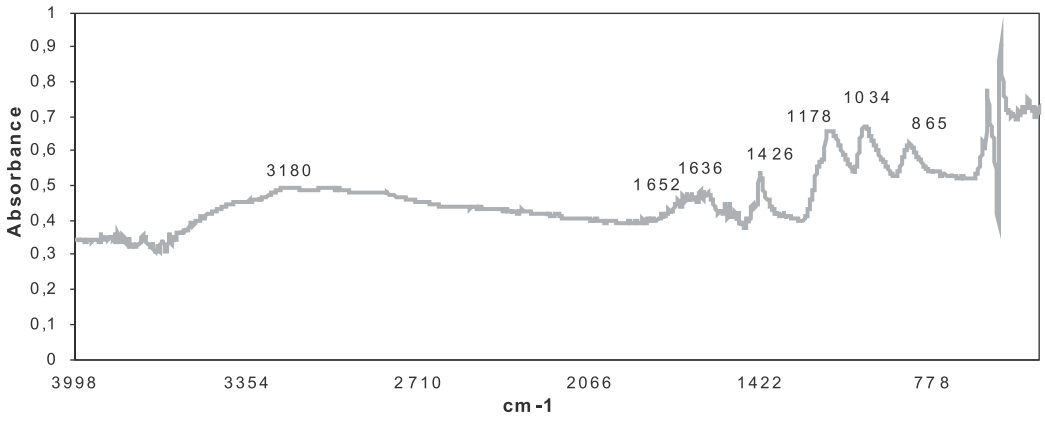

Fig. 6 FTIR spectrum of the prepared fullerene derivative

This inspired us to prepare a derivative of fullerene (DF) functionalized with -OH, -COOH by means of its oxidation with peracetic acid /17/.This derivative is partly soluble in water and its FTIR spectrum is shown in Fig. 6

For the purposes of our experiments we prepared 65 liters of DF stock solution with the concentration of 147 mg/l. Fig. 7 shows the difference between the initial fullerene and its derivative.

The selected model biological organism used for our experiments was the *Danio rerio* fish in juvenile age (2.5 months) without sex differentiation. This small vertebrate species has become a successful model system to study human diseases; it reproduces quickly and it is easy to keep in laboratory conditions. Before the test of radioprotectiveness as such we performed a toxicity test in vivo. After the toxicity test we concluded that 28 days of exposure of the *Danio rerio* fish to DF solution with the concentration 147 mg/L ± 0.1 mg/L had no effect on their behavior or alimentary patterns

Fig 7 Supply tank with DF water solution in comparison with an insoluble C_{60}

in comparison with the control group. In a subsequent period of time the tested fish was kept in DF-free water and we did not find any visible changes in the behavior of the fish in comparison with the control group either. Therefore it is possible to conclude that

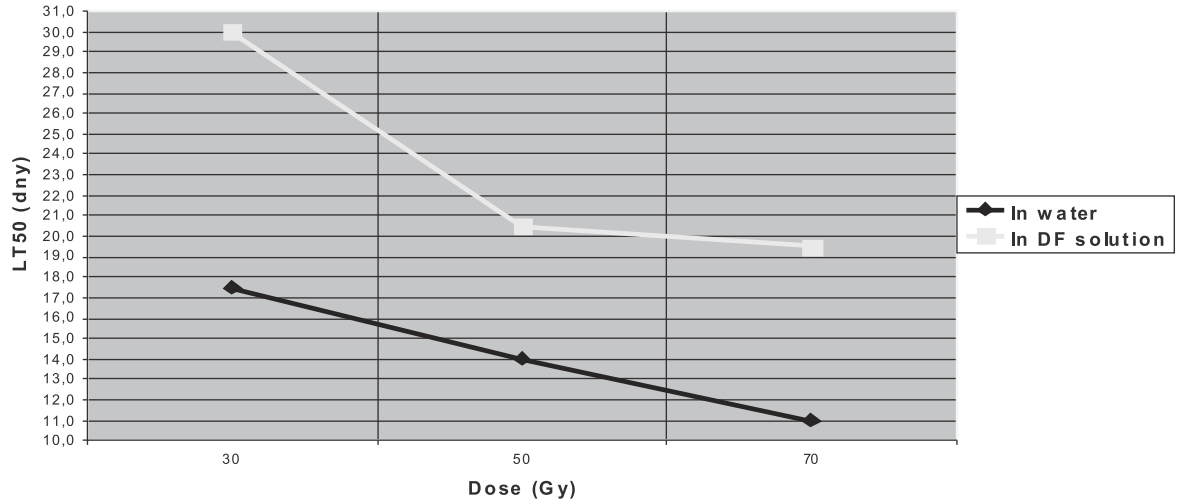

Fig. 8 Comparison of LT 50 after irradiation at Danio trio kept in water and DF solution

the 28-day exposure of the fish to the DF solution with the concentration 147 mg/L ± 0.1 did not have any visible negative effect on their health condition.

The test of radioprotective properties of DF consisted of monitoring and comparison of the survival time of Danio rerio that was before the irradiation kept for 5 days in water containing 147 mg/l DF, with the fish kept only in water.

The irradiation of the individual groups of the fish was with X radiation with the doses 10, 30, 50 and 70 Gy (therapeutic linear accelerator Climac 2100CD). Details of the course of the experiments and their detailed results were presented at conferences Nanocon 2009 and 2010 /17, 18/ Radioprotective effect of DF, i.e. increase of LT 50 as a result of DF is shown in the diagram in Fig. 8.

The exposure to 10 Gy resulted in the mortality of the fish in water up to 10 %, LT50 was not determined. For the fish in the DF solution the mortality after the exposure to 10Gy was zero. The biggest effects of DF was found for the exposure to doses 30Gy and 70 Gy and LT50 increased by 71.4 % and 77.5 % respectively. For the exposure to 50 Gy LT 50 increased by 46.5 %. LT 50 indicators were nearly the same within the observation error (max. ±1 day) for the fish kept in DF an exposed to the doses 50 and 70 Gy.

The completed detailed experiments have shown that the development of the mortality is not dependent on the duration of exposure to DF solution after the irradiation. Results of the tests are identical for organism kept in the DF solution for the entire monitored period, for the fish relocated into water after one week after the irradiation and for the fish placed into water immediately after the irradiation. Therefore we do not consider the effect of DF to be "curative".

6. Use of fullerene and its derivative in fire protection

The basic principle of fire fighting capacity of the aerosol system is the reaction of radicals formed from the fire-fighting composition and radicals from burning. The test involved extinguishing capacity of aerosols used by FIRE JACK BR-1 (composition: potassium nitrate, dicyandiamide, phthalic acid, formaldehyde resins) without fullerene C_{60} and with fullerene, whose content in the composition was 1–5 %. The experiments have shown that to extinguish the same quantity of n-heptane requires less than a half of the composition that contains fullerene [19].

Nanocomposites are new materials which have been currently intensely investigated and they promise extensive applications [20]. The materials consist of a polymeric matrix and a non-polymeric component – filling agent – while the filling agent has at least one of its dimensions in the nano range. It may consist of isometric nanoparticles, nanotubes or stratified nanoparticles. Nanocomposites have better mechanic and material properties than polymers alone and they have an increased thermal stability and significantly reduce heat release rate. In cooperation with the Technical University in Liberec we tested the possibility to introduce DF as a nanocomposite into nanofibers made of polyvinylalcohol. Results of DTA nanofibers prepared only from PVA and from PVA with DF have shown that the nanofiber containing DF demonstrated a lower quantity of released heat in case of an exothermic decomposition.

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PARTIAL UPDATE ALGORITHMS AND ECHO DELAY ESTIMATION

In this paper, we introduce methods for extracting an echo delay between speech signals using adaptive filtering algorithms. Time delay estimation is an initial step for many speech processing applications. Conventional techniques that estimate a time difference of arrival between two signals are based on the peak determination of the generalized cross-correlation between the signals. To achieve a good precision and stability in estimation, the input sequences have to be multiplied by an appropriate weighting function. Regularly, the weighting functions are dependent on the signals power spectra. The spectra are generally unknown and have to be estimated in advance. An implementation of the time delay estimation via the adaptive least mean squares is analogous to estimating the Roth generalized cross-correlation weighting function. The estimated parameters using the adaptive filter have a smaller variance, because it avoids the need for the spectrum estimation. In the following, we discuss proportionate and partial-update adaptive techniques and consider their performance in term of delay estimation.

1. Introduction

Time delay estimation (TDE) has always been and remains a popular research topic. It finds application in many areas of electrical engineering [1-4]. As technology advances and the data transmission methods tend more to packet-switching concepts; the traditional echo problem remains important. An issue in echo analysis is the round-trip delay of the network. The main problem associated with IP-based networks is that the round-trip delay can be never reduced below its fundamental limit. There is always the delay of at least two to three packet sizes (50 to 80 ms) [5] that can make the existing network echo more audible [6]. A number of efforts were made in order to improve the TDE precision. Various methods based on the Generalized Cross-Correlation (GCC) were recently proposed [7–10]. The GCC algorithms mainly arrange a pre-filter to obtain the modified signal spectrum for optimal time delay estimation. To specify the filter's characteristic, it requires a priori knowledge of the statistics of the received signals. However, the efficiency of the algorithms decreases considerably when little or no prior knowledge about the signal statistics is known. From the time when B.Widrow proposed an adaptive filtering technique based on Least Mean Squares (LMS) [11–13], an adaptive theory also found an application to delay estimation. An adaptive implementation of the time delay estimation via Widrow's LMS algorithm is usually referred to as TDLMS. Comparing to the GCC algorithms, the adaptive filtering techniques do not require a priori information of the signal statistics, because the estimation of the signal spectrum is no longer needed. The adaptive filtering algorithms determine the time delay in an iterative manner. There are comparative studies, which provide comparison of the LMS versus the generalized cross-correlation [14], [15]. Generally, the time domain implementation of any adaptive filter is associated with high computational complexity. It directly depends on the length of the adaptive filter [16]. In order to reduce the computational load of the TDLMS, we offer using adaptive filtering algorithms with reduced computational complexity [17-19].

2. Time Domain Adaptive Techniques

Traditionally in the implementation of the echo canceller, the NLMS algorithm performs as a reference [13]. Basically, the NLMS algorithm is a simple extension of the Widrow's LMS algorithm [12]. Knowing the adaptive theory, it is trivial that the delay estimation can be achieved by selecting the largest value from the adaptive filter weights vector, w. There is only one issue that has to be taken into account. The adaptive filter needs some time in order to converge to the optimal performance. The existing adaptive algorithms differ from each other with different convergence properties and computational memory requirements. The robust fast converging algorithms are primarily used in the acoustical echo cancellation applications. They take a lot of computational resources. In our case, it is not necessary to apply the complex algorithms, because the adaptive filter is not directly used for the purpose of echo cancellation, but for the delay estimation. Therefore, the reduced complexity adaptive filtering algorithms became the subject of our interest.

2.1 Proportionate Adaptive Filtering

The proportionate normalized least mean squares (PNLMS) algorithm proposed in [20] has been developed for use especially

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in the telephone network environment. For hybrid echo cancellers, it is reasonable to assume that the echo path has a sparse character (i.e., many IR's (Impulse Response) coefficients are close to zero). Although there are studies and research on the multiple reflection echo paths [17], a typical echo path impulse response in the practical communication networks has only one reflection, which means all the active coefficients are occupied in a continuous area of the whole echo span. Proportionate approaches achieve their higher convergence rate by using the fact that the active part of network echo path is usually much smaller (4–8ms) compared to 64–128 ms of the whole echo path that has to be covered by the adaptive filter. In case of voice transmission over the packet-switching network, these numbers may be more considerable [5]. In the PNLMS algorithm, the adaptive step-size parameters are assigned to all the filter coefficients. They are calculated from the last estimate of the filter weights in such a way that a larger coefficient receives a larger increment. As a result, the convergence rate can be increased the fact that the active taps are adjusted faster than non-active coefficients. Therefore for the sparse IR, the PNLMS algorithm converges much faster comparing to the NLMS. This feature is an advantage especially when it is necessary to estimate the long echo delays. The PNLMS algorithm can be described using the following equations [21]:

$$\boldsymbol{w}(n+1) = \boldsymbol{w}(n) + \frac{1}{\boldsymbol{x}^T(n)\cdot\boldsymbol{G}(n-1)\cdot\boldsymbol{x}(n)}\cdot \\ \cdot\mu_0\cdot\boldsymbol{G}(n-1)\cdot e(n)\cdot\boldsymbol{x}(n) \quad (1)$$

$$\boldsymbol{G}(n-1) = diag\left\{g_0(n-1),\ldots,g_{L-1}(n-1)\right\} \quad (2)$$

where $\boldsymbol{G}(n-1)$ is a diagonal matrix adjusting the step-size parameters, μ_0 is an overall step-size parameter. The diagonal elements of $\boldsymbol{G}(n)$ are estimated as follows:

$$\gamma_l(n) = \max\left\{\rho\max\left[\delta_p\left|w_0(n)\right|,\ldots,\left|w_{L-1}(n)\right|\right],\left|w_l(n)\right|\right\}, \quad (3)$$

$$g_l(n) = \frac{\gamma_l(n)}{\sum_{i=0}^{L-1}\gamma_i(n)},\ 0\le l\le L-1\,. \quad (4)$$

Parameters δ_p and ρ are positive numbers with typical values $\delta_p = 0.01$ and $\rho = 5/L$. The first term in (5), ρ, prevents $w_l(n)$ from stalling when it is much smaller than the largest coefficient and δ_p regularizes the updating when all coefficients have zero values at initialization.

In spite of the sparse system identification, which is a vital requirement for the fast converging adaptive filters, there is another requirement. It is directly addressed to the adaptive filter implementation. The algorithm should have reasonable power concerns. Unfortunately, the PNLMS algorithm has several drawbacks. One of them is an increase in the computational complexity by 50 % compared to the NLMS algorithm. Furthermore, the PNLMS algorithm shows the slow convergence rate after the fast initial start. It is because of the slow convergence rate dedicated to the small coefficients [22]. The increased computational complexity can be reduced by the way of selective partial-updating. In turn, the slow convergence of the PNLMS in the stable state can be improved by switching from the PNLMS to NLMS equations after the fast initial convergence has been achieved [23].

2.2 Partial-Update Adaptive Filtering

The partial-update algorithms can be seen to exploit the sparseness of the echo path in two different ways. It is known that when the unknown system's impulse response is sparse, many of the adaptive filter's weights can be approximated to zero. Alternatively, the sparseness may be present in the weight update vector as a consequence of the distribution of the input samples in the $(Lx1)$ input vector, $x_n = [x(n), x(n-1), ..., x(n-L+1)]^T$. In both these cases, exploiting the sparseness properties can reduce complexity and improve performance of the adaptive algorithm [24], [25]. Some of the first work on the partial-update algorithms was done by Douglas [26]. It presents the periodic and the sequential updating schemes for the Max-NLMS algorithm. However, these partial-update algorithms show slow convergence 2properties compared to the full-update algorithms. The reason is inconsistent updating schemes. More recently, the partial-updating concept was developed by Aboulnasr [27]. It leads to the M-Max NLMS algorithm and supporting convergence analysis [28]. Another block-updating scheme for the NLMS algorithm was studied by Schertler [29]. The latter work was published by Dogancay and Tanrikulu. They consider approaches for more robust Affine Projection Algorithm (APA) [30], [31].

M−Max NLMS

The algorithm selects a specified number of the coefficients providing the largest reduction in the mean squared error per iteration [32]. Only M out of the total L filter coefficients are updated. Those M coefficients are the ones associated with the M largest values within the following vector $|x(n-i+1)|$; $i = 1; ...; L$. The update equations for this algorithm are

$$\boldsymbol{w}_i(n+1) = \boldsymbol{w}_i(n) + \frac{1}{\boldsymbol{x}^T(n)\cdot\boldsymbol{x}(n)}\mu_0\cdot e(n)\cdot\boldsymbol{x}_i(n), \quad (5)$$

$$w_i(n) = \begin{cases}1, & i\in\left\{M\text{ maxima of }\left|x(n-i+1)\right|\right\},\\ 0, & \text{otherwise}\end{cases}, \quad (6)$$
$$0\le i\le L$$

One of the features of the M-MAX-NLMS algorithm is that it reduces the complexity of the adaptive filter by selectively updating the coefficients while maintaining the closest performance to the full-update NLMS algorithm. We present misalignment curves for the algorithm in the follow-up section.

Selective-partial-update NLMS

This algorithm opposed to the M-Max NLMS has a block structure. An objective behind the latter is the same: it reduces computational costs by updating a subset of the filter coefficients. But

first, the vector $\boldsymbol{x}(n)$ and the coefficient vector $\boldsymbol{w}(n)$ are arranged into K blocks of length $M = L/K$, where L is an integer as in

$$\boldsymbol{x}(n) = \left[\boldsymbol{x}_1^T(n)\ \boldsymbol{x}_2^T(n)\ \ldots\ \boldsymbol{x}_K^T(n)\right]^T \tag{7}$$

$$\boldsymbol{w}(n) = \left[\boldsymbol{w}_1^T(n)\ \boldsymbol{w}_2^T(n)\ \ldots\ \boldsymbol{w}_K^T(n)\right]^T. \tag{8}$$

The coefficient vector's blocks $\boldsymbol{w}_1(n)$, $\boldsymbol{w}_2(n)$, ..., $\boldsymbol{w}_K(n)$ represent candidate subsets that can be updated during the current iteration. For a single-block updating scheme, the constrained minimization problem, which is solved by the NLMS algorithm, can be written as

$$\boldsymbol{w}_i(n+1) = \boldsymbol{w}_i(n) + \frac{1}{\left\|\boldsymbol{x}_i(n)\right\|^2}\mu_0 \cdot e(n) \cdot \boldsymbol{x}_i(n), \tag{9}$$

The selection of the block that has to be updated is made by determining the block with the smallest squared-Euclidian-norm update [30]. According to (9), that justification can be described by the following terms

$$i = \arg\min_{1 \le j \le M} 1/\left\|\boldsymbol{x}_j(n)\right\|^2 = \arg\max_{1 \le j \le M}\left\|\boldsymbol{x}_j(n)\right\|^2 \tag{10}$$

Generalization from the single-block to the multiple-block updating scheme is done through the following. Suppose that only the B ($B < K$) blocks with the largest magnitudes are selected to be updated. Let a vector $I_B = \{i_1, i_2, ..., i_B\}$ denote the subset of B blocks out of $[1, 2, ..., K]$ to be updated. Thus, the equation for the B-block updating scheme is

$$\boldsymbol{w}_{I_B}(n+1) = \boldsymbol{w}_{I_B}(n) + \frac{1}{\left\|\boldsymbol{x}_{I_B}(n)\right\|^2}\mu_0 \cdot e(n) \cdot \boldsymbol{x}_{I_B}(n), \tag{11}$$

where $\boldsymbol{x}_{I_B}$ and $\boldsymbol{w}_{I_B}$ are defined as follows

$$\boldsymbol{x}_{I_B}(n) = \left[\boldsymbol{x}_{i_1}^T(n)\ \boldsymbol{x}_{i_2}^T(n)\ \ldots\ \boldsymbol{x}_{i_B}^T(n)\right]^T \tag{12}$$

$$\boldsymbol{w}_{I_B}(n) = \left[\boldsymbol{w}_{i_1}^T(n)\ \boldsymbol{w}_{i_2}^T(n)\ \ldots\ \boldsymbol{w}_{i_B}^T(n)\right]^T. \tag{13}$$

The computational and memory requirements of the selective-partial-update NLMS algorithm are almost identical to those of the selective-block-update algorithm proposed in [28]. Nevertheless, simulation results illustrated in the next section shows that this approach does not lead to the reasonable trade-off between performance and simplicity. The algorithm's efficiency is weaker than the one of the M-Max NLMS algorithm. As an alternative approach, a sparse-partial-update NLMS algorithm applies more relevant selection criterion.

Sparse-partial-update NLMS

This algorithm utilizes a so-called sparse-partial (SP) weight selection criterion [33]. The adaptive filter weights are updated based on the largest product of the multiplication of $\boldsymbol{x}(n)$ and $\boldsymbol{w}(n)$. The SP-NLMS single-block update equations are given by

$$\boldsymbol{w}_i(n+1) = \boldsymbol{w}_i(n) + \frac{1}{\boldsymbol{x}^T(n) \cdot \boldsymbol{x}(n)}\mu_0 \cdot e(n) \cdot \boldsymbol{x}_i(n), \tag{14}$$

$$w_i(n) = \begin{cases} 1, & i \in \left\{M \text{ maxima } of \left|x(n-i+1)\right| \cdot w_i(n)\right\} \\ 0, & \text{otherwise} \end{cases}, \tag{15}$$

$$0 \le i \le L$$

Hongyang and Dyba recently suggested a generalization for updating B blocks out of K [17], i.e.

$$\boldsymbol{w}_{I_B}(n+1) = \boldsymbol{w}_{I_B}(n) + \frac{1}{\boldsymbol{x}_{I_B}^T(n) \cdot \boldsymbol{x}(n)}\mu_0 \cdot e(n) \cdot \boldsymbol{x}_{I_B}(n) \tag{16}$$

$$I_B = \{i\text{: is one of the } B \text{ largest among} \\ \boldsymbol{w}_{i_1}^T(n) \cdot \boldsymbol{x}_{i_1}(n), \ldots, \boldsymbol{w}_{i_B}^T(n) \cdot \boldsymbol{x}_{i_B}(n)\} \tag{17}$$

Simple-partial-update PNLMS

The approach is based on the proportionate technique and partial updating of the adaptive filter coefficients. The algorithm exploits the sparseness of the communication channel to speed up the initial convergence and employs the partially updating scheme to reduce the computational complexity. A selection procedure is performed in accordance with the estimated magnitude of the channel's impulse response. The S-PNLMS algorithm for single – block update is defined as follows. Arrange $x(n)$ and $w(n)$ into K blocks of length $M = L/K$ in the same way as it is done in (7) and (8). Then let $\boldsymbol{G}_i(n)$ denote the corresponding $M \times M$ block of the diagonal weighing matrix, $\boldsymbol{G}(n)$. The recursion for updating adaptive filter weights is given by

$$\boldsymbol{w}_i(n+1) = \boldsymbol{w}_i(n) + \frac{1}{\boldsymbol{x}_i^T(n) \cdot \boldsymbol{G}_i(n-1) \cdot \boldsymbol{x}_i(n)} \cdot \\ \cdot \mu_0 \cdot \boldsymbol{G}_i(n-1) \cdot e(n) \cdot \boldsymbol{x}_i(n) \tag{18}$$

where the block selection is done according to the following

$$i = \arg\min_{1 \le j \le M} G_j(n)$$

It is different to

$$i = \arg\min_{1 \le j \le M} x_j \cdot G_j(n) \cdot x_j,$$

which is used with the SPU-PNLMS algorithm [30]. It is apparent from the simulations that the S-PNLMS has similar performance to the SP-NLMS and outperforms the SPU-PNLMS algorithm. Its misalignment curves are presented in the next section. The S-PNLMS algorithm for updating B blocks out of M has these update equations

$$\boldsymbol{w}_{I_B}(n+1) = \boldsymbol{w}_{I_B}(n) + \frac{1}{\boldsymbol{x}_{I_B}^T(n) \cdot \boldsymbol{G}_{I_B}(n-1) \cdot \boldsymbol{x}_{I_B}(n)} \cdot \\ \cdot \mu_0 \cdot \boldsymbol{G}_{I_B}(n-1) \cdot e(n) \cdot \boldsymbol{x}_{I_B}(n) \tag{19}$$

$$I_B = \{i\text{: } G_i(n) \text{ is one of the } B \text{ largest among} \\ \boldsymbol{G}_1(n), \ldots, \boldsymbol{G}_M(n)\}. \tag{20}$$

Further, we provide the comparison results for the presented algorithms and demonstrate their performance while estimating

the predefined echo delay. Table 2 illustrates the computational complexity of the full-update algorithms and shows saving achieved by the partially updating schemes. The only down side is that in order to find out the M largest outputs or inputs, you have to sort the output or input values. If the fast sorting algorithm is chosen [34], only $2\log_2(L)+2$ comparisons are required. For large L and small M, which is appropriate for the sparse impulse response, big computational savings are expected.

Comparison in computational complexity Table 2.

ALG.	MULT.	ADD.	DIV.
NLMS	$3L+1$	$3L-1$	1
M-Max-NLMS	$3M+1$	$3M-1$	1
SPU-NLMS	$3M*B+1$	$3M*B-1$	1
SP-NLMS	$3M*B+1$	$3M*B-1$	1
PNLMS	$6L+1$	$4L-2$	$L+1$
M-Max-PNLMS	$6M+1$	$4M-2$	$M+1$
SPU-PNLMS	$6M*B+1$	$4M*B-2$	$M*B+1$
SP-PNLMS	$6M*B+1$	$4M*B-2$	$M*B+1$
S-PNLMS	$6M*B+1$	$4M*B-2$	$M*B+1$

3. Results of experiments

To evaluate the performance of the algorithms, we implemented an adaptive filter in MATLAB. The filter has to estimate the predefined echo path's impulse responses specified in the ITU-T Recommendation [35]. The overall step-size parameter, μ_0, is chosen to be 0.1. The control parameters ρ and δ_p are chosen to be 0.001 and 0.01 respectively. For simplicity reason, a double-talk situation is not considered. In the first part of the experiment, we look at the misalignment curves of the M-Max-, SPU-, SP- and S-PNLMS algorithms. They are illustrated in Fig. 1 below. The SPU-updating scheme produces the worst results. The proposed S-criterion considerably outperforms it, especially in terms of the initial convergence speed. The rest of the algorithms have nearly the same convergence and tracking performance. All the algorithms, except the M-Max-PNLMS, show poor results when the M value equals 64. It can be explained by the fact that the active part of the IR is approximately 16ms long. This value corresponds to 128 samples for sampling frequency of 8kHz, therefore, 64 samples are not enough to cover the active region completely. Regarding to the dissimilar selection criterion, the M-Max-PNLMS algorithm can deal relatively well with that problem. The Max-updating formula does not count with the sparse character of the IR. It performs selection according to the distribution of the values of the input vector. Otherwise, its drawback is lower initial convergence speed comparing to the SP-PNLMS algorithm. The second part of our experiment concerns the performance of the adaptive algorithms versus the ones based on the generalized cross-correlation function. They are compared in the context of the time delay estimation.

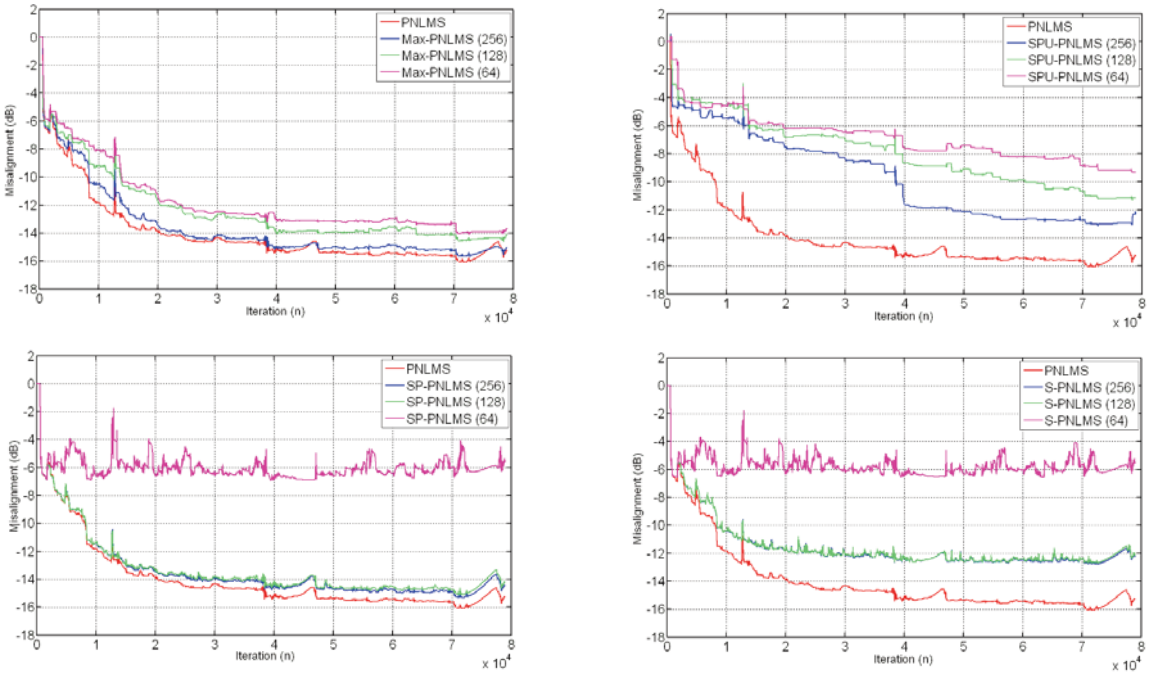

Fig. 1 Misalignment curves of the partial-update algorithms (M = 256; 128; 64)

Mean values of the estimated echo delays Table 3.

[ms]	ROTH	SCOT	CPS-2	HB	M-Max	SPU	SP	S	samples
5	5.1	5.2	5.2	5.2	5.1	5.1	5.0	5.0	40
10	10.3	10.3	10.3	10.4	10.3	10.3	10.4	10.1	80
20	19.6	19.7	20.0	20.0	20.5	20.5	20.1	20.3	160
30	29.3	29.6	30.1	30.0	30.8	30.8	30.1	30.2	240
50	49.0	49.7	49.4	49.8	51.3	51.3	50.3	50.1	400
100	98.1	99.4	98.8	99.6	102.5	102.5	100.5	100.6	800
200	196.2	198.8	197.6	199.1	205.1	205.1	201.3	201.2	1600
300	294.2	298.1	296.4	298.7	307.6	307.6	301.8	301.9	2400

4. Conclusion

The presented paper is a comparative study on the partial-update algorithms and their application to the time delay estimation. When delivering the VoIP service in the packet-switching network, it is important to have the value of the echo delay under control. The increasing transmission delay associated with packet data transmission can make a negligible echo more annoying. Therefore, it is suggested using the echo assessment algorithm based on the reduced complexity partial-update adaptive filters. If the estimated echo is considerably delayed, it can be audible to the user. As a decision, an additional attenuation has to be placed to a particular channel in order to activate an echo canceller that removes the echo. The experiments show a reliable performance of these algorithms. Their precision only suffers at the initial stage when the adaptive filter's coefficients have not converged to the optimum value yet. According to the ITU-T Recommendation G.168, this period should not last more than one second. Taking into account the fact that the generalized cross-correlation algorithms operate in the frequency domain and use advantages of the fast Fourier transform, further computational savings for the adaptive filters can be achieved. It can be done through the multi-delay filters that outperform their time domain counterparts in terms of convergence rate and complexity. Therefore, the multi-delay filters and their implementation aspects are the next subject to our research of the adaptive filtering theory.

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Stanislav Lichorobiec *

DEVELOPMENT OF ALTERNATIVE PROJECTILE TO DEACTIVATE AN IMPROVISED EXPLOSIVE DEVICE – PIPE BOMB

The article describes a possibility of dealing with the problem represented by an improvised explosive device in the form of a pipe bomb so that the problem may be solved quickly and reliably, i.e. so that the pipe bomb may be deactivated without explosion. The article describes the development of an alternative projectile that will replace the water content in the water gun; thus it will make it possible to remove metallic end caps closing pipe bombs so that the bombs can be disassembled without explosion, and subsequently to subject the dismantled parts to forensic examination to detect a designer of the improvised pipe bomb.

Key words: Improvised explosive device, pipe bomb, alternative projectile, water gun

1. Introduction

To the most insidious improvised explosive devices in bomb disposal practice belong those that contain so-called fragmenting components, such as various metallic subjects in the form of beads, rollers, small nuts and nails embedded into an explosive material and so-called pipe bombs. A pipe bomb is a metallic pipe filled with an explosive material in the form of high explosive, primary explosive, most frequently homemade propellant, or pyrotechnic composition.

The explosive material that is enclosed in a casing and brought to detonation usually causes the rupture of the casing and spray of its particles – fragments that then have destructive effects. This is called the fragmentation, or splinter effect of explosion [1].

For instance, fragments from the exploding metallic pipe bomb, in which a rapid explosive material was used, have the velocities equal approximately to the velocity of a projectile from a military riffle within the distance of several meters from the point of detonation, i.e. about 700–900 m/s; they move on their deadly trajectories straight as far as a barrier. They either reflect from the barrier, or enter into it, or penetrate through it. If they do not reach the barrier within a distance of about 100 m, then their velocity will decrease and they will fall to the ground [1]. These fragments may directly endanger the bomb disposal specialist even if protected by a heavy bomb disposal suit, and may break through e.g. the frontal part of the helmet protected only by reinforced and hardened plexiglass. The front of this part of the suit has the lowest splinter protection coefficient, and in case of breaking through it, the specialist's face and/or hands that are protected only partly by a so-called ballistic overlap, see Fig. 1, may be injured [5]. Splinters of the metallic covering of the pipe bomb casing, where rapid explosives exploded – e.g. high explosives, are owing to the action of huge temperatures and pressure during explosion twisted, torn, deformed and sharp-edged. When a slow explosive is used – e.g. a propellant, splinters of larger size are formed on the contrary; they are not deformed, narrowed and sharp-edged so much. About one half of total explosion energy released by explosion will be consumed for rupturing the metallic covering of the casing itself. However, if the strengthened casing containing the rapid, or slow explosive material was cut, or crimped regularly, then final fragments will have the thus formed shape, size and corresponding weight and kinetic energy.

Fig. 1 EOD-8 heavy bomb disposal suit

In this way, substantially improved splinter effects will be obtained as well. As already mentioned at the beginning, if however the explosive article consists of an explosive material, into which

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small metallic subjects are embedded, e.g. beads from bearings, small nuts or nails, then a considerable so-called shrapnel effect will be achieved [2].

Such insidious improvised explosive devices can be secured against manipulation in the case of their detection, and their explosion can be timed. For bomb disposal specialists this is an indication that in the vicinity of them it is not advisable to stay. In the course of pipe bomb disposal it is necessary to work quickly, effectively, and to avoid explosion. For this reason, the identification methods and the disposal process itself must be shortened to minimum.

Whereas for the identification of a pipe bomb various means can be used, including a portable X-ray device, when identification photographs of a specific structure can be obtained in a very short time, the process of deactivation and disposal is not so simple.

Mostly it is the case of a metallic pipe closed at both ends with metallic end caps. The initiation of explosive filler is made through wire inputs to the initiator itself either through the body of the pipe, or through one of the end caps. As for size, what is meant is a metallic pipe of the length of about 30 cm, the diameter moving from 30 to 60 mm and the wall thickness ranging from 2 to 4 mm. The explosive filler is very variable. A broad scale of explosives can be used, ranging from a propellant – black powder, pyrotechnic explosive compositions, through homemade very efficient primary explosives of the type of acetone peroxide – ACP, or hexamethylene triperoxide diamine – HMTD, to high explosives for military and industrial uses, e.g. delaborated trinitrotoluene – TNT from found military artillery ammunition, Permonex, or Danubit, stolen from some mine or quarry [3]. In Figs. 2 and 3 there are improvised explosive devices manufactured from pipe bombs used or found in Israel.

A similar pipe bomb was used not long ago in the Czech Republic as an improvised explosive device for the extortion of money under threat of the use of it as delayed-action bomb in places with high concentration of people. As for structural design, a steel pipe

Fig. 2 Body belt of Israeli suicide

Fig. 3 Improvised explosive device from Israel

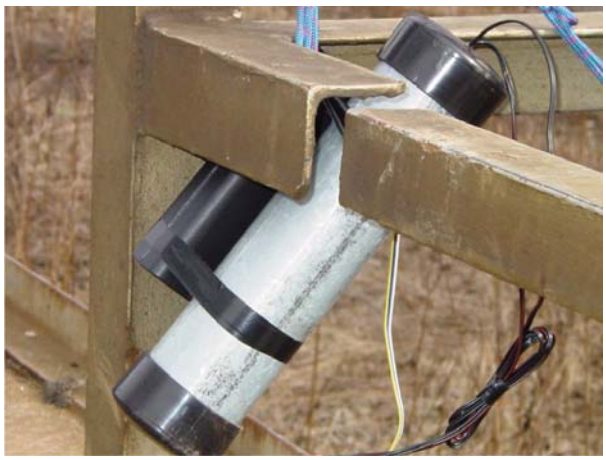


Fig. 4 Found pipe bomb

Fig. 5 After partial delaboration

having the diameter of 62 mm and the wall thickness of 4 mm was taken; this was more than enough for the creation of sufficient fragmentation effect at explosion. It contained about ¾ kg of home-made explosive – acetone peroxide (ACP). Fortunately, this metallic pipe was closed with relatively easy-to-dismantle plastic plugs of black colour, see Figs. 4 and 5.

I say fortunately because this explosive, which is one of very efficient primary explosives and which belongs to the group of organic peroxides, is made of highly volatile substances – acetone, hydrogen peroxide and hydrochloric acid, or sulphuric acid. This is a substance highly sensitive to mechanical stimuli, such as friction and impact. It is not very chemically stable; it is highly volatile and has the ability to recrystallize spontaneously, reacts to flame and spark, has a high initiation capacity and high brisance. Its detonation velocity moves in the range from 3000 to 5500 m/s, depending upon the density of a produced substance. It is a white, crystalline substance that explodes even when being manipulated carelessly, when the explosion of the whole volume occurs as a result of breaking merely one of the small crystals [4].

As already mentioned above, it was possible to remove the plastic coverings and to dissolve carefully the mentioned primary explosive in acetone. However, a question arose concerning the procedure if the pipe would have been closed with metallic screwed-on end caps, because any attempt to screw them off could result, in the case of this explosive used as filler, in explosion, injury or death of the bomb disposal specialist.

2. Development of Alternative Projectile

Thus it was necessary to solve the problem of how in any way to remove remotely – to shoot metallic end caps down from the pipe bomb without the explosion of the pipe bomb, so that the improvised explosive device deactivated like that could be subject to forensic examinations to obtain evidence for a possible finding of its designer.

If we consider pipe bomb demobilization, two fast methods can be taken into account. As for the first method, an elongated cumulative charge will be used and the pipe will be cut by the cumulative jet; a possibility of detonation wave transmission to the used explosive embedded in the pipe may however occur, and most likely the explosion of the whole pipe bomb will take place [3]. As for the other method, we shall try to remove one of screwed-on end caps and thus to dismantle the pipe bomb and to pour the explosive content out or to deactivate it in another non-explosive way. Attention was then paid to the latter variant – i.e. non-explosive removal of the end cap and thus preservation of possible relevant evidence for further forensic examination. As a tool for the removal of the end cap a water gun was chosen. It is used in the invasive dismantling of improvised explosive devices by means of the directional waterjet. The proper water filled projectile however was not able to throw off the screwed-on end caps. For this reason, an alternative projectile, which would be able without any risk to throw off the end cap without activation of the explosive filler of the pipe bomb and thus its explosion, began to be developed. Water guns of types VORO 98 of Slovak production and RADC – Royal Arms, of USA production, see Fig. 6, were chosen because in both the types as a driving filler for water ejection was used a designed special 12/70 gauge cartridge, used usually as charge in weapons of the type of shotgun; the cartridge can be modified advantageously for the design of an alternative projectile.

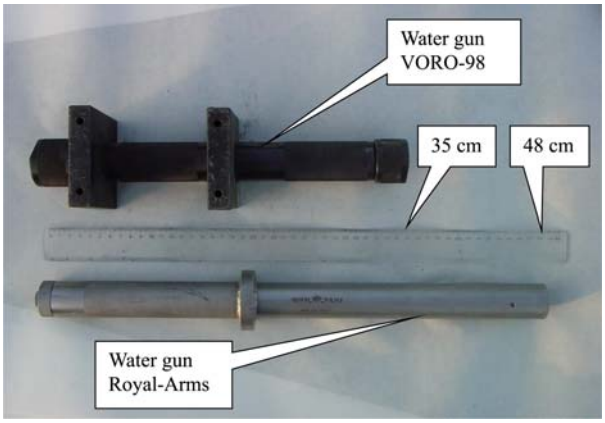


Fig. 6 Comparison of sizes of both water gun types

The alternative projectile must fulfil the following parameters:
- 100 per cent operating reliability in shooting down the screwed-on metallic end cap in the case of pipe bomb,
- the powder filler sufficient for achieving the required operating pressure at a shot,
- non-vulnerability of the surroundings after work performed, i.e. a steel piece cannot be used as uniform projectile that can reflect non-controllably to any point in space, but such projectile is to be used that will disintegrate after work performed, i.e. – shot projectile,
- the shot projectile must be sufficiently compact so that the full burning out of the powder filler can occur and sufficient pressure can develop during the whole time of projectile flight inside the barrel, and thus a suitable muzzle velocity of this projectile, which will be then able to remove the metallic end cap, can be achieved,
- absence of sparking in the course of shooting down the end cap, i.e. the minimization of risk of initiation of the explosive, or the igniting filler inside the pipe bomb,
- easy availability of all the materials that are necessary for the manufacturing of the alternative projectile.

As I have already mentioned, for the design of the alternative projectile, a 12/70 gauge cartridge was used, for which the cartridge chambers of both chosen water guns for shooting water were modified. This cartridge is adjusted to electrical initiation by initiator or to initiation by fire by means of timed safety fuse. The original powder filler for water shooting was used – powder Lovex; so that the alternative projectile may fulfil all determined parameters, a shot working filler composed of metallic microbeads used in metal-working plants to work metallic products by a so-called sand-blasting technology was selected after various experimental tests.

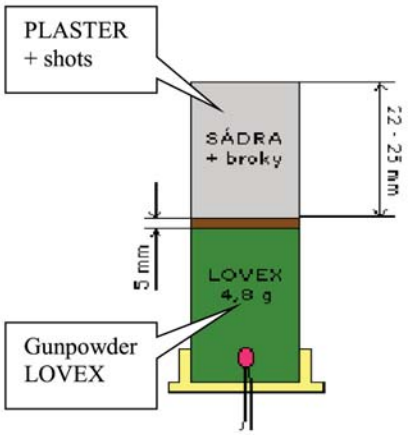


Fig. 7 Design of alternative projectile

Fig. 8 Real alternative projectiles

As a binder, dental plaster was selected. It reliably binds steel microbeads together in one whole, compacts the entire projectile and when being shot, it ensures the non-sparking action of steel microbeads in the course of shooting down the metallic end cap of the pipe bomb.

Fig. 9 Position of water gun Royal-Arms before shooting

As the best ratios of the mixture of plaster and microbeads for the formation of the alternative projectile the ratios of 1 : 1 for the test projectile AS-1 and of 1 : 2 for the test projectile AS-2 were selected. A diagram of structural design and real manufactured alternative projectiles can be seen in Figs. 7 and 8.

For the imitation of the pipe bomb in tests, common water pipes of the length of 30 cm and the diameter of 1 ½″ (32 mm) and 2″ (64 mm) were used; for the mounting of metallic end caps minimally five threads were cut so that the end cap might hold on its whole thread surface.

Of several possible angles of approach of the water gun to the pipe bomb just before the shooting down of the end cap, an angle of 20°, see Fig. 9 turned out to be the most effective.

At the projectile developed like that and at the proved angle of approach of the water gun, the complete shooting down of the end cap was regarded as sufficiently well done task, see Figs. 10 and 11.

In Figs 13 and 14, there are examples of insufficient result of shooting the end cap down, as given in Table 1 - no effect or the end cap not shot down, only a hole.

Figs. 10 and 11: Effective shooting down of the end cap from the pipe bomb

Figs. 13 and 14: Insufficient result of shooting down the end cap

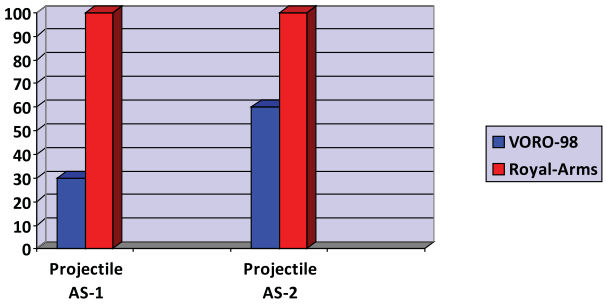
Results that were achieved with the specific water guns and the developed alternative projectiles are compared in Table 1 and plotted in Graph 1.

Results of tests with water guns and specific types of alternative projectiles — Table 1

Test No.	Type of projectile	Type of water gun	Pipe size	Result
1.	AS-1	VORO-98	1 ½″	No effect
2.	AS-1	VORO-98	1 ½″	End cap shot down
3.	AS-1	VORO-98	1 ½″	End cap not shot down, only a hole
4.	AS-1	VORO-98	1 ½″	No effect
5.	AS-1	VORO-98	1 ½″	No effect
6.	AS-1	VORO-98	2″	End cap not shot down, only a hole
7.	AS-1	VORO-98	2″	End cap shot down
8.	AS-1	VORO-98	2″	End cap shot down
9.	AS-1	VORO-98	2″	End cap not shot down, only a hole
10.	AS-1	VORO-98	2″	No effect
11.	AS-1	Royal-Arms	1 ½″	End cap shot down
12.	AS-1	Royal-Arms	1 ½″	End cap shot down
13.	AS-1	Royal-Arms	1 ½″	End cap shot down
14.	AS-1	Royal-Arms	1 ½″	End cap shot down
15.	AS-1	Royal-Arms	1 ½″	End cap shot down
16.	AS-1	Royal-Arms	2″	End cap shot down
17.	AS-1	Royal-Arms	2″	End cap shot down
18.	AS-1	Royal-Arms	2″	End cap shot down
19.	AS-1	Royal-Arms	2″	End cap shot down
20.	AS-1	Royal-Arms	2″	End cap shot down
21.	AS-2	VORO-98	1 ½″	No effect
22.	AS-2	VORO-98	1 ½″	End cap not shot down, only a hole
23.	AS-2	VORO-98	1 ½″	End cap shot down
24.	AS-2	VORO-98	1 ½″	End cap shot down
25.	AS-2	VORO-98	1 ½″	End cap shot down
26.	AS-2	VORO-98	2″	End cap shot down
27.	AS-2	VORO-98	2″	End cap shot down
28.	AS-2	VORO-98	2″	No effect
29.	AS-2	VORO-98	2″	End cap shot down
30.	AS-2	VORO-98	2″	End cap not shot down, only a hole
31.	AS-2	Royal-Arms	1 ½″	End cap shot down
32.	AS-2	Royal-Arms	1 ½″	End cap shot down
33.	AS-2	Royal-Arms	1 ½″	End cap shot down
34.	AS-2	Royal-Arms	1 ½″	End cap shot down
35.	AS-2	Royal-Arms	1 ½″	End cap shot down
36.	AS-2	Royal-Arms	2″	End cap shot down
37.	AS-2	Royal-Arms	2″	End cap shot down
38.	AS-2	Royal-Arms	2″	End cap shot down
39.	AS-2	Royal-Arms	2″	End cap shot down
40.	AS-2	Royal-Arms	2″	End cap shot down

3. Conclusion

From this research project on coping with the insidious improvised pipe bomb using a developed alternative projectile for water guns, several facts can be determined.



Graph 1: Representation of efficiency of water guns with specific types of projectiles

When a water gun VORO-98 is applied, it is possible to use merely special shot ammunition designated AS-2, when the hit rate, i.e. the complete opening of the pipe bomb and shooting down of the end cap can be determined to be about 60%. In the case of the other type of used shot charge AS-1, any complete burning of powder filler of the charge will not occur, because the shot projectile is not probably consistent enough. Individual grains of unburned powder were found before the muzzle of the water gun. The cluster of shots in the barrel vibrates, its kinetic energy decreases, and thus only a slight or partial opening of the tube bomb takes place. The complete shooting down of the end cap occurred only in 30 per cent of cases.

In the case of water gun Royal-Arms, a 100 per cent success rate of both developed special shot fillers was achieved. At the presented mixing ratios between iron microbeads and plaster, the complete opening of tube bomb and the complete shooting down of end cap always occur. By using the mixture having the plaster/shot ratio of 1:1 or 1:2, the shot projectile produced like that was sufficiently consistent to cause the complete burning of powder filler, and thus sufficient pressure generation during the flight of shot cluster in the barrel. The sufficient muzzle velocity of the shot projectile was achieved; as a consequence the metallic end cap of the pipe bomb was shot down. This is essentially possible owing to the barrel of the water gun Royal-Arms which is sufficiently long for the longer acting of the pressure of gas on the shot projectile; the length being by 1/3 greater than in the water gun VORO-98. Naturally, the fact that the interior of the barrel is hard-plated with chromium, and thus has much better quality, plays its role as well. In contrast to the water gun VORO-98, any ricochet of shots does not occur inside the barrel, the cluster of shots does not vibrate and thus does not lose energy.

Dental plaster reliably forms a compact whole with metallic shots, coats them, and produces a plaster cloud when being shot. Thus it prevents the development of sparks due to the impact of iron microbeads on the metallic body of the pipe bomb and limits the initiation of filler of the pipe bomb prone to bursting into flame or explosion as a result of this possible sparking.

In conclusion I state that if the pipe bomb is initiated through one of end caps, it is suitable to shot just this end cap, because together with the shooting down of this end cap, wires with the initiator are drawn away from the pipe bomb, i.e. outside the explosive filler of it. The risky handling of the initiator in the used explosive is avoided. This fact was often confirmed in tests. In addition, it can be stated that never the explosion of experimentally used filler of the pipe bomb occurred, regardless of whether some propellant, including black powder, pyrotechnic composition, or high explosive had been used. Homemade types of high explosives and primary explosives were not used in the tests owing to a high risk associated with explosive manufacturing and handling.

It follows from the above-presented knowledge and experience that as far as the deactivation of an improvised explosive device – pipe bomb is concerned; a water gun Royal-Arms with both developed alternative projectiles is an absolutely reliable solution for bomb disposal specialists.

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ANALYSIS OF FOREST FIRE BEHAVIOUR BY ADVANCED COMPUTER FIRE SIMULATORS

Computer modelling of dangerous phenomena related to fire in forest or in wildland-urban interface is an important tool to support emergency planning for such complicated events. In this paper, the use of FARSITE (Fire AReа SImulaTor), adapted for real conditions in Slovak Paradise National Park (Slovakia), and WFDS (Wildland-urban interface Fire Dynamics Simulator) for simulation of forest fires and fires in wildland-urban interface is demonstrated. Computer reconstruction of an especially tragic destructive forest fire happened in 2000 as well as simple examples of automobile fire in wildland-urban interface are illustrated.

Keywords: computer fire simulation, forest fire behaviour, FARSITE, FDS, WFDS

1. Introduction

Unwanted forest fires and fires in wildland-urban interface (WUI) are known as highly dangerous destructive phenomena threatening people's lives and causing great vegetation and property damages. Forest fires devastate badly natural scenery, eco-systems and environment of the landscape afflicted by fire. Advances in information technologies stimulate the development of computer systems capable to simulate fire spread and its spatial and temporal behaviour to support fire management decisions. Such systems can be used for fire prevention and planning purposes, for education and training, but also for operational purposes facing active fires. Computer simulation can also be used as a means to analyse the effectiveness of suppression strategies and tactics taking into account existing infrastructure and specific regional conditions. It can be useful also for past fire events reconstruction to better understand the circumstances that lead to fatal tragic incidents and great losses of values and property during the fires [16, 27, 37 38, 44]. Several advanced forest fire simulators (e.g. the FARSITE, WILDFIRE, FIRESTATION, FIREMAP, WFDS, FIRETEC, FIRESTAR, CAFME systems) have been developed for such purposes. Mostly they are based on empirical and semi-empirical fire spread models suitable for simulation of more extensive forest fires being applicable also for operational purposes and realized on currently available computer equipment. However, some of them utilize physical models which allow to capture more of complexity of burning process in smaller spaces with higher spatial data resolution. Since physical models are based on numerical solving complex differential equations, they require specialized high-performance computational environment operating in parallel [26].

In this paper, we demonstrate the use of two advanced simulators, the FARSITE (Fire ARrea SImulaTor) and WFDS (Wildland-urban interface Fire Dynamics Simulator) systems, which are representatives of both classes of simulation systems. FARSITE is illustrated by results of the reconstruction of one especially tragic forest fire which happened in 2000 in the Slovak Paradise National Park (Slovakia). During the fire, dozens of hectares of unique forests in Three Hills Natural Landscape Reservation were burnt off and six people died. We adapted FARSITE for real fire conditions and studied reasons which made the fire so tragic and destructive. For such purposes, we made detailed analysis of the region to detect dangerous tendencies of fire propagation and risky places in the territory. The mentioned tragic consequences of the fire in Slovak Paradise in 2000 stimulated the forest fire research in Slovakia. Research focusses both on new as well as on existing means and know-how applicable for fire prevention, planning and fire-fighting in Slovak forests. Several national research institutions began a joint research project covering also the study of computer fire simulation as a means for fire management decision support.

The use of WFDS is illustrated studying the interaction between automobile fire and vegetation fire sometimes occurred in WUI. Since Slovakia belongs to countries with high forest cover (about 45% of total area; 23% from that are national parks and other protected areas) and to countries with highest automobile production per capita in Europe, the number of automobiles and their concentration grow rapidly and automobile fires have become a significant part of registered fires in Slovakia [4, 6, 28, 29, 31]. Moreover, at eastern Slovak border (which is also the EU border, the great part of which is covered by wild forest), terrain automobile patrols are inevitable for border protection, which makes readiness for possible failures and fires particularly significant. From these reasons, national consortium of research and fire-fighters teams was established to solve practical problems of fire safety, including automobile fire safety and particularly automobile-in-WUI-fire safety.

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For these purposes, in 2009 and 2010, a series of full-scale automobile fire experiments was carried out in testing facilities of Fire Protection College of the Ministry of Interior of Slovak Republic in Povazsky Chlmec (Slovakia) and in two experimental tunnels of Scientific Research Coal Institute in Stramberk and in Ostrava (Czech Republic) [17, 28, 32, 34, 43] to gather data required for subsequent computer simulation of various possible automobile fire scenarios [17, 41–43]. The primary objective of these experiments was to measure gas and surface temperatures to gather data for validation of computer simulations of the tested automobile fire scenarios and to obtain better knowledge about ignition and burning of a single automobile and about the fire spread from one vehicle onto other vehicles, or onto other structures or vegetation.

2. FARSITE simulation for past fire event reconstruction

FARSITE [5, 30] belongs to the best forest fire simulators based on semi-empirical fire spread models. We studied mathematical foundations of methods implemented in FARSITE and in other selected simulators [8–12, 15, 39, 40] to make possible the proper use of FARSITE and its adaptation for intended computer fire simulation in Slovak conditions. Its applicability for Central European forests was assumed because it has already been tested in several countries of Mediterranean and Western Europe (see e.g. [2, 3, 18, 19]). Since the standard NFFL fuel models [1] were originally developed for conditions of top fire season outside Europe, new original fuel models had to be defined to fit specific vegetation conditions in Slovak Paradise (see Figs. 1–2). In order to achieve reliable computer fire reconstruction, real input data describing topography, vegetation cover and meteorological situation were gathered [21, 33, 35, 36] and FARSITE was calibrated to real fire conditions. An original fuel model representing real vegetation at the site was defined (see Table 1) validating the fuel parameters by field investigations and laboratory evaluation of collected vegetation samples [21, 35].

To answer two questions, why the burning area in first hours had such a significantly elongated oval shape and why the people were entrapped by the fire, we investigated various fire scenarios and made a big number of particular FARSITE simulations to better understand specific fire behaviour in given region. The simulation results confirmed increasing fire danger just in the vicinity of the place of human tragedy [7, 13, 14, 16] (see Fig. 3 and Tables 2–3). FARSITE showed its great potential for fire danger analysis and computer reconstruction of past fire events, as well as for fire prevention and planning purposes.

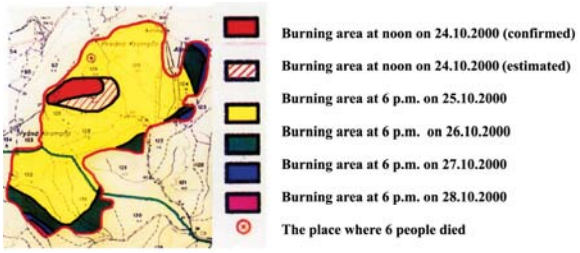
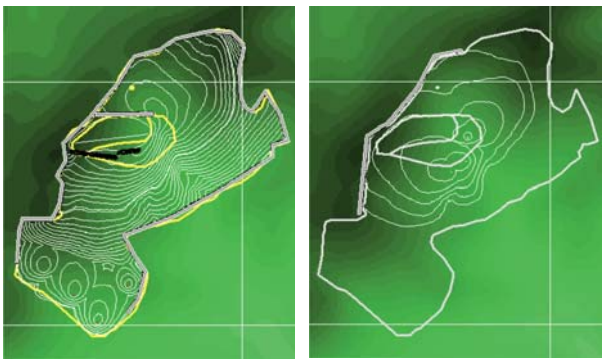


Fig. 1 Fragment from the fire documentation [20]



(i) *(ii)*

Fig. 3 (i) First two days simulation (1-hour perimeters plotted); (ii) simulation initiated at three points (1.5-hour perimeters plotted)

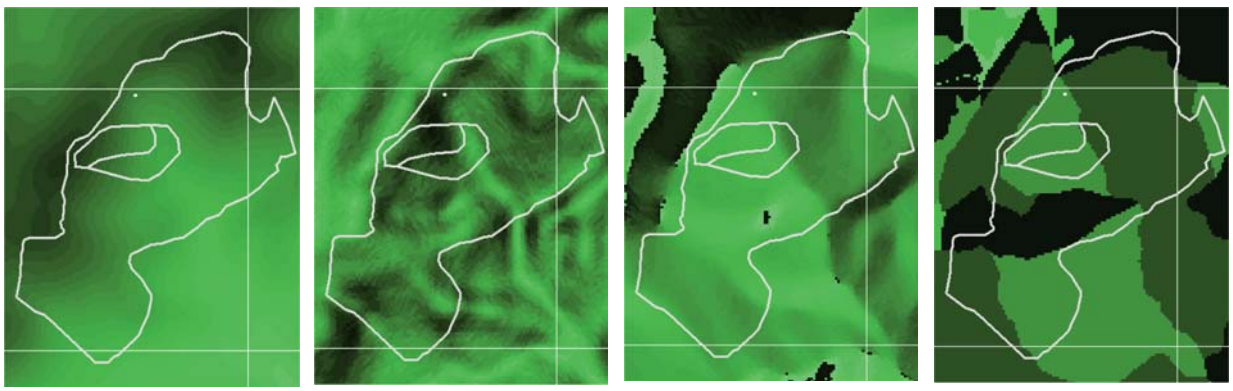


Fig. 2 Spatial data layers (elevation, slope, aspect, canopy cover) for the fire simulation

Fuel model parameters where DFL is 1h, 10h and 100h dead fuel loading [t/ha], LHFL is live herbaceous fuel loading [t/ha], LWFL is live woody fuel loading [t/ha], DFSTR is 1h dead fuel surface to volume ratio [1/cm], LHFSVR is live herbaceous fuel surface to volume ratio [1/cm], LWFSVR is live woody fuel surface to volume ratio [1/cm], FBD is fuel bed depth [m], DFEM is dead fuel extinction moisture [%], HCDF is heat content of dead fuels [kJ/kg], and HCLF is heat content of live fuels [kJ/kg] Table 1

DFL 1h	DFL 10h	DFL 100h	LHFL	LWFL	FSVR 1h	LHF SVR	LWF SVR	FBD	DFEM	HCDF	HCLF
5.842	3.499	0.339	0.473	1.57	77.8	49.0	49.0	32	27	18600	18600

Fire behaviour parameters where ST is simulation time [month/day time], RoS is rate of spread [m/min] and FL is flame length [m] Table 2

ST	RoS	FL
10/24 10:00	0.6	0.7
10/24 11:00	0.1	0.3
10/24 12:00	0.3	0.5
10/24 13:00	0.3	0.5
10/24 14:00	0.4	0.5
10/24 15:00	1.7	1.0

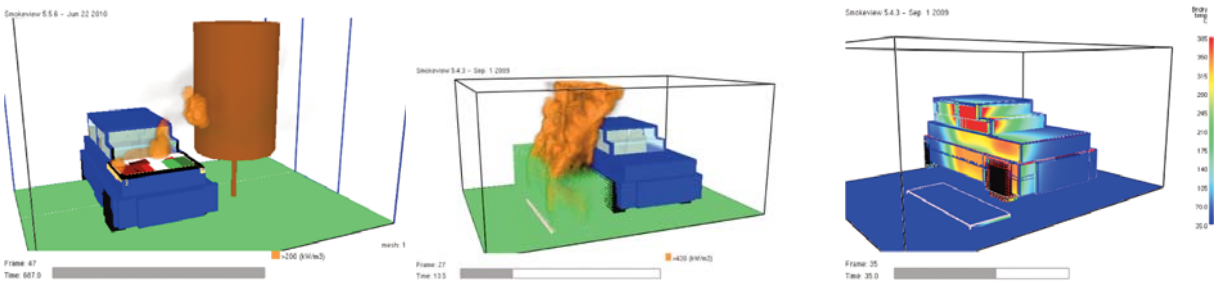
Fire size where ST is simulation time [month/day time], PL is perimeter length [km] and BA is burned area [ha] Table 3

ST	PL	BA
10/24 9:00	0.71	0.00
10/24 10:00	0.94	4.11
10/24 11:00	1.32	5.44
10/24 12:00	1.73	6.44
10/24 13:00	2.24	8.22
10/24 14:00	2.72	11.59
10/24 15:00	3.24	16.51
10/24 18:00	3.87	26.74
10/24 21:00	4.27	34.09
10/25 21:00	6.31	69.99

3. WFDS simulation of automobile fire in WUI

Computer simulation of automobile fires in WUI belongs to the most complex simulation problems at all. However, in recent years several advanced simulation programs capable to model some features of the problem have been developed. WFDS [22-24] was developed as an extension of the well-known Fire Dynamics Simulator [25] which is meant to simulate fires in human structures. The WFDS system allows to include vegetation fuel into fire simulation and to utilize increasing computational power of current computer systems even for more complex fire scenarios. In this part, two typical fire scenarios which occur during automobile fires in WUI are illustrated: the first scenario represents the spread of fire ignited in automobile engine compartment onto the crown of a near standing tree and the second one simulates the spread of shrub fire onto a near standing automobile. Firstly, we made FDS simulation of automobile fire ignited in engine compartment which provided a realistic description of typical automobile fire scenario [41, 42]. The simulation reproduced the main features of the fire spread correctly and provided realistic fire spread description in the vicinity of the vehicle engine compartment. Next, we incorporated the automobile fire behaviour into WFDS simulation using the heat release rate (HRR) behaviour and observed material parameters of bodywork varnish as input data for both fire scenarios.

The first fire scenario configuration is shown in Fig. 4i, where the automobile bodywork is modelled explicitly and the automobile fire behaviour is prescribed by the HRR values obtained from the FDS simulation. The fire above the bodywork interstices is represented by six stripes of prescribed HRR located bellow the



(i) *(ii)* *(iii)*

Fig. 4 (i) Automobile fire spread onto a tree; (ii) shrub fire spread onto an automobile and (iii) impact of shrub fire on automobile in the distance 10 cm and wind speed 2 m.s^{-1}

front window corresponding to the FDS simulation. In order to simulate the fire spread on the lid, the varnish fire HRR is prescribed distinctively for the particular parts of the lid which ignited one after another. The used tree crown parameters correspond to tree with the moisture content 20%, surface to volume ratio 4000 m^{-1}, fuel element density 520 $kg.m^{-3}$ and crown bulk density 1.5 $kg.m^{-3}$. The crown of cylindrical shape has the following parameters: the crown height 3.4 m, crown base height 1 m and crown base width 1.6 m. Initial temperature is set to 35 °C. The whole calculation domain (600 × 450 × 360 cm with the resolution 5 cm and 10 cm) was decomposed into three meshes (120 × 30 × 72 cells, 60 × 15 × 36 cells and 60 × 15 × 36 cells); the finer resolution was used in the region including the lid and parts in the wind speed direction where the main part of fire transfer was expected. Simulation of 100 s of fire required 7–8 hours of CPU time at Intel Q9550, 2.83 GHz CPU. The influence of wind speed and the distance between automobile and vegetation on the tree crown ignition was investigated (see Table 4).

Time of crown ignition for different values of wind speed and tree distance — Table 4

	0 cm	20 cm	40 cm	70 cm	100 cm
0 $m.s^{-1}$	735 s	no ignition	no ignition	no ignition	no ignition
1 $m.s^{-1}$	673 s	736 s	842 s	no ignition	no ignition
2 $m.s^{-1}$	659 s	685 s	726 s	825 s	no ignition

The second fire scenario configuration is shown in Fig. 4ii, where the shrub is represented by a rectangular block consisting of four particle classes (see Table 5). We studied the influence of wind speed and the distance between vehicle and shrub on the automobile ignition. The computational domain dimensions are 500 × 250 cm in y- and z-coordinates varying from 500 to 600 cm in x-coordinate (in dependence on the distance) with the resolution 5 cm. Simulation of 60 s fire required 18–35 hours of CPU time at Intel Q9550, 2.83 GHz CPU. Table 6 shows the impact of the shrub fire onto the automobile (see also Fig. 4iii).

4. Conclusion

Computer reconstruction of past forest fire events and the use of advanced fire spread simulators can help fire management as means of strategic fire-fighting and planning decision support.

Material properties of shrub fuel classes where SFC is shrub fuel class, SVR is surface to volume ratio [1/m], VM is vegetation moisture [%], VD is vegetation density [kg/m^3] and VBD is vegetation bulk density [kg/m^3] — Table 5

SFC	SVR	VM	VD	VBD
1	4000	50	520	1.5
2	2667	50	520	0.25
3	889	50	520	0.25
4	500	50	520	0.25

The FARSITE reconstruction of the fire in Slovak Paradise National Park, during which six people were entrapped by fire, demonstrates that FARSITE, adapted for specific Slovak conditions, is able to reproduce fundamental fire behaviour features. Fire propagation analysis indicates especially dangerous fire spread tendencies and increasing fire danger just in the vicinity of the place where the people died. The simulation results also helped exclude some earlier assumptions related to the way of the fire origin and showed several probable ways how the fire could start. Since quickness and efficiency of fire suppression and fire management answer to fire event is very important, such advanced simulation tool, operating almost in real-time on commonly available computers, allows the fire management to test various aerial and/or ground attack tactics and strategic fire-fighting decisions.

The use of advanced fire simulation tools to study automobile fires in forest (or in WUI), validated by full-scale automobile fire experiments carried out, is a challenging not yet solved problem. In this paper, two WFDS simulations of automobile fires in WUI are described. The knowledge obtained during the series of fire experiments conducted in Slovakia and in Czech Republic in 2009 and 2010, and the subsequent FDS simulation of various automobile fire scenarios are used to study the spread of automobile fire onto near standing vegetation and vice versa. The first scenario represents the spread of automobile fire onto the crown of near standing tree. The FDS simulation allows to simulate the fire behaviour in the vicinity of the automobile in detail with high resolution. Then, the simulation results are incorporated into WFDS simulation, performed on the larger scale with lower resolution, in order to study the impact of automobile fire on near standing tree. In the second fire scenario, WFDS was used for studying the spread of shrub fire onto near standing automobile. Ignition of combustible automobile components is a very complicated and complex process which will require more detailed research. However, it was demon-

Automobile components ignited by shrub fire for different values of wind speed and shrub distance — Table 6

	10 cm	25 cm	50 cm	75 cm	100 cm	125 cm	150 cm
0 $m.s^{-1}$	tyre	tyre	tyre	tyre	no ignition	no ignition	no ignition
1 $m.s^{-1}$	tyre	tyre	tyre	tyre	no ignition	no ignition	no ignition
2 $m.s^{-1}$	tyre, varnish	tyre	tyre	tyre	no ignition	no ignition	no ignition
3 $m.s^{-1}$	tyre, varnish	tyre	tyre	tyre	tyre	tyre	no ignition

strated that the used approach allows to solve practical problems of great importance for fire safety purposes. The simulation can describe the main fire spread tendencies as well as quantitative fire characteristics providing useful information for the design of automobiles and human structures, the fire safety arrangements and regulations, as well as for the development of fire-fighting strategies in specific conditions. Since the computational requirements of such simulations are significant, proper parallel implementation of typical fire scenarios on clusters of computers is a challenging problem.

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CASE STUDY ON THE SPATIAL DEVELOPMENT IMPACT ASSESSMENT TOOL APPLIED IN THE SPATIAL DEVELOPMENT ENVIRONMENTAL SECURITY ASSESSMENT

The paper deals with the spatial development environmental security assessment employing the Spatial Development Impact Assessment tool and the geographical information systems. The first part includes a more detailed description of the Spatial Development Impact Assessment tool and ESRI – ArcInfo, which were the basis for elaborating the case study. The case study is presented in the second part of the paper, which includes the spatial development environmental security assessment for a fictitious hazardous waste incineration plant located in the zone of Moravian-Silesian region of the Czech Republic. The acquired outcomes are presented in the final part of the paper together with the proposed measures to be taken in order to reduce the potential risk of intended spatial development.

Introduction

At present there are a number of anthropogenic phenomena having the negative impacts on population. Spatial development causes number of risks [1] which may have negative impacts on balanced relations among spatial conditions and the environment, economic development and integrity of communities of population, i.e. on the sustainable development of territory [2, 3]. Therefore one of the prerequisites of spatial development is the continuous provision of security, i.e. the spatial development environmental security [4].

The Spatial Development Impact Assessment [5] tool has been developed for the above mentioned purpose. The aim of the application is to realistically assess the potential hazard to the environment resulting from spatial development. The tool was developed in compliance with the national legal regulations of the Czech Republic, which makes the impact assessment process acceptable both from technological and legislative aspects.

1. aterials and Methods

The following chapter includes the most significant materials and methods, which were the basis for the presented case study on the Spatial Development Impact Assessment Tool Applied in the Spatial Development Environmental Security Assessment.

1.1 Spatial Development Impact Assessment

Spatial Development Impact Assessment tool for assessing the spatial development environmental security is based on the principle of semi-quantitative assessment of potential negative aspects of spatial development and the areas of their possible impacts. The key part of the tool is the Assessment Process Algorithm, which is based on integrated approach and stems from the algorithms of the Fire & Explosion Index method [6] and the Hazard & Impact Index method [7]. The assessment process algorithm defines basic relations among individual elements of the process, which may be divided into two basic groups: 1) the Hazards Group, which includes individual negative aspects of spatial development [8]; and 2) the Assets Group, which includes individual environmental elements. The algorithm itself consists of individual steps which result in determining the level of potential risk that the environment will be damaged due to intended spatial development (see Fig. 1).

The Catalogue of Hazards and Assets Groups consisting of individual categories and elements is another significant part of the Spatial Development Security Assessment tool. The individual categories of both groups then include partial elements with corresponding index values respecting their levels of hazard (in case of hazards group) and vulnerabilities (in case of assets group). The classification of the Catalogue of Hazards and Assets Groups is shown in Fig. 2.

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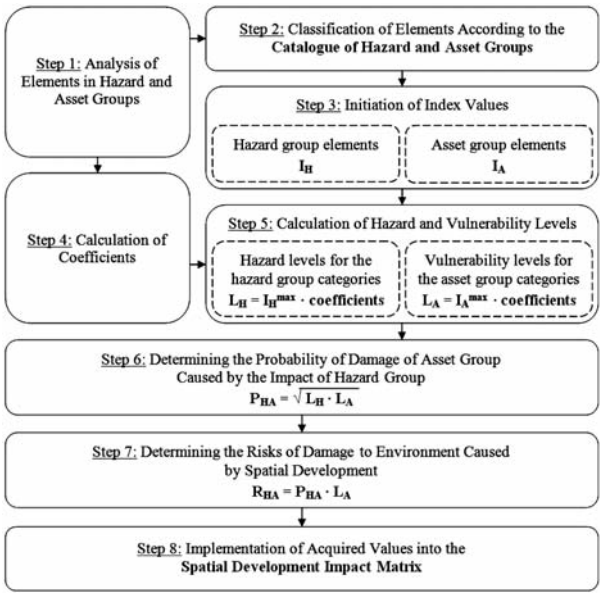

Fig. 1 Assessment Process Algorithm

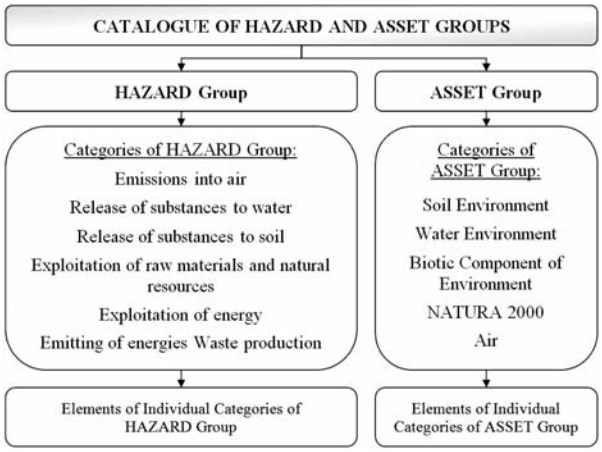

Fig. 2 Classification of the Catalogue of Hazards and Assets Groups

The outcome of the assessment process is the Matrix presenting the potential level of risk of environmental damage caused by intended spatial development (Spatial Development Impact Matrix). The risk is classified into 3 categories. The A Category indicates a low risk, which is assessed as acceptable, i.e. the intended spatial development may be fully brought into effect. The B Category indicates an increased risk, which will have to be reduced, i.e. the intended spatial development may be carried out with increased precautions. The C Category indicates a high risk, which is assessed as unacceptable, i.e. the intended spatial development would seriously damage the environment. Therefore its implementation is not recommended.

1.2 ESRI – ArcInfo

The general applicability of the geographic information system for the spatial development risk analysis is supported by the fact that there are a number of specific applications regarding e.g. the localization of the source of danger, the development of emergency scenarios, and various ways of assessing the combined risks in the territory [9]. The central program tool of the geographical information system (GIS), which will be used for developing the following case studies, is the product of ESRI – ArcInfo Company. It includes more than 200 data processing tools, the vector data analysis, full potential of data administration, the tools for generalizing the spatial data, and many others. It is the top set of applications for the Desktop GIS of the above mentioned company [10]. The mentioned software has been selected, because it is the most frequently used software in the Czech state administration authorities compared to other GIS solutions.

The Primary Basis of Geographical Data (ZABAGED – ZÁkladní BÁze GEografických Dat) serves as a key data source for display, modelling and calculation. It is a digitized topographic model of the Czech Republic derived from the map picture of the base map of the Czech Republic at a scale of 1:10 000 in the S-JTSK grid system (see Fig. 3). The ZABAGED data are divided into planimetric and hypsometric data. The planimetric data include the objects classified into a number of classes (e.g. residences; economic and cultural facilities; roads; supply networks and pipelines). The hypsometric data include 2 m contour lines. The data were elaborated by the Czech Office for Surveying, Mapping and Cadastre [11].

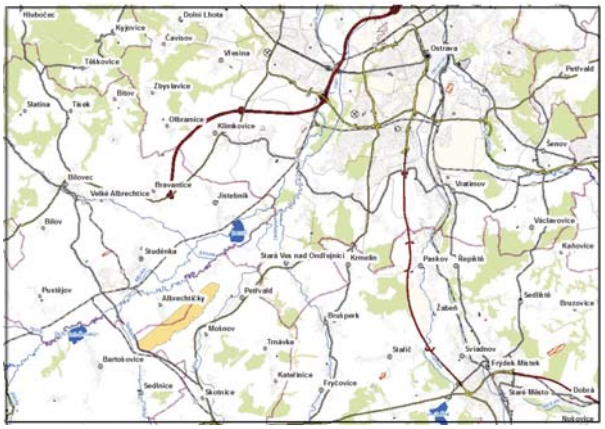

Fig. 3 The Primary Basis of Geographical Data (ZABAGED)

The Digital Basis of Water Management Data (DIBAVOD – DIgitální BÁze VOdohospodářských Dat) is another data source. It is a working reference name for the proposed catalogue of objects as a thematic water management upgrade of ZABAGED. It is a reference geographic database developed primarily from the corresponding levels of ZABAGED and targeted at creating the thematic cartographic outcomes with the themes of water management and

water protection. The administrator and provider of data is the T.G. Masaryk Water Research Institute in Brno. The data are provided free of charge [12]. Some data concerning the classification of protected landscape are taken from the Agency for Nature Conservation and Landscape Protection.

2. Results of Case Study

The following chapter is aimed at the case study on the Spatial Development Environmental Security Assessment for a fictitious hazardous waste incineration plant located in the zone of Moravian-Silesian region of the Czech Republic. The acquired outcomes are presented in the final part of the paper together with the proposed measures to be taken in order to reduce the potential risk of intended spatial development.

2.1 Analysis of the Selected Element of Spatial Development: Description and Outcomes

The element of spatial development, which has been selected for the case study, is a large capacity incineration plant of hazardous wastes. Its specification is as follows:

- Intended activities: treatment, storage and incineration of hazardous wastes;
- Capacity of incineration plant: 15 tons/day (1 rotary furnace);
- Received wastes: solid, pasty, liquid;
- Type of received waste: industrial hazardous wastes; medical and veterinary wastes;
- Waste dosing: grap, elevator, nozzle.

Based on the analysis of the above mentioned functional element of spatial development the particular negative environmental aspects have been assessed. Then the aspects have been inserted into the Catalogue of Hazards and Assets Groups and classified into individual categories (see Table 1).

The Outcomes of the Analysis of Spatial Development Element — Table 1

Category	Elements
Emissions into air	Occurrence of stationary sources of air pollution – extra large incineration plants
Release of pollutants into water	Treatment of oil substances, extra hazardous substances, radioactive emitters and radioactive wastes
Release of pollutants into soil	Treatment of extra hazardous substances
	Treatment of hazardous substances
Emission of energies	No environmental aspect occurs in this category
Waste production	Production of municipal waste
	Production of inert waste

2.2 Analysis of the Selected Area of Interest: Description and Outcomes

The area of interest has been selected in order to verify the Spatial Development Impact Assessment tool and its possible interconnection with GIS. The area of interest is located in the Moravian-Silesian Region of the Czech Republic, east of the regional town of Ostrava, between the villages of Doubrava and Karviná (see Fig. 4).

The area is located in the close proximity of a primary road and a railway. Therefore it is easily accessible. Two zones have been created, 500 m and 1 km far from the facility, for better visualization of the facility located in the area. The zones only serve for easier interpretation of the ratio scale of the displayed area, otherwise it would be difficult to read it (the incineration plant itself covers the area of 160x200 m).

Fig. 4 The Area of Interest Displayed in Maps

The analysis of the area of interest has identified the occurrence of individual environmental elements, which may be damaged in the process of implementing the intended spatial development. Then the information has been inserted into the Catalogue of Hazards and Assets Groups and classified into individual categories (see Table 2).

2.3 The Outcomes of the Spatial Development Environmental Security Assessment

Upon inserting the acquired information into the Catalogue of Hazards and Assets Groups it was possible to assign appropriate index values (I) to the initiated elements. When creating the Spatial Development Impact Assessment tool the index values have been set by 20 expert assessors, who deal mainly with the issues of spatial planning, environmental protection and spatial development environmental impact assessment. The index values for the categories of the Assets Group are known to the users upon earmarking the area of interest into the GIS, as the GIS is interconnected with the database of the Catalogue of Hazards and Assets Groups.

The Analysis of the Area of Interest: Outcomes Table 2

Category,	Elements
Soil Environment	Meadows and Pastures
Water Environment	Water sources second level protection zones
Biotic Component of Environment	Other Areas Without Special Protection
NATURA 2000	Neither the area of European significance, nor the bird area occur in the assessed area
Air	Air is highly polluted in the area (the average annual immissions of PM10 exceed the permitted immission limit values of 40 μg/m^3)
Cultural Heritage	No element of cultural heritage occurs in the assessed area

Then it was possible to calculate the coefficients by inserting the selected parameters into the pre-set formulas. The final coefficients consider variable parameters, which are e.g. range, frequency, and probability.

The acquired index values are then inserted into the formulas for calculating the levels of hazard in the categories of Hazards Group (L_H) and the levels of vulnerability in the categories of Assets Group (L_A). The level of each category has been calculated as the product of maximal index values of initiated elements classified in a particular category and the corresponding coefficients ($L = I^{max} \cdot$ coefficients).

The next step was aimed at determining the probability (P_{HA}) of damage to the categories of Assets Group caused by the categories of Hazards Group. The probability of damage has been mathematically determined through goniometric mean of the hazards and vulnerabilities of the assessed categories ($P_{HA} = \sqrt{L_H \cdot L_A}$).

The final step in the assessment process was to determine the level of risk of potential damage to the environment caused by the intended spatial development (R_{HA}). The calculation of such risk is based on general platforms [13, 14, 15]. The level of risk has then been determined as the product of vulnerability level of a particular category of Assets Group and the probability corresponding to the assessed categories of Hazards and Assets Groups ($R_{HA} = L_A \cdot P_{HA}$).

The outcomes of the spatial development environmental security assessment are presented in the Spatial Development Impact Matrix (see Fig. 5).

The final levels of risk of potential damage to the assessed environmental categories in the area of interest caused by the impact of the environmental aspects of intended element of spatial development are classified into the following 3 risk categories:

- *The A Category* (0.1 – 0.45) – The environmental aspects of spatial development in this category are of low potential risk of damage to the environment in the assessed area (*risk is acceptable*). Even highly hazardous elements may be located in the area when following common safety measures. Achieving this category of risk is a necessary prerequisite for building the new industrial facilities.
- *The B Category* (0.46 – 1.75) – The environmental aspects of spatial development in this category are of increased potential risk of damage to the environment in the assessed area (*it is necessary to reduce the risk*). The planned spatial development may be carried out in the area. However, it is necessary to take an increased precaution into consideration in order not to damage the environment. In case the final level of risk is getting near the upper limit, it is recommended the planned spatial development to be re-analyzed and possibly re-planned and re-assessed.
- *The C Category* (1.76 – ∞) – The environmental aspects of spatial development in this category are of high potential risk of

SPATIAL DEVELOPMENT IMPACT MATRIX		Categories of Hazard Group				
		A_A	A_W	A_S	A_E	A_P
Categories of Asset Group	Soil Environment		1,47	1,47		1,09
	Water Environment		2,08	2,08		1,61
	Biotic Component of Environment	0,55	0,62	0,62		0,41
	NATURA 2000					
	Air	2,18				
	Cultural Heritage					

Fig. 5 Spatial Development Impact Matrix

Legend:
A_A – Emissions into air
A_W – Release of pollutants into water
A_S – Release of pollutants into soil
A_E – Emission of energies
A_P – Production of wastes

Note: The crosshatched field indicates that the assessed categories either do not relate to each other or one of them is not assessed. Therefore the level of risk is not determined for such a relation.

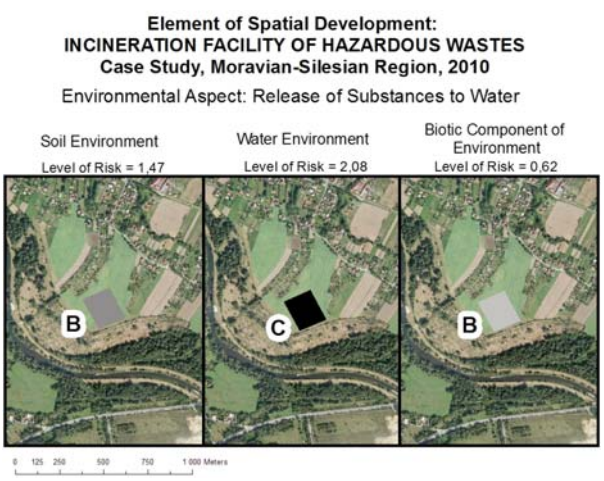

Fig. 6 Display of Assessment Outcomes in GIS

damage to the environment in the assessed area (*risk is unacceptable*). This category indicates high probability that the planned spatial development will cause extensive and serious damage to the environment. It is recommended not only to look for another, less vulnerable area, but also thoroughly review the range and hazardousness of intended spatial development.

The display of outcomes of the environmental security assessment of the intended spatial development in the GIS is demonstrated on the environmental aspect of spatial development entitled "Release of pollutants into soil" (see Fig. 6).

Conclusion

The aim of the above presented case study was to assess the spatial development environmental security for a fictitious hazardous waste incineration plant located in the zone of Moravian-Silesian region of the Czech Republic. Based on the acquired outcomes it is possible to classify the potential risk of damage to the environment caused by spatial development into three categories.

The risk is acceptable (the A Category) in case of a potential negative impact of intended incineration plant on the biotic component of the environment – such a risk need not be further treated. The risk, which has to be reduced (the B Category), has been detected when analyzing the impacts of incineration plant on soil environment. The unacceptable risk (the C Category) has been detected when analyzing the impacts of incineration plant on water and air environment. Therefore it is not recommended to carry out the intended spatial development in the given area and either look for more suitable territory, or locate another element of spatial development into the area of interest, which is not of such a high risk for this particular area.

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Ondrej Zavila – Lenka Herecova – Dalibor Micek – Tomas Hejzlar *

NUMERICAL SIMULATION OF HEAVY AND LIGHT POLLUTANTS MOTION AS A TOOL OF EXPERIMENTAL DATA VERIFICATION

Computational Fluid Dynamics (CFD) codes including software ANSYS Fluent represent worldwide accomplished group of tools for fluid mechanics phenomena numerical simulations. These codes are based on numerical solution of partial differential equations that are not to be solved analytically. The only way of numerical data verification is to execute comparison with experimental data respecting the same boundary conditions. This article deals with experimental data verification by using CFD code ANSYS Fluent 12.1.4 as a tool for numerical simulations. Comparison of pollutant's plume and its scattering considering different density of each pollutant is the main point of the problem. Results are presented by means of commented graphs and pictures.

Key words: Aerodynamic Tunnel, Computational Fluid Dynamics (CFD), Physical Experiment, Numerical Model, Pollutant

1. Introduction

Toxic gas leak industrial accidents in the past proved how dangerous these accidents could be for living environment and inhabitance. That is why it is advisable to prevent these accidents before they happen. When designing and optimizing preventive measures, it has been very helpful to utilize some tools of mathematical (numerical) modelling. Numerical modelling enables the investigator to predict a possible way of running the accident and its impact on the surrounding area. Research on physical and chemical properties of the gaseous chemical substance, whose presence is assumed at the accident, is also one of the main points of preventive measures creation process.

For this purpose, low scale physical models including simple or complex terrain and source of pollutant inserted could be used for investigation of gas pollutant motion and scattering phenomena depending on defined physical properties. For example, it is possible to observe and then even formulate general principles of different pollutant motion and scattering in real atmospheric boundary layer that way.

Physical experiment results could finally be used for verification of numerical models, CFD codes for example. In case of equivalence between experimental data and numerical data which is up to investigator's mind and demands, numerical model is considered to be verified successfully and can be used for the next progress and investigation of the issue only by way of numerical simulation. Of course, the simulations could cover a low scale experiment as well as the real scale experiment. Final results obtained by this kind of analysis could be very helpful in the process of designing industrial building's safety and security systems, searching for the ideal location of gas detectors or choosing and securing the most sufficient ways for evacuation. One of many possible comparative issues is the main point of the following lines.

2. Physical Experiment in Aerodynamic Tunnel

In 2008 physical experiment of light and heavy pollutant's motion and scattering in a low speed aerodynamic tunnel was executed. Flow field was vertically stratified as simulating the real air velocity profile out in the atmospheric boundary layer. Low speed aerodynamic tunnel belongs to the Aerodynamic laboratory of Academy of Science of the Czech Republic (nearby Prague, the capital city of the Czech Republic). Main objectives of the experiment were:

1. *Proving* the functionality of a gauging system when detecting chosen gas pollutants;
2. *Detection* of pollutant plume position and range measuring concentration in points;
3. *Optimization* of pollutant concentration measuring method in points of a space.

The experiment was executed in the gauge section of the low speed aerodynamic tunnel (see *Fig. 1*). Gauge section has the following dimensions: 2 [m] (length), 1.5 [m] (width) and 1.5 [m] (height). The space of gauge section represents simple flat terrain with a chimney placed right in the middle of the floor, i.e. in the distance of 1 [m] from the gauge section threshold and 0.75 [m] from both sidewalls (*Fig. 3*). Chimney (small nozzle) serves as a source of the air-pollutant mixture. The nozzle has cylindrical shape with following dimensions: 20 [mm] (height), 6 [mm] (outside diameter) and 3.5 [mm] (inside diameter, i.e. diameter of

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Fig. 1 Gauge section of the aerodynamic tunnel

Fig. 2 Inlet part of the aerodynamic tunnel with turbulent elements

Fig. 3 Pollutant source on the floor and measuring probe

the leak). The air-pollutant gas mixture was generated in simple "System for pollutant generation" that was placed out of the tunnel.

"System for pollutant generation" consists of air pump with constant set flow rate and glass flow chamber where permeation tubes with liquid pollutant were placed inside [2]. Pollutant permeates through the walls of permeation tubes in gaseous state, mixes with flowing air and is drifted through the hose to the nozzle placed in the tunnel gauge section floor. The source of pollutant is defined to be constant (concentration of pollutant in mixture is constant for a few hours until the permeation tube is empty).

There was generated vertically stratified logarithmical profile of a horizontal air flow velocity. The reference value of air flow velocity was 1.5 [m/s]. This profile was measured experimentally using LDA (Laser Doppler Anemometry) method [4]. The flow field in the tunnel is not stratified thermally. Turbulence, generated by turbulent construction elements on the tunnel's floor of the inlet section, simulates real atmospheric conditions (*Fig. 2*). Temperature in the tunnel was about 17 [°C] (the air for gauge section was sucked from outdoors), temperature of the air in laboratory was 22 [°C] ("System for pollutant generation" took the air from indoors), the air pressure was 98 200 [Pa] and air relative humidity was 50 [%]. Values of concentration in points were determined by taking the sample of the air from the gauge section and its analysis by CO_2 laser photoacoustic spectrometry system (Edinburgh Instruments, type WL 8 – GT) [5]. Photoacoustic signal (values of voltage) is detected and transformed into the values of mass fraction (concentration) based on the calibration curve for certain pollutant.

This physical experiment resulted in three series of concentration data measured in several points of space in the aerodynamic tunnel gauge section. The following gas pollutants were measured: Methanol CH_3OH ($\rho = 1.43$ [kg/m^3]); 1,1,2,2-Tetrachlorethylene CCl_2CCl_2 ($\rho = 7.01$ [kg/m^3]); Acetone CH_3COCH_3 ($\rho = 2.46$ [kg/m^3]).

3. CFD Numerical Simulation

Advanced software ANSYS Fluent 12.1.4 belongs to the most widespread CFD codes all over the world [1],[3]. In this case, it was used for the numerical simulation of heavy and light pollutant motion and scattering. The code is based on numerical solution of partial differential equations set by the finite volumes numerical method. Equations represent physical law of weight conservation, law of momentum conservation and law of energy conservation. Software includes wide range of sub-models that enable the investigator to solve wide range of issues considering various differing boundary conditions.

Geometry shape, grid and types of boundary conditions were defined using the software Gambit 2.2.30. Geometry grid consists of 443 850 cells. Cells are smoothed vertically to the floor of the gauge section and horizontally to the pollutant source (nozzle). "RNG k-ε model" of turbulence was chosen for basic stratified flow field calculation and "Species transport model" was used for transport of species calculation. Gauge section inlet boundary condition was defined as "Velocity Inlet", gauge section outlet as "Outflow", floor of the gauge section as "Wall" and sidewalls together with ceiling were marked as "Symmetry". Pressure was set on the value of 98 200 [Pa] and temperature on the value of 300 [K] (16.85 [°C]). Also air flow velocity profile, intensity of turbulence profile, turbulent kinetic energy profile and dissipation rate profile were defined on the gauge section inlet (see equations 1–4):

$$v = 0.2371 \cdot \ln(Y + 0.0001) + 1.3571 \qquad (1)$$

$$I = -0.0673 \cdot \ln(Y + 0.0001) + 0.1405 \quad (2)$$

$$k = 1.5 \cdot (v \cdot I)^2 \quad (3)$$

$$\varepsilon = \frac{1.225 \cdot 0.09 \cdot k^3}{1.4}. \quad (4)$$

In these equations, v [m/s] is the air flow horizontal longitudinal velocity (in direction of X-coordinate), I [%] is the intensity of turbulence, k [m^2/s^2] is the turbulent kinetic energy, ε [m^2/s^3] is the dissipation rate and Y [m] is the vertical length coordinate (axis orthogonal to the plane of the tunnel floor).The leak surface of the pollutant source was defined as "Velocity Inlet". The velocity of the flow through the leak surface was set on about 1 [m/s]. Pollutant source leak velocity has always been a bit different for different pollutants because every pollutant permeates differently through permeation tube (the velocity of permeation, i.e. the pollutant amount leaked per time is different). This issue was solved as steady (time-independent). Calculation accuracy (criterion of convergence) was set on the value 0.0001. Results are presented in figure (*Fig. 4*) and in comparative graphs, where final concentration values at points are displayed.

4. Numerical Data Verification

In *Fig. 5*, *Fig. 6* and *Fig. 7*, XY-coordinates of measured points are displayed. All of them were measured in single vertical longitudinal plane, in which the source of pollutant (nozzle) is located. In *Fig. 8*, *Fig. 9* and *Fig. 10*, comparative graphs of concentration values in points obtained by physical experiment, as well as by numerical model, are displayed. Serial number of each measured point was established with respect to the consecutive order of measurement.

Comparative graphs show similarity between the results of physical experiment and numerical model. The maximum difference between both data sets is one order. The greatest variance can be observed at points that are located close to the pollutant source.

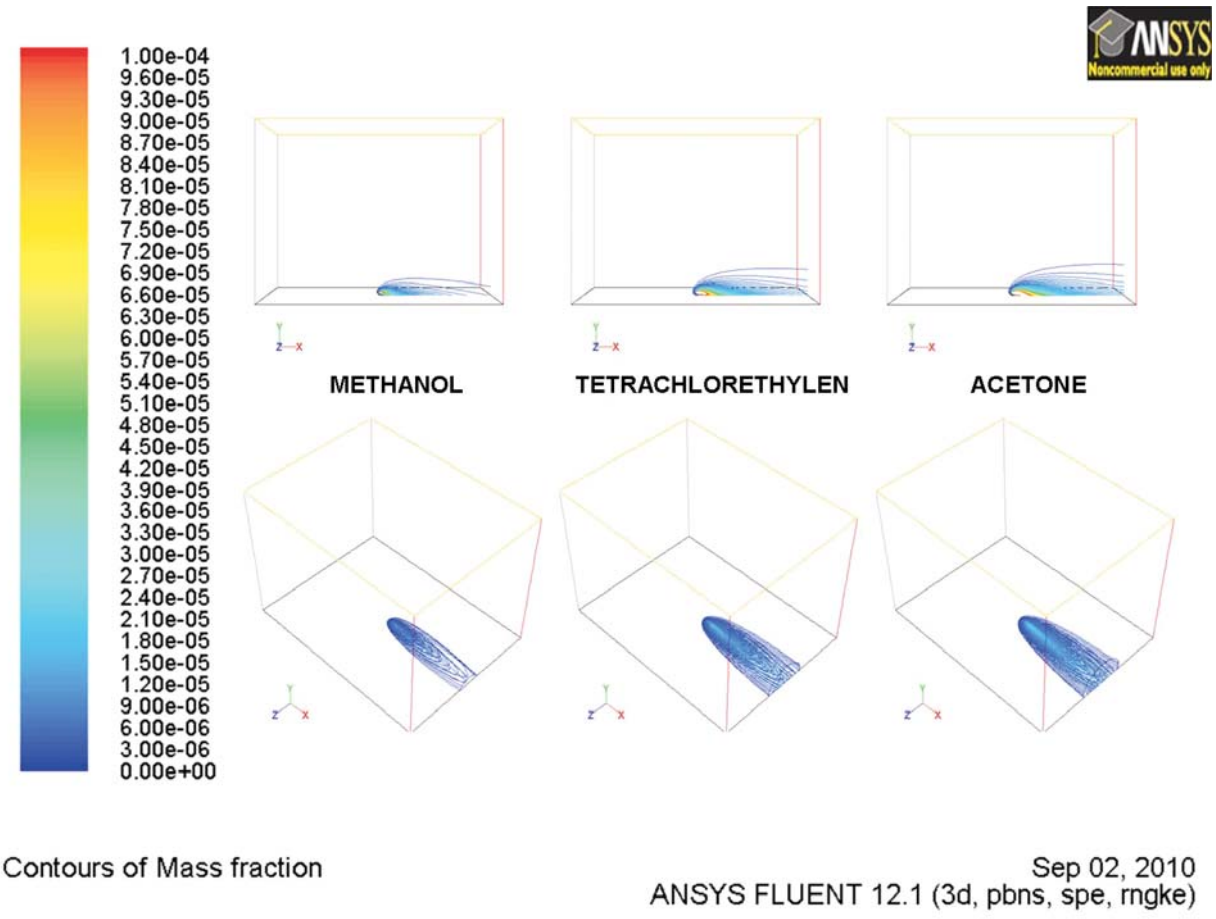

Fig. 4 Contours of mass fraction of Methanol CH3OH, 1,1,2,2-Tetrachlorethylen CCl_2CCl_2 and Acetone $CH3COCH_3$ (ANSYS Fluent 12.1)

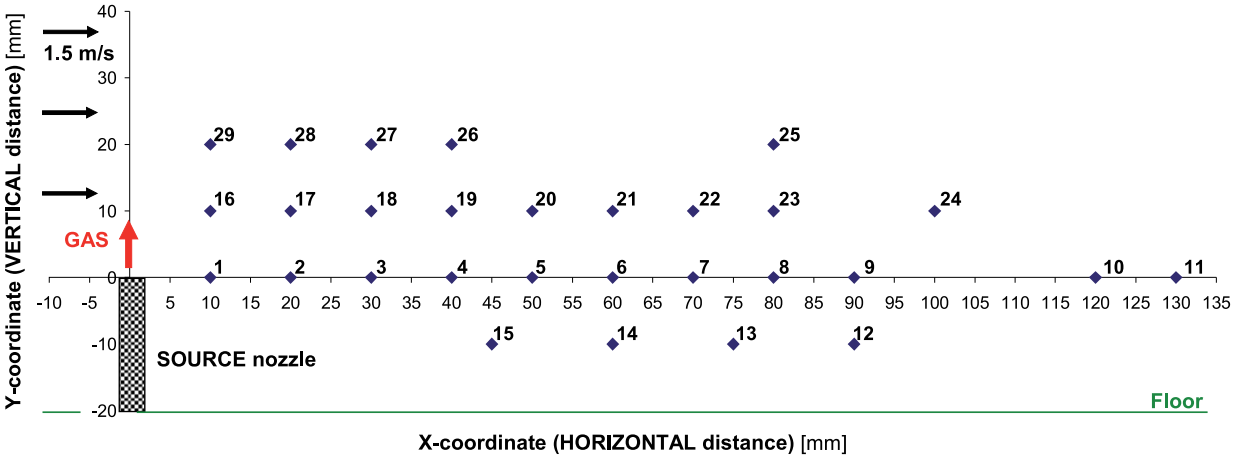

Fig. 5 Methanol CH_3OH (X, Y-coordinates of measured points)

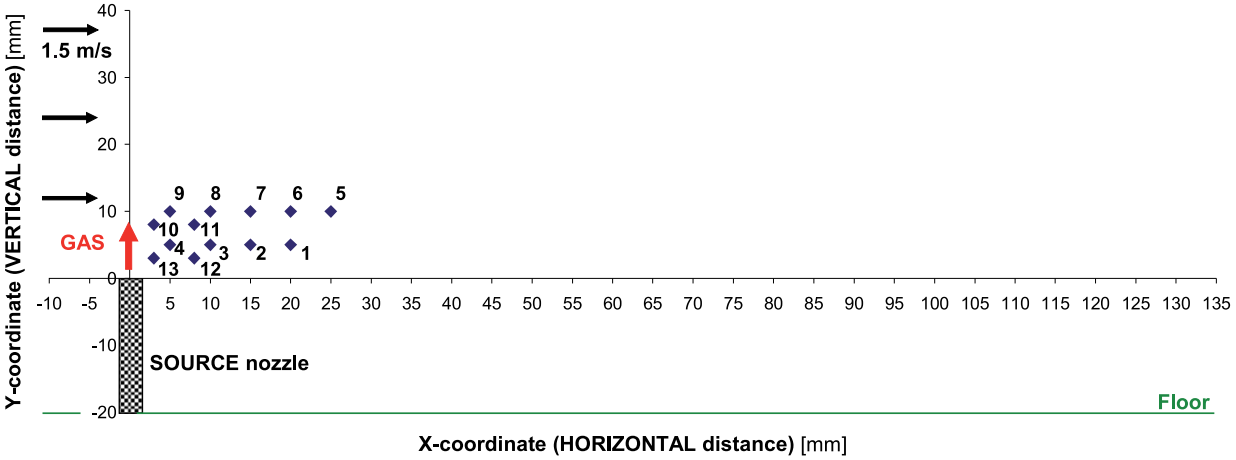

Fig. 6 1,1,2,2-Tetrachlorethylen CCl_2CCl_2 (X, Y-coordinates of measured points)

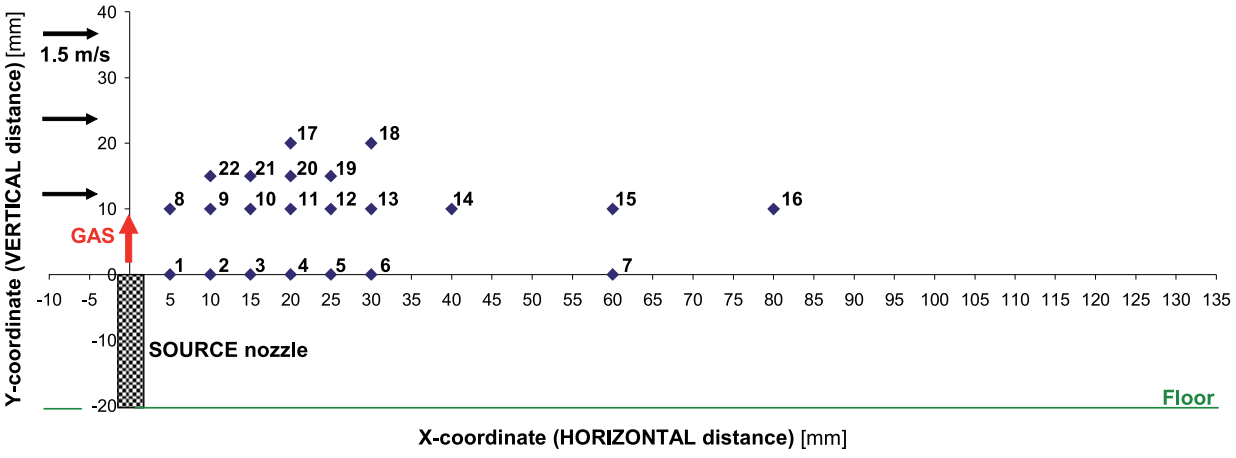

Fig. 7 Acetone CH_3COCH_3 (X, Y-coordinates of measured points)

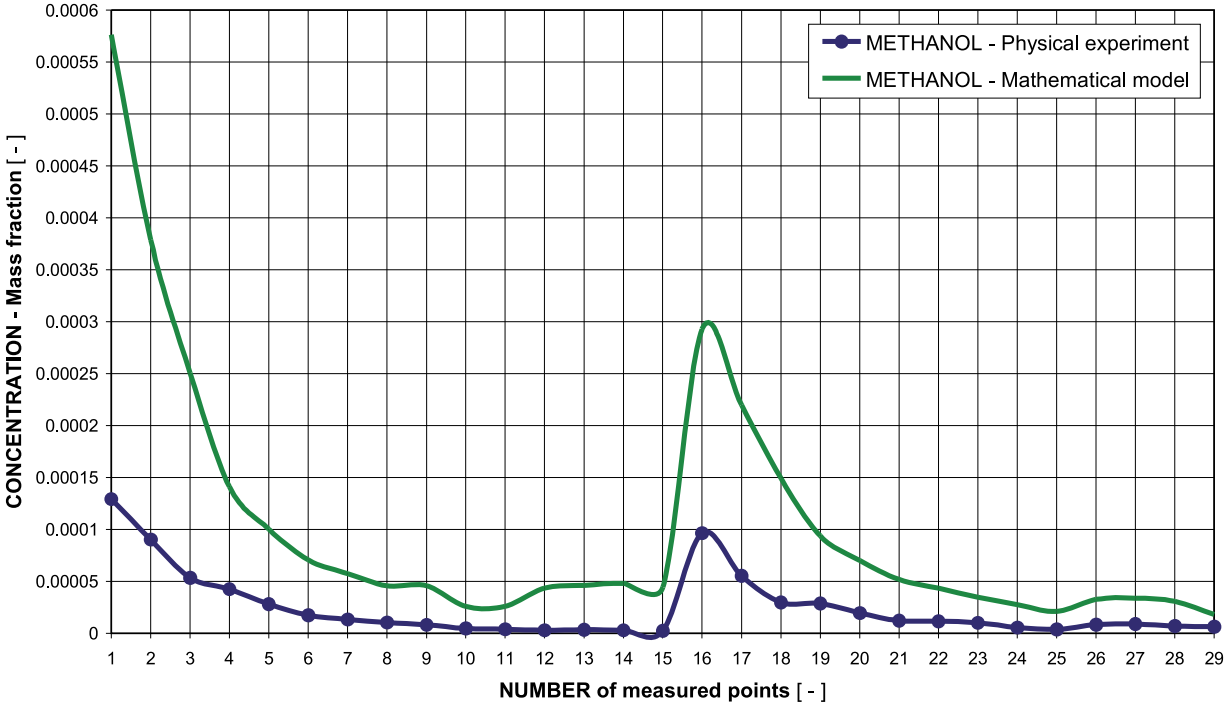

Fig. 8 Methanol CH3OH (comparative graph of physical experiment and numerical model results)

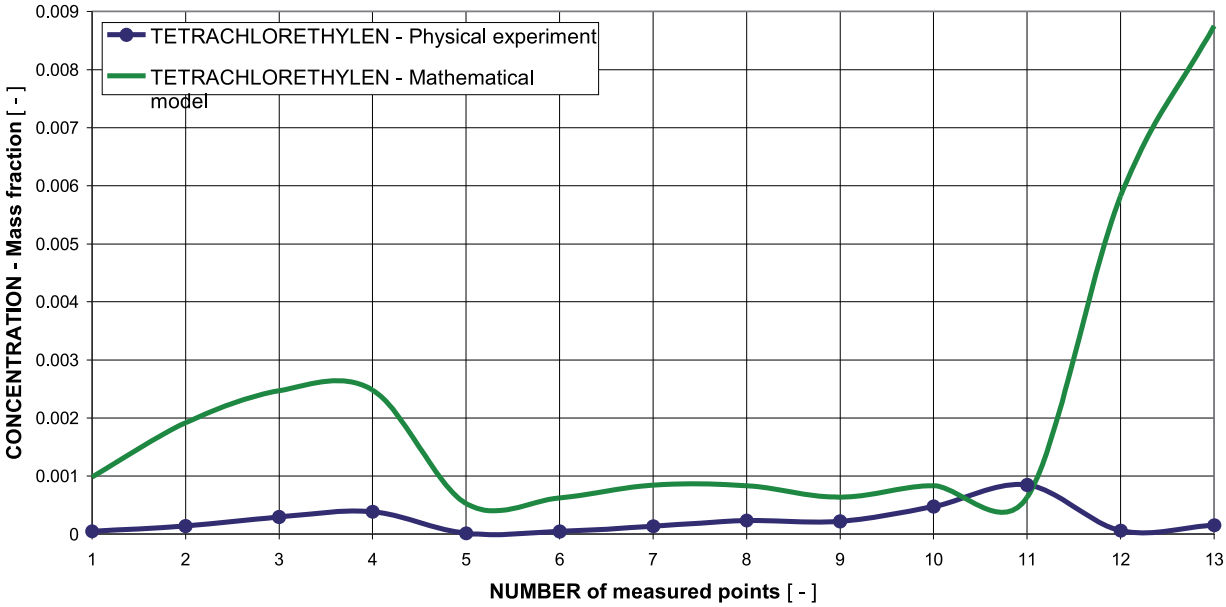

Fig. 9 1,1,2,2-Tetrachlorethylen CCl_2CCl_2 (comparative graph of physical experiment and numerical model results)

In case of Methanol CH_3OH, the greatest variance is visible at points No. 1 – 3 (Fig. 5 and Fig. 8). Air-pollutant mixture plume was probably slightly elevated due to the turbulence behind the source nozzle. At all other points, the variance is minimal. It is still impossible to model the turbulence accurately as it works in the real atmosphere. There has always been some degree of inaccuracy following from the physical experiment as well as from the mathematical model.

In case of 1,1,2,2-Tetrachlorethylene CCl_2CCl_2, both result data sets are very similar. The only exception is represented by the points No. 12 and 13 (*Fig. 6* and *Fig. 9*). Concentration in these

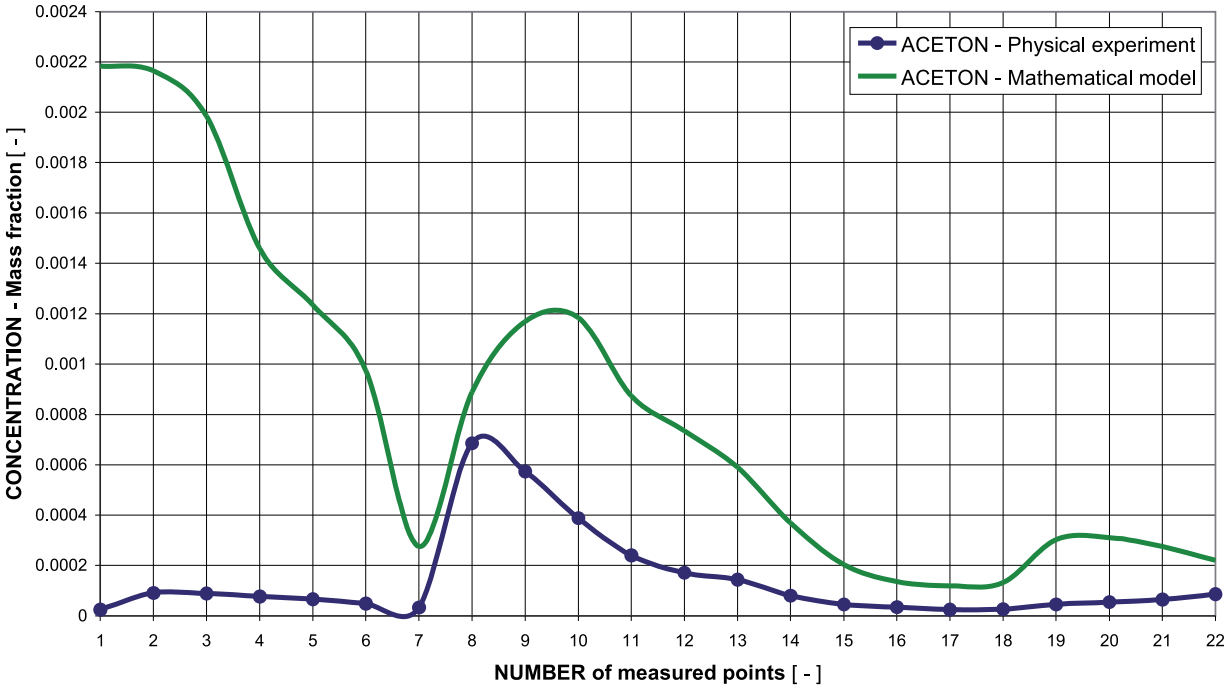

Fig. 10 Acetone CH_3COCH_3 (comparative graph of physical experiment and numerical model results)

two points was measured by the end of the experiment and it can be clearly seen that the permeation tubes (source of pollutant in "System for pollutant generation") were almost empty. That is why the final amount of pollutant was strongly reduced. This fact can be considered to be a methodical mistake during the execution of physical experiment.

In case of Acetone CH_3COCH_3, both result data sets are very similar again except points No. 1 – 6 (*Fig. 7* and *Fig. 10*). Air-pollutant mixture plume was probably again slightly elevated due to the turbulence behind the source nozzle, and declined back after passing greater distance behind the nozzle. At all other points, the variance is minimal.

5. Conclusion

It was proved by physical experiment and numerical simulation that velocity of permeation differs depending on the kind of pollutant. Assuming the constant amount of air in the mixture given by air pump, the amount of pollutant permeated through the walls of permeation tubes is always different depending on the kind of pollutant. This fact is confirmed by pollutant plumes of different sizes and areal ranges (*Fig. 4*). For the reason of pollutant amount variance in every kind of mixture, it is hardly possible to draw comparisons of motion and scattering between heavy and light pollutants based on their density. Heavy pollutant plume (the value of pollutant density is higher than that of air density at constant temperature and pressure) should descent to the ground. Light pollutant plume (the value of pollutant density is lower or approximately equal to that of air density at constant temperature and pressure) should climb. In this case it is impossible to observe any pollutant plume descent or climb. For example, it could be caused by small value of pollutant concentration in the mixture, as well as by the high air velocity in the tunnel gauge section.

Results of physical experiment could be used with success for the verification of numerical model that has been included in software ANSYS Fluent 12.1.4. Based on executed verification, there is an opportunity to work up an analysis leading to physical experiment optimization using CFD tools.

According to both modeling approaches result (see section 4), it can be deduced that numerical model verification by means of physical experiment data was successful, and this kind of numerical model can definitely be used for mathematical modelling of similar issues, considering even more difficult geometry, different pollutant source location and different boundary conditions.

In the future this work can be developed by further similar comparative studies and studies of turbulence, pollutant's motion and scattering theories in real atmosphere, leading to better and more complex understanding of these phenomena.

Acknowledgement

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ECONOMIC SECURITY – A PRINCIPAL COMPONENT OF MULTILEVEL SECURITY CONCEPT IN GLOBAL ECONOMY

Abstract: This paper is focused on the problem of the economic security as the principal component of a multilevel security concept in the present global economy. The authors characterize various theoretical and practical notions of security as the complex phenomenon. The economic security as an integral component of the mentioned security concept is also characterized. The further text is concentrated on the global aspects of economic security, which are depicted in the examples in economies of China, the U.S.A. and the EU.

Key words: Security, Economic security, Crisis management, Instruments and tools of an economic security, Global economic competition

1. Introduction

Nowadays there is a real need to create a new approach to questions related to security as a theoretical issue, as well as a real and practical problem.

The main causes of this can be specified through the changing character of risks and menace threatening not only the individual human security, but mostly the state (or integrated groups of states) security, together with interdependence of the separated economies and economic subjects, correlated to their activities in global economic surroundings.

2. Security

It can be said that the definition of a security and therefore also of an economic security is mostly focused on intentionally. We can also state that Security as a scientific term is used by several scientific disciplines and it is related to many areas of individual's life or life of society itself, too. It should be underlined, that the perception of selected dimensions of security, "securities" social, economic, food, military, etc., is based on the perception of security as a comprehensive summary of several security dimensions, which are synergistic positive or negative influencing each other in its relation to the requirement of safety and keeping the target function of security's object.

In such a perception of security, it is not about multiple securities, but about several aspects of security, which affects the final level of security, or of danger. It is necessary to draw the attention to a possible ambiguity of security's perception, e.g.:

- A system can be secured in terms of existence assumptions conservation of the objective function (for the internal conditions of the system and ambient conditions).
- A phenomenon or system can be secured/dangered in terms of threatening other systems (it is the system's externall effect)
- A subject may perceive threats of its security more sensitively than the real state of the environment and internal system's conditions are, and vice versa.

The source of the presented ambiguity is based on the subjective-objective nature of security as a real state, or perceived threats. Security is a unity of objective and subjective factors. A subjective perception can significantly influence many decisions. Danger perceived as the opposite of security leads to decisions and activities, reducing effectiveness and efficiency of the system (especially in a long-term horizon).

The explicit indication of the security as a situation, which corresponds to the required target behavior and the existence of the assumptions of its sustainability, is used throughout the large number of disciplines.

Šimák and Ristvej distinguish two levels of security – the security of a citizen and security of a society. Security of companies is divided into external (international, military, macroeconomic) and internal (economic, transport, food, health, environmental) security [1].

In the Glossary of Crisis Management, security is defined as a state of social, natural, technical and technological system or any other system which, in specific internal and external conditions, allows a perfomation of the established functions and their devel-

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opment in accodance with the interests of a human and society [2].

Korzenowski [3] presents four elements of a dynamic model of security: an objective situation (threat), subjective perception of this situation, action (decision, action) based on the subjective perception of the situation and the consequences that depend on the objective situation or on the creation of a new objective situation.

Dependence between human security and economic stability is expressed in social relations.

In the old sense of understanding security, it meant a study of threats, using and managing military forces. In the current security concepts, under the pressure of blending and mutual concomitant action of sophisticately structured risks, there is extension of the security agenda, because of possible threats arising from the disturbance of the environment, economy, health and international crime, which significantly affect the human (individual and social) security.

Moran [4] identifies three key factors operating in international interpretation: maintaining trade and capital imbalances, increasing the U.S. dependence on other countries in the field of strategic materials and technologies and declining international competitiveness.

Mesjacz provides the following basic security investigation areas: military, economy, politics, environment and society [5].

Presented classifications and definitions of security can be seeen as an attempt to comprehensive conceptualizing of security concept considering any of its significant dimensions. This is influenced by a subjective assignment of priorities in relation to the classification of objective reality to more or less structured units whose safety have to be assessed. This is, actually, the impact of subjectivisation in defining security that is natural to the character of security.

3. Economic Security

It is just the previously presented necessity of comprehensive perception of all security characteristics that has an effect on opening a dynamic discussion about the issue of economic security as an important dimension of security, which fundamentally affects the overall security level. Various institutes and politicians begin to deal with (mainly from a macroeconomic point of view or if it is possible from a global level) the issues of economic security.

The content of the term “economic security” is evolving. Despite the very limited information sources in available related literature, it is possible to find several different definitions that are often focused only on selected aspects of economic security (They usually define the economic security only at the individual level as a regular access to a sufficient income, or to full citizenship and social protection). In relation to the orientation of this article, there only are definitions that can be applied universally or accentuate the national security or global dimension of economic security.

The Canadian Council on Social Development defines the economic security as a guaranteed and stable standard of living with a neccesary participation level in economy, politics, social policy and culture for the benefit of society [6].

The International Committee of the Red Cross International defines the economic security as a condition for the ability of an individual, household or company to cover their basic needs and necessary expenses in a sustainable way and according to cultural standards [7].

Zeman et al. defines the economic security as a condition in which the economy of object, whose security has to be secured (individual, family, firm, country, alliances of a countries, world, etc.), is not threatened, which reduce in a significant way or would be able to reduce the performance necessity to secure the defense and other security capabilities, social harmony and object’s competitiveness and its individual components (in particular, individual companies) in internal and external markets [8].

The economic security can be viewed from a different perspective as the national security and population, but also in terms of actors performing a certain economic activity.

Then the economic security can be defined as security of economic entities and processes and relations between them, but also it can be seen as the sustainability of processes and relations between economic entities in terms of compliance economic efficiency requirements. We can say that the definitions of economic security are more oriented on protecting against negative impacts, more than on a detection of economic efficiency. The economic security can be defined as:

- A state or situation in which the object’s economy, whose security should be secured, is not exposed to risks and threats that could be significantly reduced (or being educed) the performance needed for a fulfillment of basic functions and achieving its objectives,
- Principles and tools which are intended to protect individuals and society against economic disaster.

Jiang Yong, who deals with China’s economic security, characterises the economic security as a steady growth of people’s living standards, through an economic development. Economic security is seen as the composition of two factors: the competitiveness and independence.

Economic sovereignty should be viewed as a measure of independence of the country and its ability to be resistant against external interventions. It contains: "undistributed" economic authority that is inherent to the country and cannot be shared with other nations and “distributed” economic force that can be shared with other nations. In the economy, souvereignty is a reflection of a domestic market control and governance management of key

industries and enterprises. The biggest negative aspect of purchasing and mergering of foreign capital is their ability to monopolize the market by reducing competition and undermining China's national security. It is also perceived as an unequal approach to domestic companies vs. companies with foreign owners, as the problem of economic security. It is clear that China must adopt a policy of "selective opening". It follows the need for a selection of foreign business that consumes lots of energy or other resources (energy and environmental threats of security). Another factor is the need for "reciprocity". If China has to open its economy, the same actions from these countries towards China are expected, too [9].

Concerning the diversity of denominations and the content of separated components of economic security for a better orientation and classification, it is good to approach the mentioned characteristics of the economic security, by the aspects of the character and origin:

- Object (objects) – whose economic security is monitored and whose economic security has to be secured
- Threats – by which the object of economic security could be affected,
- Resources – tools and measures by which the economic security of the object (objects) have to be secured.

It is possible to agree with Mareš's definition of the economic security as a state where the economy of the object whose economic security has to be ensured (individual, family, firm, country, alliances of a countries, world, etc.), is not threatened, which significantly reduces or would reduce the performance necessity to ensure the defense and other security capabilities, social harmony and object's competitiveness and its individual components (in particular, individual companies) in internal and external markets [8].

In relation to the nature of the alleged definition it can be stated, there is a need to extend it in terms of economic security for the future economic security object's development.

Especially, requirement to ensure sustainable development except ensuring of resources, capacities and efficiency of target-focused system's processes of social-economics system is the most important component of extended frame of economic security.

Therefore, it can be concluded that the definition and assessment and management of socio-economic system is influenced by this issues:

- securing the sovereignty and integrity of socio-economic system's basic elements,
- efficiency and sustainability of target-focused processes,
- operations of socio-economic system and ensuring of resources for building capacities system's operation and it's sustainable development

The mentioned issues are considered according to previously mentioned classification. On the state's level or level of integration clusters, it can be identified following components of economic security: state sovereignty and integrity of socio-economic system's entities, transparency and effectiveness of relationships and processes between them, internal resources of economic growth (e.g. raw material base, technical and technological base, the quantity, structure and efficiency of human resources utilization), sources of external growth and assumptions of further development, socio-economic structure and external political relations, security position of a country, assets outside of a home country and optimization of an external state policies. On the level of economic security instruments which affecting the country or integration cluster it is possible to identify particular instruments of internal and external economic policy and economic diplomacy. These instruments are focused on building relations and economic-political-security position of the country or clusters within the frame of a transnational regions or global economy.

4. Examples of Using an Economic Security Tools by Selected States in Global Context

In spite of supporting the globalization processes, we are witnesses of a paradoxical phenomenon in the global economy, namely the existence of several protectionist measures of major world economies motivated especially by security aspects and consequences of such economic transactions.

The case of the Chinese oil company CNOOC gives us the evidence about links between security, economy and policy. "CNOOC in 2005, tried to buy the American company Unocal, the ninth largest petroleum company in the world. This transaction would allow the Chinese access to a strategic source of natural gas in Southeast Asia and other areas. Although, their interest was motivated commercially and the company's management had very broad autonomy, in relation to the government, the American Congress entered into the matter. Its members argued that it was not a market-conform trade. Seventy percent of the company was owned by China; moreover, Middle Empire was banning the U.S. companies from reciprocal purchases of similar assets in China's home territory. The next chapter contained security and strategic arguments. After all Unocal remained "in the family", because it was bought by the U.S. company Chevron." [10]. The Chinese telecommunication company Huawei, which wanted to make a strategic investment in telecommunications, faced a similar aversion. The U.S. Congress hindered the acquisition of the IT Company 3Com in the amount of 2.2 billion USD because of "concerns about the disruption of national security" [2]. In telecommunications, the position of the two Chinese companies, ZTE and Huawei, is very strong in a global context. In 2009 they reported revenues in amount of 7 and 17 billion USD [11]. Economic and technological power of Chinese companies, together with a political background, causes the fact that these firms are perceived as a security risk. On the other hand, they represent very important suppliers for major companies in the U.S.A. and the EU, by the quality/price ratio (e.g. mobile operators).

In comaparison to the U.S.A., the positive perception of the tender's economic advantages and acceptance of Chinese producers and operators of telecommunications technologies dominates

in the rating proces of similar strategic investments in most European countries.

In principle, two fundamentally different points of view about the way of considering Chinese strategic investments in the global economy can be identified. The Chinese investments can be perceived to be economically attractive, mainly thanks to a thoughtful monetary policy of the Chinese government. Its monetary policy creates perfect conditions for succeeding China in the global fight for limited natural resources and new markets, particularly through the pro export-oriented strategy of state development with the specific role of the state in China's economic system.

There is an increasing global pressure of the U.S. government and the European Commission on the Chinese government which keeps the undervalued Chinese currency in the artificial position. The result is a highly competitive ability of the Chinese producers/exporters. Another effect is the rapidly growing excess of export over import – China has generated huge volumes of financial reserves in U.S. dollars, which they have tried to invest in world financial markets – mainly in raw materials resources. Moreover, the Chinese government assured the U.S. government that it was going to continue on keeping the high volumes of U.S. dollars as the financial reserves of the Chinese economy. By this approach, the Chinese government affects the economic security of U.S.A. and even a global economic security. In principle, it is possible to identify a deliberate usage of economic instruments to ensure a positive trading and payments balance in the development strategy of China. In present, China tries to build advantageous dependencies on international trade relations and to strengthen its position in the global politics-economics and security context, in order to secure the sources for its future development in a long term horizon. China, by increasing its economic security, also increases its overall security and vice versa, the overdependence of Chinese business partners reduces their own economic security when trading with China.

It is especially the example of China which significantly affects the conditions of the global economy with its pro export-oriented development strategy. China affects the economic security of other countries in a direct and indirect way, too. It documents the importance of developing the concept of economic security on a global level.

An element of state control of strategic economic processes and operations in the long term horizon emerges in the outlined perspective. Taking into account the activities of China and the U.S.A., which are focused on ensuring the future sources of economic development, it can be stated that in the current reality of exhausting natural resources we witness a fight for raw material base (mostly) from the African continent. Especially ensuring resources for future development of the country is considered as a strategic priority of security. In the relation to the Chinese-American "fight for Africa (especially for its raw material base)", This is documented e. g. by the rising of Chinese and African trade balance from 4,1 billion USD in 1992 to 107 billion USD. [12] We can observe two different approaches in this fight for the African resources. The U.S.A. tries to promote its interests in Africa through transnational institutions, in which it has a significant position, and its involvement in numerous military conflicts. On the other hand, China tries to promote business partnerships through the creation of long-term contacts for the exchange of cheap natural resources for building new infrastructure and deployment, with individual African states.

Therefore, there is a close connection between economic security and energy security. Now the right issues of ensuring adequate resources for sustainable and safe development of the country are major strategic priorities for all dominant economies in the world economy. From this perspective, mentioned China's activities appear to be significant in relation to its future prosperity and also to the improvement of its position in international trade relationships. The question remains, whether a need of ensuring the economic security of the separated states will not lead to a new wave of protectionism in an international community. In principle, this should significantly reduce the global economic growth and it can also lead to increasing of using the economic and security tools to strength the economic security as the important component of strategic national activities.

Another example which highlights the importance of economic security may be considered in the pressure of Germany and France in solving the Greek crisis in the Eurozone. The collapse of German and French banks, which are really badly infected by Greek bonds, considering the large number of small economies in a strong dependency to the German and French economy can cause a domino effect which would significantly destabilize the situation in the EU.

The presented examples show that in the present state of the global economy it is essential to take into account the security implications, in assessing the economic benefits of foreign direct investments. Therefore, it is possible to argue that economic activities could significantly affect the security of all key subject at all levels of the global economy.

Presented arguments implicate a real requirement for a multidimensional approach for a security concept. In many cases, there are intersections among the influence of several features of security as a complex phenomenon to the subject of security. Reviewing presented arguments, we can state the rising of the scientific discussion about changing the basic theoretical background and assumptions, but also practical approaches for addressing security issues and problems.

5. Summary

We can see that dealing with economic security is an integral part of security as a comprehensive phenomenon, from the presented approaches to security and economic security. More complex elaboration of issues of security and economic security should be a priority in developing the theoretical background and practical approaches of security and crisis management.

It is clear that in the present conditions of the interdependent globalizing world's economy, it is just the usage of economic instru-

ments that create an important component influencing the strategic development of countries. In the environment of an increased global competition, to ensure that security of economic growth includes questions of ensuring economic security to the strategic objectives and expected the future prosperity of the state or the integration unit.

Accenting orientation of developing countries in the strategic objectives of economic security leads to the need of theoretical considering of possible approaches, not only to optimize international-trade position over the world's economy, in relation to the efficiency but also in relation of meeting the requirements for ensuring a sufficiently high rate of economic security of the country. This creates conditions for the continuous sustainable economic development of the country. Presented facts, practical experiences and also development of theoretical knowledge in the field of using instruments, which support state economic security or reduce the economic security of another country, should result in new strategies of influencing the world economic system by individual countries. This creates new challenges for new approaches to using security and crisis management tools.

Finally, we can state that security became a new phenomenon of a long term development of society, firm, and global world.

Long term economic sustainability has to deal not only with solving the problem of gaining profit, economic efficiency, but also the security and economic security.

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HUMAN FACTOR POSITION IN RISE AND DEMONSTRATION OF ACCIDENTS

This article deals with the human being – the human factor and its participation in the rise of industrial disasters (hazard – human error), in preventing their rise (hero – intrepid recoveries) and the way how the accidents affect the people in the form of impacts (victim – accident impact). It is necessary to emphasize also another role of the human factor in the rise of accidents – the solver who takes a share in coping with and managing the disaster, the so called crisis manager who will not be the object of this article. A common feature of all three groups is the psyche of the human factor (personality) and the specific is represented by the different going through and behaving of people during the rise and the course of the accident.

Key words: human factor, crisis event, accident, hero, error, victim

1. Introduction

1.1 Key terms resolution

At the beginning it is necessary to define chosen terms which will be used in the article due to the terminological heterogeneity in other sources. There are the following key terms – personality, human factor and accident that we understand as follows:

Personality is defined as an organic unity of the physical and mental, inborn and acquired properties typical for the given individual and reflecting in his/her perception, behavior and performance.

Human factor is understood as a set of human properties and abilities which in the given situation affect the performance efficiency, effectiveness and reliability of the system in various ways. It is an interdisciplinary term integrating the knowledge from biology, sociology, psychology and natural sciences which orient on achieving an optimal compliance between the people and environment (especially the working one) with the aim to minimize the number and extent of the human errors and their consequent influences. [3, 8]

Accident (disaster) is understood as an emergency which causes a deviation from the stable operational status and results in leaking hazardous substances or performing other negative factors which affect life, health or property.

Methods utilised in the social sciences have been used in the article. Based on deduction individual definitions of the introduced area were stated and they were based on the already existing definitions and their analysis and comparison with the basic assumptions in the area of industrial accident prevention. Furthermore there were general theoretical methods – analysis and synthesis through which we analysed several approaches in the Slovak Republic and abroad concerning the human factor and especially its positions in the rise and demonstration of accidents.

2. Human contribution to accident occurrence and influence of accident on human factor

2. 1 Human errors and recoveries in practice

The risks connected with the technical and technological processes can be a source of unplanned interruption of the manufacturing processes or can violate providing a service and can cause material losses, damage the environment, threaten the health and lives of people. They can endanger not only the participating employees but also inhabitants from the surroundings and in the case of a leakage of dangerous substances it can become the source of violating the nature, the environment and endangering the inhabitants for a long-time period, if not forever. One of the causes of the rise of industrial accidents is also the failing of the human factor and this is one of the topics of the paper submitted.

In the past models of accidents dealing with the causes and relationships of accident rise were created. They insubstantially emphasized the human factor; it was only introduced as an immediate cause of events leading to an accident. Currently there is an effort to understand why and when the human factor affects the rise and development of serious accidents (it is the cause or part of accidents). What makes it possible to forecast, to prevent acci-

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dents as well as to decrease the share of the human factor on the rise and development of serious disasters? [4]

The analysis of events which occurred and were caused by the human factor is one of the methods for creating the preventive measures. According to this method it is possible to foresee partially the human behavior in the crisis situations.

Over the past 50 years there has been a dramatic widening of the scope of accidents investigation across many different hazardous domains:

- system and cultural issues (1960s Metal fatigue, Aberfan Inbrox)
- unsafe acts (errors and violations) (1970s Flixbourgh, Seveso, Tenerife TMI MT Erebus)
- equipment failures (hardware – software) (1980s Chernobyl Zeebrugge Bhopal PiperAlpha Dryden, 1990s Paddington Long Island Alabama Eschede, 2000s Linate Uberlingen Columbia). [11]

Chemical incident statistics are very sketchy with respect to root causes and many reported incidents do not furnish much detail about the cause. Chemical safety and hazard investigation board published in 600K Report that:

- Among cases where the cause was known, 49 % were as a result of mechanical factors, 39 % from human factors and just 2 % to weather-related phenomena, 10% causes not found,
- Among cases involving mechanical factors, an overwhelming 97 % were attributed to general equipment failure; 63 % of human factors cases were attributed to human error. [5]

The high rate of general equipment failure among reported incidents suggests that mechanical integrity/maintenance issues are significant and from the human error that training and proper procedures should also be examined.

We can introduce instances of accidents which were caused by failing the human factor or saving lives by human factor. The first of them is the *Chernobyl disaster.* An industrial accident of exceptional size had a lot of victims that cannot be counted exactly (the epidemiological analysis is not available). Various scientific studies assume from 9,000 to 475, 000 victims. The most frequent conclusions and maybe the most probable values are in several tens of thousands (30,000 to 60,000). The 1986 Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident (INSAG-1) of the International Atomic Energy Agency's (IAEA's) International Nuclear Safety Advisory Group accepted the view of the Soviet experts that "the accident was caused by a remarkable range of human errors and violations of operating rules in combination with specific reactor features which compounded and amplified the effects of the errors and led to the reactivity excursion." In particular, according to the INSAG-1 report: "The operators deliberately and in violation of rules withdrew most control and safety rods from the core and switched off some important safety systems."

Another example of the human factor failure in the environment of the nuclear power stations is the disaster *Three miles island* which happened at 4 am on 28th March 1979 and where the second nuclear reactor was partially melted. The operational building was contaminated and an extensive leakage of radioactivity to the environment also occurred. The investigation commission later designated for the reason of the accident a breakdown of the safety valve. The proportion of the human factor was that operators were unable to diagnose or respond properly to the unplanned automatic shutdown of the reactor. Deficient control room instrumentation and inadequate emergency response training proved to be root causes of the accident.

Last example is connected to another type of accident – nearly accident. As an example we can introduce the *Apollo 13* program. Its objective was the third landing of the human crew on the Moon surface, this time in the area of Fra Mauro. The typical sentence: "Houston, we've had a problem," says how very close the crew was to a disaster. During the flight one of the oxygen tanks exploded and seriously damaged the service module. The consequences of this explosion were serious. Not only this situation caused the crew did not fulfill the task of this flight but it threatened the lives of the crew members. The Manned Spacecraft Centre (today Lyndon B. Johnson Centre) had to develop with an extreme effort emergency scenarios thanks to which they succeeded in transporting the crew alive back to the Earth. Hundred of people were involved in the rescue: off – duty controllers, astronauts, simulation technicians, contractors' personnel and many more. But this case is only to show how the team effort, and a magnificent display or sheer unadulterated professionalism, both in he spacecraft and on the ground brought the crew to the Earth alive. [11]

All crisis events have a potential impact on human factor as it was showed in previous text. We can mention human death, injuries, homeless people and other negative impact. Another type of negative impact on personality psyche relate to the human perception and behavior.

2.2 Human factor positions in case of accident occurrence

There is a stark contrast between unsafe acts and these intrepid recoveries. Errors and violations are commonplace, banal ever, they are as much as a part of human condition as other ordinary human activities. Successful recoveries, on the other hand, are singular and remarkable events.

The human factor in relation to the rise and demonstrations of the industrial accidents can play several roles. These roles are as follows:

- the human factor as the cause of the rise of the industrial accidents (hazard – human error),
- the human factor as the recipient of the negative consequences of the industrial accidents (victim – negative impact),
- the human factor as a hero (hero – heroic recoveries).

Human Factor as the Cause of the Rise of Industrial Accidents

When the human factor fails, there is a whole chain of small errors which if occurred individually they would not have fatal consequences. However, from a certain point on the tragedy is unavoidable.

There are several definitions of the human error. One of them says that the error is an action or a decision which was not determined (planned) and which leads to undesirable result. [13] Furthermore, the human error defines a certain fact, statement or decision which deviates from the standard and the result is an actual or potential unfavorable event. However, this event can but also need not lead to an unfavorable result.

There are several possible definitions and there are also many ways in which errors can be classified. When we are talking about deviations concerning the human error we should mention such deviations that could be from upright (trip or stumble), from the current intention (slip or lapse), from an appropriate route towards some goal (mistake), or in some circles, it could even involve straying from the path of righteousness (sin).Human error classification should be done based on possible generic classification based on action: omission, intrusions, repetitions, wrong objects, disordering, mistiming, blends etc.

In the industrial processes there are the following possible causes *of errors and failure of the human factor:* bad reflection of risks of the attendants; errors in communications; insufficient or incorrect knowledgeability of the employees, insufficient qualification, insufficient experience (lack of training) – practice, personality and health assumptions of the employees; failing to keep the working procedure; unsuitable working conditions and working environment; inattentiveness (momentary) of the employees and many others. [7, 8]

Human Factor as Hero (Intrepid Recoveries)

Another perspective according to human factor, one that has been relatively little studied in its own right is human factor as a hero. This presents a human factor as an element whose adaptation and compensation have brought trouble systems back from the brink of disaster on a significant number of occasions. We have already presented an example Apollo 13 where human factor saved several lives of astronauts. Other examples to be mentioned concerned to intrepid recoveries are connected to aeroplane crashes for example British airways flight 09 from London Heathrow to Aucland then BAC 1 – 11 flight to Malaga and many others.

Reason (2010) presents: "I find the heroic recoveries of much greater interest and in the long run, potentially more beneficial to the pursuit of improved safety in dangerous situations (operations)."

Human Factor as Recipient of Negative Consequences of Industrial Disasters

As already mentioned people are in many cases the reason for rising industrial accidents and they also significantly affect their development. However, on the other hand, people are also affected by them, tangibly by their negative consequences. The accidents affect the *people* – their lives, health, property but also the *environment* in dependence on the concrete form of the accident. The impacts on people can be divided into two groups, namely the impacts on the employees working in the company and impacts on the non-employees (the general public). The impacts of the industrial disasters on the employees according to their levels can be: death of the employee; serious damage of health with permanent consequences; serious industrial accident; light industrial accident; dangerous event (almost an accident); stress resulting from the situation arisen.

2.3 Psyche of Human Factor in the Rise and Performance of Accident

The survival of the human being in all roles is a common denominator. The disasters have an impact on the whole human personality; they affect people's survival which subsequently reflects also in their behavior (see Fig. 1). The accuracy of the psychical processes decreases: the sense cognition (feeling, perceiving), intellectual recognition (e.g.: of the way of thinking, attention, memory) that can lead to the rise of further errors which can cause further accidents. They also affect the overall life of a human being. The human psychics play an important role also from the point of view of industrial accidents (human error) and intrepid recoveries (human as a hero). On Fig. 1 there are shown psyche parts. It consists of consciousness, unconsciousness and perception. The psyche appears in human behavior also externally which has connection with behaving human factor in rise and demonstration of technological accidents too.

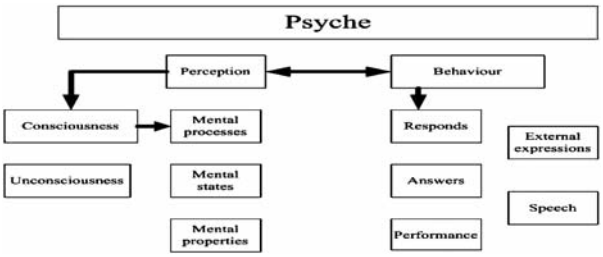

Fig. 1 Personality psyche structure

Personality psyche has very wide possibilities of use in this area and also offers many ways of research possibilities. This should be an idea to develop for another article.

3. Conclusion

The aim of this article was to assess and specify the position of the human factor from the point of view of the rise and performing the consequences of the crisis phenomena. It is necessary to emphasize that each of these roles has its specifics in which the

psyche of the people plays an important role. Especially the role of the human factor as a hero seems interesting due to the fact that it is one of the potential preventive tools when preventing the industrial accident. The individual roles of the human factor during the rise and development of the accident can be played by one person who can cause the accident as well as to solve it; however, each role can be played by an individual person. The analysis of the causes of the rise of the industrial accidents, the intrepid recoveries and the ways of the human perception in the case of demonstration of industrial accidents provides an incredible space for research activities and opens new horizons of knowledge.The area of the human factor is a key one in the crisis management and new facts should be incorporated in the study material of Faculty of Special Engineeringof University of Zilina also in a form of a special subject. Similarly the research results have opened a space for a further investigation aimed especially at the research of specifics of survival and behaviour of the human factor (personality) in three positions identified.

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Ladislav Kittel – Tomas Lovecek *

PASSIVE PROTECTION ELEMENTS BREACH RESISTANCE MODELING

This article originated in response to requirement for creation of quantitative evaluation system of passive protection elements resistance, which could be implemented into complex process of technical effectiveness evaluation of property protection systems. It deals with design of model, which could be a basis for estimation of breach resistance time and which would use attributes of material of chosen homogeneous passive protection element - building construction. The article analyses possibilities of mathematical modeling of attack on homogeneous passive protection element on the basis of specifically chosen tool and attack method. The model used will simulate an attempt to overcome a wall made from single layer monolithic concrete panel using a hammer as chosen tool. For the purpose of attack modeling a model of contact force effect of direct central impact on passive protection element, while omitting the deformations on tool and the effect of deformation forces created by impact on the wall section will be studied. Subsequently the model will be applied to the breach resistance time assessment method based on the number of impacts required for overcoming of barrier.

1. Introduction

Property crime in the Slovak Republic has still the most numerous representation between individual crime types. The issue of protection of property from intentional human activities as: terrorist attacks, organized crime, sabotage, theft or vandalism, is covered by many legal acts, technical norms and professional publications. Neither of them approaches the property protection complexly and gives satisfying answer to question, how to design these systems optimally from the viewpoint of technical effectiveness and economic efficiency. Most of approaches to property protection are based on qualitative expert evaluations of designers or security managers, where the owner or property administrator has to fulfill minimal required amount of points set by corresponding law regulation while implementing the security measures or implement exact combination and specification of security measures. It is not possible to exactly prove technical effectiveness or economic efficiency of designed property protection system.

In the USA, software tools were developed to protect nuclear facilities, making use of qualitative-quantitative methods evaluating the existing or proposed system for property protection. These tools are based on certain measurable values. No similar tool for resolving effectiveness of protection systems using exact methods based on the probability theory and mathematical statistics has been developed in the EU so far. However, application of these tools has several disadvantages – they were developed for protection of specific materials and non-commercial facilities and were not intended to protect items of critical infrastructure with different modes of operation. There has been no principal modifications done to these tools since their development, as can be seen from criticism of their authors and users (see [7], for an early discussion of this). It is impossible to evaluate level of protection in multi-level buildings and to evaluate level of protection in linear structures (such as a railway track, oil pipeline, electricity distribution system). And these tools do not consider European technical standards, standards and certifications applied in the field of property protection, making them unusable in EU conditions (e.g. safety classes or passive protection component resistance classes). [4]

It is possible to achieve safety of property as desired state by the means of technically effective and economically efficient security system. By security system we understand optimal combination of mechanical means of protection (passive protection elements), alarm systems (active protection elements), organizational and regime measures and physical protection for the purpose of this article. The objective of effective protection system of object is to prevent the violator to achieve his goal. Safety of object can be then characterized as a condition in which the access to protected interest is secured so the presence of violator during the attempt to overcome the protection system detected by alarm system and subsequently the violator will be detained by physical protection before reaching his goal. Object protection system effectivity can be assessed by multiple methods. Since we are interested in stopping the violator by physical protection before he reaches the protected interest, we will assess effectiveness of protection system by comparation of time necessary for overcoming the system by violator and time necessary for physical protection intervention. There-

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fore it is vital to specify time needed for overcoming individual passive protection elements, which can be very complicated in particular cases (e.g. the building construction).

2. Passive protection elements

Passive protection elements create a system of physical barriers, whose primary purpose is to influence the violator so he gives up on his intention. If he does not give up, then the purpose is to create sufficient time delay between the moment the attack begins and the moment violator reaches his goal, i.e. to impede or practically make the violator's penetration to the protected interest impossible [5].

Passive protection elements can be classified from different viewpoints – by their position in security system and protected area (e.g. passive elements of perimetric, shell, room and item protection), by breach resistance (e.g. sorting into security classes), by type (e.g. building construction, opening fillings, locks etc.). One of viewpoints that have not been yet elaborated is classification of passive protection elements into homogeneous – those composed of homogeneous components (e.g. building constructions) – and inhomogeneous – those composed of inhomogeneous components (e.g. opening fillings such as windows, door etc.). Homogeneous passive protection elements can not be bypassed by non-destructive methods, so we can focus on destructive means of their bypassing in specifying their breach resistance.

3. Tools used for bypassing passive protection elements

For the purpose of this article the term tools for bypassing passive protection elements will be understood as items used by violator to enable the bypassing of passive protection element or facilitate it. The term tool in this article encompasses either normal tools, improvised ones, weapons and ammunition, vehicles and explosives. The disadvantage of such approach is wide range which makes the creation of complete database of tools impossible. It is possible to narrow this range in two ways:

- creation of integrated standard set of tools, which would reflect the preferences and abilities of chosen group of potential violators (e.g. use of only improvised tools by random violator),
- classification of tools by the method of their use in process of bypassing the passive protection element and selection of one tool for each such group as standard or average representative of the group of tools.

The violator can use both destructive and non-destructive methods to bypass the passive protection elements. It usually depends on the violator which tool he chooses. For destructive methods, the passive protection elements breach time depends not only on structural design of passive protection element, but also from the set of tools used for its bypassing and ability of passive protection element to resist the attack. His choice can be influenced by multiple factors:

- characteristics of passive protection element material,
- power and consumption of tool,
- skill necessary for tool operation,
- possible sources of electricity,
- construction material,
- concealability, noisiness and mobility,
- availability, anonymity/registration of owner,
- unambiguous identification of tool in case of use (partial, full),
- standby time.

4. Breach resistance of passive protection elements

Currently no breach resistance times of passive protection elements are defined complexly for all categories of tools. For instance, the norm for opening fillings [7] does not define breach times corresponding to appropriate resistance classes for all tools, but only for some of them. For example, the breach resistance time defined by the norm for resistance class 3 is 20 minutes, but only for defined set of tools (screwdriver, wedge, crowbar), which makes it difficult to assess how the opening filling would resist more aggressive type of tool. Breach times for specific tools are then identical with values of breach times corresponding to specific resistance class according to the norm [7]. Breach time is working time during manual break-in test, including times shorter than 5 seconds for exchange of tools (e.g. exchange of screwdriver for crowbar).

The norm intended for security depositories [9] is more elaborate. In it the breach resistance time of appropriate security class depends on tool expected to be used and so it is possible to calculate it for all tool categories. Breach times are equal to sum of operational time periods expressed in time units (minutes), defined for security depositories in [9]. The sum of operational times $\sum t$ depends on value of breach resistance Vr in resistance units RU (unit of resistance against break-in, which results from one minute use of tool with tool coefficient value equal to 1 and with base value equal to 0) and sum of all base values of every used tool ($\sum BV$) in resistance units too. [9]. In case of security films and security glass the norms do not mention time units, but only quantity of impacts by different tools which the specific passive element should resist [10], [11], [12]. No technical norm defines breach resistance of building constructions, which belong to passive elements of shell protection, and all passive elements of perimetric protection. National security authority of the Slovak Republic processed a classification of most used building constructions, where individual building constructions were divided into four basic groups by degree of confidentiality [13]. There is innumerable amount of passive elements of perimetric, shell and item protection and also there are several approaches to their assessment. Due to this normative disharmony it is not possible to determine breach resistances of all passive protection elements available on the market in relation to specific type of tool used. This disharmony is caused mostly by the fact that there are several technical committees which deal with development of technical norms for passive protection elements (e.g. CEN/TC 33, CEN/TC 370, CEN/TC 129, CEN/TC 263) in international (e.g. ISO) or European (CEN) organization/committee for normalization and simultaneously there are representatives of producers in these committees so they may lobby for their own benefits.

From given facts results that it impossible to determine breach resistance expressed in time units for most of passive protection elements, but it is only possible to verify/certify conformity of attributes for these elements. It is possible to state that security class 3 door made in the Slovak Republic have the same or similar attributes as the door of same class made in Germany, but it is not possible to say, what time the door will be able to resist an attack by an aggressive cutting thermal tool, for example. By certification of passive protection elements we mean the activity that verifies conformity of attributes with appropriate security standard/norm. In order to allow the customer to orientate between wide spectrum of passive and active protection elements available on the market and compare them qualitatively, there exist specific certification symbols of authorized subjects [2]. An example of such certification symbols is the mark "SECURITY TESTED" from Revimont-DG, s.r.o. or „SECURITY PYRAMID", which was introduced by the Czech association of insurance companies for purpose of insurance contracts. Similar certification symbols of authorized subjects are issued across Europe (e.g. VdS Schadenverhütung GmbH – Germany, SKG – Stichting Kwaliteit Gevelbouw – Netherlands). But that does not change the fact that for most of passive protection elements it is only possible to determine qualitative difference from other passive elements and not directly breach resistance expressed in time units.

The same applies for known practices across the world. Usual method for breach resistance time determination are expert estimations and even use of minimal breach time from the norms that deal with certification of passive protection elements. Currently there are no methods for exact calculation of breach resistance time used in practice.

5. Methods of passive protection elements bypassing

Passive protection elements breach resistance should represent the time it takes to bypass a chosen passive protection element. But breach resistance does not depend only on attributes of material the passive protection element is made of, but also on tools used for bypassing. Passive protection element can be for example made of hard material that resists the mechanical stress well, but it may be in the same instance particularly vulnerable to thermal cutting. So it would be useful to determine breach resistance for each tool, but that is practically impossible given the amount of existing tools. But it is possible to determine attributes that affect process of protection element bypassing and subsequently sort tools into groups by attributes that affect breach resistance time most significantly.

As stated before, the methods for bypassing security system elements can be divided into destructive and non-destructive. The bypassing of protection element with use of destructive methods is based on damaging or destruction of part or whole protection element, or creation of opening which will allow the bypassing. After successful bypassing with use of destructive methods the protection element is no longer able to fulfill its original function until repair or replacement. Non-destructive methods include bypassing with use of deceit, stealth, evasion by utilization of insufficiently secured elements of system (e.g. climbing over/digging under the fence) and other methods. The basic characteristic is that these methods need not damage the protection element and it can be still be rendered usable without other costs.

For purpose of this article we will deal only with destructive methods of bypassing. Destructive methods can be further classified by attributes of passive protection element and tool that most significantly affect breach time. Proposed classification of destructive methods of bypassing is as follows:
- contact force effect of impact,
- dynamic application of force,
- utilization of machine tools,
- utilization of explosives,
- thermal cutting,
- combined use of multiple methods.

For each of these methods there can be defined specific attribute of passive protection element material that limits effectivity of chosen method. These attributes can be mechanical (e.g. tensile strength, spatial rigidity, elasticity) or physical (e.g. melt temperature). It is also possible to define specific attribute of tool that limits its effectiveness (e.g. force of impact, power, rpm, torque).

The example given in this article deals with modeling of contact force effect of impact of hammer on a monolithic wall made of concrete.

6. Contact force effect of impact model

Contact force effect of impact covers wide range of tools, both improvised and intended for this method of use. So it is necessary to propose the model in such way, it will allow for calculation of breach resistance time with few basic attributes. These attributes should be common for all tools.

It is possible to utilize tools driven both by power of human muscle (e.g. impact by hammer, axe, ram etc.) and driven by other sources of energy (e.g. pneumatic hammer, impact by vehicle, impact by bullet etc.) to breach the passive element by contact force of impact. It is necessary to design the model with possible application for both types of tools.

Effects of contact force impact can be studied through Newton's elementary impact theory, which takes course of force during time into account. During contact of two moving bodies, it is possible to observe significant change of their speeds. This phenomenon is called impact of bodies. Accompanying event during the impact are deformations of bodies induced by effect of impact force. The impact force of two colliding bodies has two components – normal and tangential component. Shear and pressure stress forms during impact. [3]

The model used for calculation of penetration depth of tool into passive protection element described in this article is based on constant spatial rigidity and it can be used for estimation of

protection element resistance. General attributes of tool and passive protection element are defined by geometric shape and coefficient of rigidity.

For calculation of penetration depth we shall assume in this model that the tool is made of infinitely rigid material in comparison to material of protection element and so the deformations of tool can be omitted. Tangential force will be omitted too so we will deal with the deformation as during direct central impact without change of motion state and neglect the restitution of material after impact.

Rigidity is measured by rigidity coefficient S, which is defined as ratio of force applied on construction and its deformations. Rigidity is affected by bulk modulus E, geometric characteristics of cross-section A and also length dimensions of stressed cross-section l. [1]

Coefficient of rigidity can be calculated as in equation 6.1

$$S = \frac{E \cdot A}{l} \quad [\mathrm{Nm}^{-1}] \tag{6.1}$$

Bulk modulus E for class B20 concrete is equal to value of 277 000 MPa. [14]

Geometric characteristics of cross-section A are equal to dimensions of affected area squared, which in our case means the width of section hit by hammer squared. Length dimensions are characterized by wall thickness.

Penetration depth can be calculated as in equation 6.2.

$$\lambda = \frac{F}{S} \quad [\mathrm{m}] \tag{6.2}$$

where λ stands for penetration depth [m], F stands for contact normal force [N] and S stands for protection element rigidity coefficient [Nm^{-1}]. [3]

By substituting we can obtain equation 6.3 for penetration depth of tool into passive protection element for one impact.

$$\lambda = \frac{F \cdot l}{E \cdot A} \quad [\mathrm{m}] \tag{6.3}$$

For total number of impacts necessary for creation of breach opening with needed dimensions we have to calculate circumference of such opening and determine total number of impacts needed. For this example we will assume the violator needs to create opening with dimensions of 400 × 250 mm as stated in norm [8].

The model described does not provide us directly with breach resistance time. It provides us with an answer to the question: "How many single operations (impacts) will the violator need to create breach opening of specified dimensions?" So we need to determine the time needed for one operation. One possible way to do this is to use standardization of operations, which lies in determining time needed for one operation by means of expert estimations or experiments.

For purpose of this article we assume that it takes precisely one second for single impact.

7. Example of contact forces effect of impact model application

For the breach resistance time calculation example we decided to simulate bypassing of 100 mm thick monolithic wall of class B20 concrete, whose bulk modulus E equals to 277 GPa. The tool chosen by the violator for bypassing is in this case a hammer used for security glass breach resistance testing.

The hammer head is made of steel block with a square cross-cut 40 mm wide and 232 mm long weighing 2 kg. The impact edge has a diameter smaller than 1 mm. The impact speed must be 12.5 m/s, so the hammer causes the impulse force of F = 2500 N for duration of impact equal to 0.01 seconds. [11]

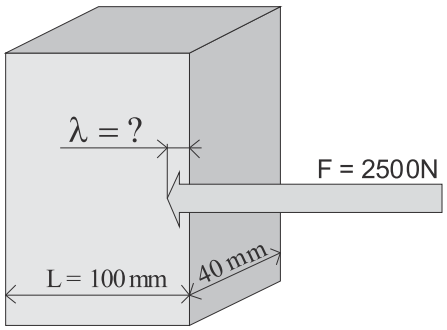

Fig. 1: Example of contact forces effect of impact model application scheme

Equation 6.3 shows us the formula for calculation of penetration depth of tool into protection element. After substitution of values we get the result λ = 0.564 mm (7.1).

$$\lambda = \frac{2500N \cdot 0.1m}{2.77 \cdot 10^{-8}Pa \cdot 0.04^2} = \\ = 5{,}64 \cdot 10^{-4}m = 0.564\ mm \tag{7.1}$$

This means that the penetration depth of one impact will be 0.564 mm. From this we can easily calculate that for breach of one opening in the chosen wall 178 impacts with hammer will be necessary.

Breach opening circumcision is 1300 mm and width of impact area is 40 mm. With this in mind we can state that to create opening of set dimensions 5785 impacts will be necessary, which means that with specified time for one operation the total time of breach resistance will be T_{pr} = 5785 s.

Based on this calculation the estimated breach resistance time of a 100 mm thick wall of class B20 concrete will be 96 minutes and 25 seconds.

8. Disadvantages of model, possible improvements and alternatives

This model is considerably simplified, which can have negative impact on its precision. This can be improved by more exact standardization of operations (e.g. implementing the violator's fatigue, needed pauses in work etc.), more precise determination of individual variables (e.g. experimental determination of impact force of chosen tools and application of findings into calculation) and finally application of eccentric impact, tool skid and material restitution after impact.

The disadvantage of this model is necessity of an impact force estimation, which is lowering the precision of model mainly for muscle powered tools. If we take into account all factors affecting assumed strength of the violator and practically infinite amount of their combination, we will find out that it is not possible to exactly determine impact force and so it is necessary to simplify the method of impact force determination. This is possible by determination of average impact force based on examination of statistic data obtained through experiments or by classifying the potential violators into groups by their assumed physical attributes and determining a typical representative for each given group and his attributes.

There are several alternatives to breach resistance of passive protection elements determination. One of these is already mentioned standardization of operations, which can be based on empiric assessment, experimental research or their combination. Experimental research would be very demanding both on time and sources. However, empiric assessment does not allow determining exact time of breach resistance. Their combination – experimental research of breach resistance time for one passive protection element in group and utilization of this element as gauge with subsequent deduction of breach resistances for other elements based on coefficients determined by expert estimations – allows us to obtain approximate breach resistance times for specific group of elements (e.g. for walls) from one series of experiment with relatively low costs and based on real breach resistance time. Such approach is possible even without experimental research – utilizing expert estimations of several experts could increase precision of breach resistance time approximation. Another possible way is utilization of norms for demolitions.

9. Conclusion

It is possible to somewhat apply methods proposed in this article into quantitative system of security system effectivity evaluation, but it is necessary to develop these methods with newly acquired knowledge and to review possible applications in practice. It is also necessary to consider possible application of alternative methods of breach resistance time approximation. Subsequently a method should be created for estimation of time of passive protection system bypassing by non-destructive methods and implemented into complex system of security system effectiveness evaluation.

Calculations used in contact forces effect of impact model are estimations of protection elements resistance and are, at this time, too inaccurate to be fully applied into practice. Future research should concentrate on precise determination of individual variables, maybe even experimental determination of impact force of chosen tools, more exact standardization of operations and eccentric impact, tool skid and material restitution after impact should be implemented for increased accuracy. The results should be then proved by experimental methods.

If improved to be more accurate, the model could be used for calculation of breach resistance time, which could be implemented into process of security system evaluation and design.

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INFORMATION SYSTEMS FOR CRISIS MANAGEMENT – CURRENT APPLICATIONS AND FUTURE DIRECTIONS

The management of crisis situations is undergoing rapid changes due to advances of Information Technology. We discuss the role of information systems in supporting decision making processes in crisis management. The crisis management poses particular challenges for information systems – it is characterized by dynamic, complex environments involving many actors in often very unique and extreme situations. We review the roles, benefits and challenges of information systems' application to different phases of the crisis management. We argue that for the different phases of the crisis management, the different types of information systems varying in the aspects such as use scenarios, user requirements, critical technologies, etc. are suitable. Finally, we outline the directions for future research and applications for the field of the support systems for the emergency management.

1. Introduction

After over three decades of application of computer based information systems to the crisis management, these systems are getting wider acceptance by the community of the emergency managers. The need for Emergency Management Information Systems (EMIS) (for more see [12]) supporting the decision makers working under pressure and facing dynamically changing environments has been recognized by both practitioners and researchers. Disaster, crisis, catastrophe and emergency management are very often used synonymously and sometimes with slight differences, especially with practitioners and researchers. We use the term crisis management to emphasize that we are not concerned about small scale emergencies such as traffic accidents or building fires, but our focus is on disasters and catastrophes, no matter if natural or man-made. We would like to keep the Emergency Management Information Systems (EMIS) as the term used in the field for all of the information systems used for the crisis response and management support. The United Nations defined disaster as a serious disruption of the functioning of a society, and catastrophes refer to disasters causing such widespread human, material, or environmental losses that exceed the ability of the affected part of society to cope adequately using only its own resources. Both disasters and catastrophes create crisis situations.

2. Information Systems in Crisis Management

As defined by Simak [11], an information system is a system able to deliver information for immediate or later action. Concretely, it is a set of procedures, tasks, activities, people and technologies. An information system has four specific functions:

- data collection,
- data storage,
- data processing and analysis,
- data transfer and distribution.

Crisis management is one of the most challenging management tasks possible to imagine – combination of time pressure on decision makers, rapidly changing environment, uniqueness of each crisis situation, and high cost of decisions, often involving many human lives and large financial consequences makes crisis management a very difficult task. A general role of information systems in crisis management is to help decision making process information and make right decisions.

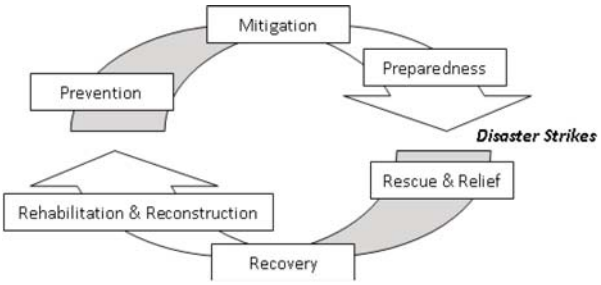

Fig. 1 Phases of disaster management cycle

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The literature within the crisis management typically identifies four to eight phases of the disaster management process, and presents them as a cycle [13]. The six phase cycle of disaster management cycle as presented in Fig. 1 by Menon and Sahay [9] is the most common one and will serve as the basis of our discussion.

Information systems can be a powerful tool that can support decision making process in all phases of the disaster management cycle. Historically, the main focus was on the response phase. With the paradigm shift, the role of crisis managers has immensely expanded and the focus is spread among all phases with emphasis on prevention.

We start by reviewing the role of EMIS for the different phases of the cycle. We argue that from the perspective of an EMIS development, the six phases of the disaster management cycle ask for different types of EMIS tools that differ in terms of:

- problems the system is intended to address,
- audience for which they are intended,
- importance of ability to provide real-time data,
- ability to accommodate multiple actors (especially multiple organizations),
- sophistication of used technologies,
- data presentation to the user.

In the remaining part of the paper we will discuss applications and development of EMIS in context of specific phases of the disaster management cycle with support of definition of each phase according to World Health Organization [14].

3. Prevention and Mitigation

Prevention is intended to eliminate possibility of disaster occurrence or, in vast majority of cases, to reduce the probability of disaster occurrence. Mitigation is intended to reduce the consequences of unavoidable disasters. Prevention and mitigation measures include building codes, vulnerability analyses, zoning and land use management, preventive health care, etc. their effectiveness depends on the availability of information on hazards, risks, appropriate measures in national and regional development.

The EMIS for prevention and mitigation focus mostly on two aspects: (1) collection relevant data that would be used for risk assessment and strategies to prevent them and/or mitigate their effects, and (2) providing tools for this data analysis that would enable to perform vulnerability analysis, define best policies, etc. The former aspect is concerned more on creating infrastructure for data collection and storage. It is mostly focused on creating repositories of documents (emergency plans, historical reports, etc.), maps (with use of GIS systems), historical measurements (for example weather information, river gage readings, medical records, etc.) and providing tools to access to this information by various actors and organizations. This type of systems uses well-established technologies based on databases, document processing and World Wide Web (WWW). From the technical perspective they do not differ from typical information systems for other domains – they are intended to be used on daily bases by domain experts who are responsible for planning and policy making, not the actual responders during crisis situations.

The later aspect is focused on systems that support analysis of risks and vulnerability. In this area special emphasis should be put on advanced methods for data analysis – machine learning, decision analysis, intelligent systems. These disciplines are experiencing rapid progress and are capable of delivering methods and solutions that can address real-life problems. The development of intelligent tools requires interdisciplinary approach where researchers, the emergency managers and domain experts should work closely to develop tools that address specific problems. It is a relatively immature area that requires significant research component, however is clearly becoming the mainstream for data analysis and decision making in the future.

4. Preparedness

The goal of preparedness programs is to achieve a satisfactory level of readiness to respond to any crisis situation through measures that strengthen the technical and managerial capacity of governments, organizations, and communities. These measures can be described as logistical readiness to respond to disasters. Readiness can be improved by developing mechanisms and procedures, rehearsals, long-term and short-term strategies, tactics, public education, and implementing early warning systems. Preparedness can also take the form of ensuring strategic reserves of food, resources, medicines, and others. Preparedness measures include emergency training and exercises, communications systems, evacuations plans, resource inventories and contact lists, mutual aid agreements, and public information/education.

The preparedness encapsulates a wide range of actions and approaches that differ in their nature. Therefore, EMIS for the preparedness phase can cover a wide range of applications and requirements on the information systems. We briefly discuss main types of EMIS that support the preparedness phase.

- Document and data sharing tools – the information technology enabled unprecedented ease of storage and access to large variety of data. During the preparedness phase it is possible to collect comprehensive data related to threats and response to them: databases of available resources (on local and national level), qualifications and contact addresses of trained personnel, hazard databases (for example localization and amounts of hazardous materials), factsheets on hazardous materials, etc. This data should be easily accessed when needed and kept up to date (which is often a practical challenge). In terms of technology, this type of systems utilizes well-established database technology and WWW user interfaces. Often trade offs between ease of use and protection from unauthorized access is an important issue – because of the fact that some of this data can be proprietary (e.g. water or electricity providers) or pose a security threat. For example, a database of hazardous materials or detailed plans of power grid can be potentially a very dangerous in hands of terrorists.

- Geographical Information Systems (GIS) – even though the GIS can fall into the category above, the traditional importance and practical value of maps in the emergency management makes it worth discussing them separately. The GIS concept is far more than just a digital version of traditional maps. It allows for real time updating, publishing, and advanced spatial analysis of data. The visual representation of data is especially suitable for humans and can enhance decision making processes.
- Early warning systems – this type of EMIS is intended to provide an advance warning prior to a disaster. They are threat specific and more typical for natural disasters: e.g. tsunami warning systems or extreme weather warning systems. They may include warning dissemination systems. They may range from simple sensing devices, often networked, to complex predictive models based on simulation and physical models. A common element is their end user – a human decision maker who is responsible for making a decision for issuing the warning.
- Training applications – a proven practical use of the EMIS are tools for training and exercise generation. The computer-based support systems can use the data collected for the other purposes such risk assessment to generate realistic exercise scenarios. One of the proposed uses of the virtual reality is use as a training tool for the responders to familiarize them with terrain and infrastructure characteristics of the area where the response will take place. In particular it can be useful for the response in the areas with which the responders are not familiar with – in the context large disasters involving international rescue teams.
- Decision support systems – a wide category of EMIS that are intended to support decision-makers by providing real-time, or close to real-time, data on various aspects of disaster management – e.g. resource management or situational awareness. Even though these systems are primarily intended for everyday use in non-disaster environment, their application can be extended to the crisis situations. One of the key strengths of these systems is users' familiarity with them gained through everyday use. Other specialization is the *dashboard system* that provides real-time data visualization by means of key performance indicators – abstract measures that provide rapid assessment of the evolving situation. A dashboard system to monitor hospital system with available number of beds, categorized by type of units and specialization, can be a good example.

By no means is the list above complete – the preparedness phase depends heavily on the nature of disasters for which it is intended. Particular regions can greatly differ in the risks (for example: earthquakes, tsunamis or major river floods are characteristic to some regions and are not a viable threat for others). So are the preparedness measures – they should be always customized toward local threats, community characteristics, available resources, etc.

5. Rescue and Relief

During crisis situations the initial response is by the government and professional organizations. Humanitarian agencies join shortly after. To respond effectively, these organizations must have experienced leaders, trained personnel, adequate transport and logistic support, appropriate communications, and guidelines for working in emergencies. A real challenge is coordination of these, often different in structure and operation, organizations. The aim of the response is to provide immediate assistance to sustain life, support recovery and providing other necessary services. Such assistance may range from providing specific but limited aid, such as transport, shelters, and food, to establishing semi-permanent settlements. It also may involve initial repairs to damaged infrastructure. The focus in the response phase is on meeting the basic needs of the affected population until more permanent and sustainable solutions are feasible.

During the rescue and immediate relief phases, the EMIS can take on critical roles of providing communication and rapid data sharing. The decision support systems that are used during everyday emergency management can provide their services during and after the disaster strikes. However, the after disaster response creates a need for different type of data, communication and decision support that is needed during everyday routine. In particular, the disaster response calls for extensive multi-organizational communication far beyond the level needed during non-crisis times. Information technology, in particular communication technology can offer enhanced means of communication.

The multi-organizational data sharing is probably the key aspect of the response that can be addressed by means of computer-based information systems. The Sahana [14] project is such an example. Sahana was initiated during the response to 2004 Indian Ocean tsunami and since then used in many major disaster response efforts throughout the world. Sahana intends to facilitate communication between response organizations and individuals on number of aspects, including, but not limited to: missing person registry, response organization registry, request management, personnel tracking, etc. One notable tool is the Situational Awareness module – a tool where individuals can place information, including photographs to create the common operating picture.

6. Recovery

As the crisis is brought "under control", the affected population is capable of undertaking a growing number of activities aimed at restoring their normal lives and reconstruct the infrastructure. The recovery period creates a unique opportunity to improve on prevention and preparedness. Ideally, there should be a smooth transition from recovery to on-going development. The recovery activities, both short and long term, include returning vital life-support systems to minimum operating standards, temporary housing, public information, health and safety education, etc. Information resources and services include data collection related to rebuilding, and documentation of lessons learned.

The recovery phase is about actions to restore normal operations. The EMIS used in this phase are a mixture of the EMIS for rescue and relief and the systems that support reconstruction and even the prevention and mitigation phases. Therefore, we believe

they have no distinctive features/requirements that would validate discussing them as an individual category.

7. Rehabilitation and Reconstruction

In the rehabilitation and reconstruction phase, considerations of risk reduction should form the foundations for all activities. The rehabilitation and the reconstruction phases are in essence about learning lessons from the disaster and the response. No matter how prepared the community was, in practice, it is always possible to substantially improve the disaster response. The first step is to collect data to gain understanding of the disaster and the response to it. EMIS can be useful in this phase. Moreover, the lessons learned may provide insight into use of EMIS in the response process – it is especially valuable because the EMIS are relatively new to the field and we believe that the concept is still in the phase of proving its value and defining directions for further development.

8. Directions for Future

In the previous sections we discussed the state-of-the-art in terms of providing support for crisis situations. We discussed the roles and requirements on EMIS for all the phases of the disaster response. Now, based on that discussion we would like to indicate some directions for development of future EMIS, they are:

- Personal computing – the Internet becomes increasingly popular, with over 1.6 billion as of Nov 2010, [3]. Internet affects how we communicate, access and share information. In the recent years popularity of cell phones, and in particular smart phones created new ways how people can access and share information even faster than ever before. Development of tools for personal computing especially in the area of the communication, geo-location (most of modern smart phones include GPS functionality), instant image sharing and access (build-in cameras), have a great potential to transform disaster management.
- Growing knowledge bases – more and more organizations are organizing their data, document processing, and other processes with use of the IT. During this process data and knowledge bases are created, enabling the EMIS to access more and more data, making certain aspects of the disaster response possible. In terms of data sharing, the sharing standards such as XML and web services are making interoperability much easier than in the past.
- Sensing technologies – the development of new sensing technologies, resulted in popularity and lowering the cost of different type of sensors, ranging from regular cameras to specialized types such as vibration sensors. The current trend is to use network-enabled sensors that can stream the real-time data to computer networks. The low cost of individual sensors enabled sensor networks – large numbers of interconnected sensors intended to improve situational awareness through sensing at multiple points at the same time.
- Simulation – increasing computational power lead to development of more sophisticated modeling and simulation techniques. Traditionally the researchers in the field of emergency management had two methods of investigation: theory and experiment. The computers enabled to address the problems that are too complex to understand theoretically or through the natural experiment [7]. Bezivin and Gerbe [2] define a model as a simplification of a system built with an intended goal in mind. The model should be able to answer questions in place of the actual system. A model is an abstract description of a system or its part written in a language. This language should have a well-defined syntax and interpretation which is suitable for automated interpretation by a computer [6]. Banks [1] defines a simulation as an imitation of an operation of a real-world process or system over time. To prepare and make a simulation we need to have a model. Simulation is a valuable problem-solving methodology for many real-world problems that are characterized by complexity and uncertainty. Simulation can be used to ask "what if" questions about the real system, and investigate the consequences of changing the design of real systems. Both existing and conceptual systems can be modeled with simulation.
- Intelligent systems – with the development of artificial intelligence, and related techniques for analyzing data, and drawing automated conclusions (machine learning, data mining, etc.), the computer-based tools become able to address increasingly complex problems. With many successful commercial tools based on these techniques (hardware diagnosis, credit valuation, customized user interfaces, etc.) it should be expected that they will slowly get recognition and applications in EMIS. Examples of applications in the crisis management include disease outbreak detection, evacuation modeling.
- Dashboard systems – importance of providing intuitive visualization of data, especially in the context of a rapidly developing crisis, is of critical importance. A dashboard system that is intended to provide situational awareness based on high-level, real-time measures has a potential to significantly enhance the emergency manager's toolbox. Especially, with increasing availability of digital databases and the development of sensing technologies, the dashboard systems can in future become a mainstream, or at least a significant class of EMIS.

A computer-based system for emergency management should:

- combine problem-specific tools into a comprehensive and integrated set of tools,
- include up to date and relevant data,
- be able to store data, archive it and produce reports based on this data,
- be capable of making anticipations,
- provide secure but easy and reliable access,
- have intuitive human computer interface.

Discussing the EMIS would not be complete without the discussion of challenges and problems the EMIS are facing. Probably the most obvious is the cost of implementation of the EMIS and their relative value to the benefits they bring. Clearly, there are systems that are beneficial from both the user's perspective (enhance human decision-making) and they are cost-effective in terms of reduction of already allocated resources. One of the facts that are surprisingly often ignored is the maintenance the system – often

the response organizations budget for introduction of a new system, but do not expect costs for the maintenance of the system, in particular keeping the database up to date.

9. Conclusion

We discussed the role of information systems in the crisis management, the current applications and future directions. The information systems for the disaster management reflect the complexity and diversity of the challenges faced at the different phases of the disaster response. We argued that the problem of development and application of EMIS should be considered in the context of phases of the disaster management, in order to address the diversity of EMIS.

The potential benefits and importance of information systems for crisis management are gaining recognition by practitioners at the all phases of the disaster management. We argue that the EMIS concept is a success measured by practical applications. There are numerous examples of EMIS that are used in a daily practice. We observe development of a wide variety of systems that contribute to the overall set of solutions. The EMIS are becoming more complex, addressing more challenging problems. There is a very active interest of the research community in proposing new ideas that, at least some of them, should soon result in new applied systems.

We believe that the future of the information systems for disaster management lies with integrated information systems that build upon a set of problem-specific tools. We view it as a gradual process where advances in modeling, simulation, data collection, etc. will lead to more complex and interdependent tools that ultimately will provide comprehensive solutions to the overall emergency management at all the phases. Until it happens, there will be a slow process of improving existing tools and developing new techniques, often based on the emerging new technologies.

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COMPARISON ON NATIONAL SECURITY STRATEGY 2002 AND 2006: TO WHAT EXTENT DID NEOCONSERVATIVES INFLUENCE PERCEPTION OF THE US FOREIGN AND SECURITY POLICY OF THE SECOND PRESIDENTIAL ADMINISTRATION OF GEORGE W. BUSH?

The purpose of this article is to identify differences in the perception of the US foreign and security policy by the first and the second Bush presidency. Due to the fact that both presidencies of George W. Bush were strongly influenced by neoconservative view on the US role in the World, the first chapter is dedicated to the impact of neoconservativism on foreign and security policy of President George W. Bush. Finally, it introduces reader to basic principles of President's Bush foreign and security policy implemented after September 11 terrorist attacks.

The second chapter is the core chapter. It compares two major documents of Bush Administrations, which materialized his foreign and security policies. These are National Security Strategy 2002 and National Security Strategy 2006.

Key words: Neoconservativism, Democracy, Unilateralism, Pre-emptive strikes, "Bush Doctrine", War on Terror, National Security Strategy

1. Introduction

It is generally agreed that Presidential Elections of 2000 were one of the most controversial elections in the history of the United States of America (the US). At that time, no one could anticipate that in foreseen future the same would be said about the presidential administration of George W. Bush. In respect to the US foreign and security policy, one could observe a rise of a unilateral approach, as well as ad-hoc solutions to global problems. Such approach brought the US into open misunderstandings with its closest allies and worsened the US relations with its global partners. This fact can be stated especially about the first presidency of George W. Bush, which was shadowed by the US intervention in Iraq and Afghanistan that worsened the US international reputation. The second presidency was marked by George W. Bush's efforts to improve international reputation of the US, as well as to repair its trans-Atlantic partnership with its closest allies in Europe. While we can argue about the extent of success of both presidencies, one fact cannot be denied. It is the fact that neoconservative thinking influenced both presidencies. The question that one might ask is whether there was a stronger neoconservative influence during the first or the second presidency, or if it remained the same throughout all eight years of George W. Bush presidency. The answer to this question could be found in the most essential documents that shaped the US foreign policy. These are *the National Security Strategy 2002 (NSS 2002)* and its modification from 2006 *(NSS 2006)*. The article will compare both national security strategies in order to answer this question.

1.1 The purpose of national security strategy

Under the current international system, it is responsibility of every state to guarantee its security, which is the precondition for development in the widest meaning of this term. In order to fulfil this task, each state must define a strategy necessary for its survival and development. The US Department of Defence defines strategy as "the art of science of developing and using political, economic, technological, psychological and military forces as necessary during peace and war to afford the maximum support to policies, in order to increase the probabilities and favourable consequences of victory and to lessen the chance of defeat" [1]. Since this represents more a military view on strategy, such definition could be misunderstood as primarily referring to military power. For purposes of this article we need a more comprehensive definition of strategy that could be called National Security Strategy. National Security Strategy could be seen as the application of the means to achieve a political objective; and consequently, as the art of using all elements of power of either a nation or an alliance of nations to accomplish a politically agreed aim, and the objectives of a nation of an alliance

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of nations in peace and war. Therefore, it must comprise the carefully coordinated and fully integrated use of all political, economic, military, cultural, social, moral, spiritual and psychological power available [2].

In order for any National Security Strategy to succeed, it must meet several core principles. First of all, such strategy must be protective and proactive strategy, not a reactive one. Thus any strategy must overcome the initial disadvantage of being forced to react by striving to quickly regain and maintain the initiative. The second core principle is proportionality, which aims to win hearts and minds of the people in the operation zone. This is a vital instrument in persuading one-time opponents to cooperate and even become partners after the conflict is over. The third, and not less important, core principle is damage limitation, which requires looking at actions taken during crisis or conflict through the lens of the post-conflict period. The last core principle is a principle of legality. This means that all actions taken must be legitimate, properly authorized and in general accordance with customary international law [3].

2. Neoconzervativism as a Backbone of Bush's Foreign and security policy

Neoconservativism represents a philosophy of political right, which was developed in the US and which calls for the use of the US economic and military power to promote its economic, democratic, and human rights values globally [4]. This political philosophy became the central theme of the US foreign and security policies throughout both presidencies of George W. Bush from 2000 to 2008. Therefore, it is not a surprise that *NSS 2002* and *NSS 2006* were significantly influenced by such political perception, known as "Bush Doctrine".

The term "Bush Doctrine" was introduced for a first time in June 2001 in reaction to the US one-sided withdrawal from the Anti-Ballistic Missile Treaty (ABM) and Kyoto Protocol [5]. By the term "Bush Doctrine" it can be understood several mutually interconnected principles of foreign policy exercised under both presidencies of George W. Bush. Its roots can be tracked into the early nineties of the 20th century. In 1992, former Secretary of Defence Richard Cheney openly stated for a first time that the US should never allow any other nation to become competitive superpower to the US. One of the founding fathers of this idea was also Paul Wolfowitz, who along with Donald Rumsfeld, Richard Cheney and other neoconservatives established a think-tank Project for New American Century (PNAC). One of the most famous PNAC initiatives was addressing an open letter to President Clinton, which called for removal of Saddam Hussein from power even by use of military force, if necessary. This idea was quickly adopted by George W. Bush administration even prior to September 11, 2001 [6].

In reaction to the terrorist attacks on World Trade Center and Pentagon on September 11, 2001, President Bush introduced a radical shift in the US foreign policy, which was based on four main pillars.

The first pillar was the US inclination to conduct pre-emptive strikes in order to safeguard its security. President Bush officially announced this decision during his speech at West Point Military Academy on June 1, 2002, when he stated:

"We cannot defend America and our friends by hoping for the best. We cannot put our faith in the word of tyrants, who solemnly sign non-proliferation treaties, and then systemically break them. If we wait for threats to fully materialize, we will have waited too long – Our security will require transforming the military you will lead – a military that must be ready to strike at a moment's notice in any dark corner of the world. And our security will require all Americans to be forward-looking and resolute, to be ready for preemptive action when necessary to defend our liberty and to defend our lives" [7].

The second pillar of this policy was the US readiness to promote democracy worldwide. Throughout the years from 2001 to 2004, President George W. Bush expressed his opinion several times that the US should, as part of its strategy on the War on Terror, actively support regime change around the globe. This was true especially for the region of Middle East. During his State of the Union address in 2003 President Bush declared:

"Americans are a free people, who know that freedom is the right of every person and the future of every nation. The liberty we prize is not America's gift to the world, it is God's gift to humanity." [8]

Similarly, during his speech at National Security University in 2005 President Bush stated that:

"The defense of freedom requires the advance of freedom." [9]

The third pillar of the "Bush Doctrine" was eagerness to intervene in countries that harbour terrorism. During his Address to the Nation on September 11, 2001, President Bush stated that the US would make no difference between those who commit acts of terrorism and those who harbour terrorists. This statement was later on reassured during his address to both Chambers of the US Congress on September 20, 2001, when he stated:

„We will pursue nations that provide aid or safe haven to terrorism. Every nation, in every region, now has a decision to make. Either you are with us, or you are with the terrorists. From this day forward, any nation that continues to harbor or support terrorism will be regarded by the United States as a hostile regime" [10].

As it is well known, this policy became the reason for the US intervention in Afghanistan.

The fourth pillar of the "Bush Doctrine" was the US will to provide its security even when it would require taking unilateral actions regardless of approval from the international community. As it was already mentioned, this approach was visible immedi-

ately at the beginning of Bush Presidency, when the US withdrew from the ABM Treaty.

The above mentioned four pillars of the "Bush Doctrine" were incorporated into both, National Security Strategy 2002 and National Security Strategy 2006, which became alpha and omega of the US foreign policy under President George W. Bush, and whose impact we observe even today.

3.Comparison of NSS 2002 and NSS 2006

Despite the fact that *NSS 2002* and *NSS 2006* were two different documents, they were strongly influenced by ideological background of Bush administration. Not surprisingly, these documents represent neoconservative perception of the US role in the field of foreign policy. The major difference between these two documents is the fact that when compared to *NSS 2002, NSS 2006* takes into account the development in international relations throughout the period from 2002 to 2006. In other words, *NSS 2006* is rephrased and adjusted *NSS 2002*. Before the comparison of *NSS 2002* and 2006 is discussed, it would be useful to remind the reader briefly about the time when *NSS 2006* was published.

Back in 2006, the US was engaged in the War on Terror for five years. Its major battlefields were located in Iraq and Afghanistan. The war however was developing in a different path than originally anticipated by President Bush. Taliban was defeated neither militarily nor politically. The opposite was true. Due to incompetence of democratically elected Afghan president to provide Afghan population with basic needs, Taliban was gaining in strength and in numbers. Moreover, the same as during the Soviet-Afghan War from 1979 to 1989, enemy combatants successfully enlarged their area of operation also into northern Pakistan [11]. In Iraq, sectarian violence among Shia and Sunny Muslims, and Kurds broke up. Furthermore, in central Iraq a strong guerrilla movement, composed of former Iraqi Army soldiers, established itself with the aim to fight occupying troops. Terrorist group al-Qaeda was defeated neither. It continued to plan and to carry out its terrorists attacks, however one must admit that it was not in such scale as on September 11, 2001 for example. Palestinian-Israeli conflict reached a new peak as the result of Bush one-sided policy toward this region. Surprisingly, after the fall of Saddam Hussein, Iran became the only state in the region that benefited from worsen development in the Middle East. These are the facts one must take into account when comparing *NSS 2002* with *NSS 2006*.

3.1 Presidential remarks

In his introduction to *NSS 2002*, President Bush highlights the importance of geopolitical and economic changes in the nations of former Eastern Bloc. At the same time, he reconfirms the US position as a solely superpower, which enjoys a position of unparalleled military strengths and great economic and political influence. According to him, the US is eager to take advantage of its unprecedented political, economic, and military potential and to spread values of democracy and free market economy globally. This approach became a central theme of *NSS 2002*. President Bush also admits that on the eve of the 21st Century the US faces asymmetric security threats, whose prevention will require cooperation of entire US security establishment. The primary threat to the US security lies at the crossroads of radicalism and technology. In this respect, President Bush reconfirms his readiness to face such threat even by taking a unilateral approach. Moreover, he openly declares the US will to carry out pre-emptive strikes if necessary.

The introduction to *NSS 2006* is untraditional one. President Bush declares that the US is in war, and *NSS 2006* is a war strategy, whose purpose is to protect the US citizens against terrorism. In his opinion, this situation represents an opportunity for the US to lay down the foundation for future peace. The future peace can be achieved only under the condition that the War on Terror is won and democracy is spread globally. This is the key philosophy behind *NSS 2006*. In respect to the US foreign policy, President Bush evaluates his foreign policy for the period from 2002 to 2006. In comparison to *NSS 2002*, he recognizes the need to move from unilateral approach to the multilateral one. Such multilateral approach however should be taken under the leadership of the US only. He concludes his opening statement with reassurance that despite the fact the US is idealistic in its national interests, it is realistic in the means necessary for fulfilling them.

3.2 Content of the US national security strategy

NSS 2002 admits that the US possesses unprecedented strength and influence in the world, which obligates the US to spread political and economic freedom, peaceful relations with other states, and respect for human dignity. From the US point of view, it can be stated that after the century of struggle between freedom and totalitarianism, freedom has won. However, this does not necessarily means that the world is any safer. In the 21st Century, the US is threatened not by conquering states but rather by failing ones. Therefore, the US must take advantage of its position and to spread the ideas of political and economic freedom, peaceful coexistence with other states, and respect of human rights. This should be achieved by championing for human dignity; strengthening alliances to defeat global terrorism; working with others to defuse regional conflicts; preventing the US enemies from threatening the US and its allies and friends with weapons of mass destruction (WMD); igniting a new era of global economic growth through promotion of free markets and free trade; expanding the circle of development by opening societies to democracy; developing agendas for cooperative action with other main centres of global power; and transforming America's national security institutions to meet the challenges and opportunities of the twenty-first century. *NSS 2006* reaffirms the core ideas of *NSS 2002*.

The only difference in *NSS 2006* is the fact that *NSS 2006* emphasizes on phenomenon of globalization. In respect to globalization, the US is eager to engage with opportunities offered by this phenomenon on one hand, and confront its challenges on the other.

When studying the above-mentioned content of both national security strategies, it can be argued that both strategies are comprehensively well-balanced documents, adequately responding to threats of global security environment in the 21st Century. This is true despite the fact that the foundation of these strategies is clearly based on four neoconservative pillars described above.

NSS 2002 as well as *NSS 2006* declares the US readiness to spread democracy, which is perceived as a tool to all global challenges, by all available means. This is a key philosophy, which was thoroughly exercised during both presidencies starting from 2000 to 2008.

Secondly, *NSS 2002* and *NSS 2006* reaffirms the readiness to conduct pre-emptive strikes toward states trying to acquire weapons of mass destruction and means of their deployment, as well as states harbouring terrorists. Despite the fact that unilateral use of power was visible especially during the first presidency, by invading Iraq and Afghanistan, this principle was not totally abandoned during the period from 2004 – 2008. The difference however was the method applied to fulfil this principle. During the second presidency of George W. Bush, the US was applying multilateral approach. The prime example of this shift was the case of Iran, when the US worked closely with its allies and other regional partners to resolve this issue.

The Third neoconservative pillar, on which both documents were built on, is waging War on Terror. During both presidencies of George W. Bush, the US did not negotiate on this principle. Besides the direct military involvement in Iraq and Afghanistan, the US was working closely with its allies and partners to disturb terrorist networks around the globe. This included military, economic, law enforcement, and intelligence cooperation with all the nations facing this threat. Such cooperation took place throughout the whole period starting after September 11 terrorist attacks in 2001 and lasted until the end of the second presidency of George W. Bush in 2008.

The fourth, and the last, neoconservative pillar incorporated into *NSS 2002* and *NSS 2006* is prevention of the rise of a peer military competitor to the US. [12] With arrival of President Bush into the White House, we could witness a significant growth in military spending. Such increases in military spending were not related only to the US involvement in the War on Terror. The significant proportion of the defence budged was dedicated to projects aiming to qualitatively reshape the US military. This included launching wide number of new modernization projects for the US Armed Forces starting with stealth fighter projects and ending with the US anti ballistic missile systems. The objective of these efforts was clearly to guarantee the US military superiority over existing as well as potential canters of power.

4. Conclusion

The aim of this article was to compare perception of the US foreign and security policy by the first and the second presidential administration of George W. Bush and to identify to what extent they were influenced by neoconservativism. When elaborating on this topic, the authors focused their attention particularly on National Security Strategy from 2002 and its modification from 2006, which materialized President Bush's perception and ambitions in foreign and security field.

In general, it can be stated without any hesitations that both presidencies were significantly influenced by neoconservative perception of the US role in foreign and security affairs. When comparing the first presidency to the second one, one may observe that the second presidency already reflected on the development and the US experience in international arena throughout the period from 2002 to 2006.

While both National Security Strategies come from the same ideological background one cannot deny differences between them. The fundamental difference between both presidencies of George W. Bush is the fact that during his second term in the office he took into account the necessity of multilateral approach when dealing with global issues. Additionally, globalization was given an attention as a phenomenon, which must be taken into account when dealing with challenges to the US national security. Despite the fact that both Strategies met the criteria introduced at the beginning of this article, they failed to meet their goals. Forceful spreading of democracy proved to be a failure. With spreading of democracy in Afghanistan and Iraq, the US military presence in the region of Middle East and Central Asia heavily depended on cooperation with surrounding regional authoritarian regimes. These regimes were not very different from those of Saddam Hussein's. As a prime example of such regimes, we can mention Uzbekistan, Turkmenistan, Egypt and others. Moreover, even when a specific authoritarian regime was toppled down, the new one that came to power was not less corrupted or more eager to stand up for democratic values. The excellent example is Pakistan. In terms of the second and the third neoconservative pillar, conducting pre-emptive strikes and waging War on Terror, these proved to be another failure. Almost ten years after invading Afghanistan and Iraq, the world is safer neither from terrorism, nor from potential misuse of weapons of mass destructions. The contrary is true. By invading these countries, the US committed itself into long lasting high intensity conflicts, which require massive military presence that may needed elsewhere in defending the US interests. Moreover, these conflicts created justification for terrorists to carry out their sinister activities and thus created a large pool of potential US adversaries. The fourth pillar, to prevent others to become the US peer competitor, proved to be failure as well. This goal is unattainable from a long-term point of view. Simply by committing a huge amount of scarce resources to long-lasting overseas regional conflicts there was not enough resources for well-proportioned modernization of the US Armed Forces. This in combination with the economic crisis prevented the US to meet this goal neither qualitatively, nor quantitatively.

Bush's successor, Barrack H. Obama has recognised these failure immediately. In reaction, he has introduced his own National Security Strategy, which has reflected on the above-mentioned

facts. Obama's National Security Strategy departs from ideas of neoconservativism. Unlike George W. Bush, President Obama believes that foundation of the US security and power does not come from abroad but it lay at home. It is an economic power of the nation. Therefore, the primary goal must be economic recovery in order to overcome the hardship of economic crisis and to boost the US economy. In his Strategy, Obama also has left the term "War on Terror", as well as the US readiness to conduct pre-emptive strikes. He has rather declared the US commitment to deal with security issues via the standards of international law and international cooperation. However, he has left the room for military action if necessary. In short, it can be said that Obama has recognised that the US dominancy cannot be backed by weapons but rather by values for which the US stands for.

The neoconservativism had not direct impact only on the US foreign policy, but also on the foreign policy of the European Union (EU) and consequently on the Slovak Republic as well. Unfortunately, it was a negative impact. While after the September 11 terrorist attacks all the EU members, as well as the countries joining the EU in 2004, unconditionally backed the US in its involvement in Afghanistan, in the period from 2003 to 2008, the situation was different. With invasion of Iraq, the EU was politically divided on countries supporting and opposing Bush's approach. This division openly supported by several US top senior officials created an environment of distrust within the EU. The EU was unofficially divided on "Old Europe" and "New Europe". While "Old Europe", represented by fully established and tenured EU members such as Germany and France, was opposing the Bush's actions in foreign policy, while the "New Europe" composed of predominantly new member states was following Bush's perception of the foreign policy unconditionally. The Slovak Republic was not exception. In 2003 the Government of the Slovak Republic unconditionally committed its Armed Forces into Iraq and Afghanistan regardless of the domestic public opinion. Moreover, it continued to maintain its military presence in Iraq despite the official reason of military intervention was proved to be a fabrication from Bush's administration. The Slovak military presence, as well as the military presence of other newly admitted EU members, in Iraq served purely for political purpose of Bush's Administration to justify this operation as an international operation. The bottom line is that Bush's foreign policy, strongly influenced by neoconservativism, undermined the US international reputation for years to come, as well as it weakened global security for a long run.

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COMPUTER SIMULATION OF AUTOMOBILE FIRES

Using CFD (Computer Fluid Dynamics) theory and its practical knowledge has become widespread in such academic disciplines as aerodynamics, fluid dynamics, combustion engineering and other fields. However, in disciplines, which examine the ongoing processes in larger sizes, CFD was applied during the last decade only. One of such discipline is a spread of fire. Fire processes are a very complicated and complex phenomenon consisting of combustion, radiation, turbulence, fluid dynamics, pressure and other physical and chemical processes. In the paper, we describe the use of FDS (Fire Dynamics Simulator) for the simulation of automobile/vehicle fires in different environment.

Keywords: computer fire simulation, CFD, fire in tunnel and car park, FDS

1. Introduction

In recent years, the number of car fires on roads has been increased gradually in Slovakia. As a result of this tendency, growing number of injured and killed people and damage caused by these fires has been noticed. Reasons of these fires are different and not always related to a technical or electrical failure of cars. Particularly, arson may cause great material damages in overcrowd town agglomeration and built-up areas, or in wildland–urban interface causing wildfire. Fires in road tunnels, although are still relatively rare in Slovakia, can be very destructive and dangerous when they arise. That is why it is necessary to pay considerable attention to fire safety issues of roads and motorway tunnels. Especially, when the traffic prognosis for Slovakia as well as for other EU countries indicates that the quantity of transported goods and number of cars and tunnels will still grow quite rapidly.

A good knowledge about complex phenomena and processes occurring during the fire in different environments is a significant component of fire safety. One of economically least expensive methods how to obtain the knowledge is computer simulation of fire. It is especially valid in the case of car fires in tunnels, because full-scale fire experiments in tunnels could cause serious damages of material and technical equipment in the tunnel. Nowadays, monitoring the processes development in fire environment allows a relatively good knowledge about the dynamics of liquids and gases. Existing software tools provided by CFD simulation also enable to visualize their development. In the scientific literature, computer simulation of fire was firstly formulated in seventies as zonal models and later as multi-zone models [1, 2]. In these models, the fire area is divided into separate fire areas (zones) so that each of these ongoing processes have been settled. The theoretical basis of these methods was the laws of conservation of mass and energy. The whole space was divided into two zones: a warmer upper portion of space containing heat and smoke and a lower part, which was significantly less affected by heat and smoke. However, the uses of these methods were significantly limited.

CFD models were introduced in nineties and reached significant development and relatively widespread use in various fields of human activity. Several advanced systems directed to simulation of combustion processes have been developed. CFX, PHOENICS and SMARTFIRE systems provide alternative radiation models which may offer a good performance. We use FDS (Fire Dynamics Simulator) system, whose first version was developed in 2000 by the NIST (National Institute of Standards and Technology, USA). At present days, significantly better FDS version 5.5 is already available.

During past ten years, number of papers paid attention to numerical simulation of car fires in open or closed spaces. Particularly, they focused on the research of fires in tunnels and garages and their possible consequences. In [3, 4, 5, 6], fires in open or closed garages were described. The effect of ventilation on the fire spread and smoke movement in car park was simulated and an optimal starting time of a smoke extraction system was studied. Other useful results were obtained by a computer simulation of car fires in tunnels. To optimize the regulation of ventilation system for the case of such fires is also very important. Thermal stratification, maximum smoke temperature under the ceiling and smoke backflow were also studied for different types of fires in tunnels [7, 8, 9, 10].

The aim of this paper is to concisely present theoretical foundations of numerical modelling combustion processes implemented in FDS to highlight also the relatively large-scale use of this system

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for various types of car fires. Moreover, we present the recent results of computer simulation of fire in engine compartment. Simulation of this type of car fire has not been published in the literature yet.

2. Basic equations of the FDS model

FDS [11] solves a form of conservation equations for low speed, thermally driven flow. Smoke and heat transfer from fires is the main concern of this system, which also includes the thermal radiation, pyrolysis, combustion of pyrolysis products, flame spread and fire suppression by sprinklers. The basic set of the conservation mass, species, momentum and energy equations are as follows [11]:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \boldsymbol{u} = \dot{m}_b^m \tag{1}$$

$$\frac{\partial}{\partial t}(\rho Y_\alpha) + \nabla \cdot \rho Y_\alpha \boldsymbol{u} = \nabla \cdot \rho D_\alpha \nabla Y_\alpha + \dot{m}_\alpha^m + \dot{m}_{b,\alpha}^m \tag{2}$$

$$\frac{\partial}{\partial t}(\rho \boldsymbol{u}) + \nabla \cdot \rho \boldsymbol{u}\boldsymbol{u} + \nabla p = \rho \boldsymbol{g} + \boldsymbol{f}_b + \nabla \cdot \tau_{ij} \tag{3}$$

$$\frac{\partial}{\partial t}(\rho h_s) + \nabla \cdot \rho h_s \boldsymbol{u} = \frac{Dp}{Dt} + \dot{q}^m - \dot{q}_b^m - \nabla \cdot \dot{\boldsymbol{q}}^n + \varepsilon \tag{4}$$

where $\dot{m}_b^m = \sum \dot{m}_{b,\alpha}^m$ is the production rate of species by evaporating droplets or particles; ρ is the density; $\boldsymbol{u} = (u, v, w)$ is the velocity vector; Y_α, D_α, and $\dot{m}_{b,\alpha}^m$ are the mass fraction, the diffusion coefficient and the mass production rate of α-th species per unit volume, respectively; p is the pressure; f_b is the external force vector; τ is the viscous stress tensor; hs is the sensible enthalpy; the term $\dot{q}^m$ is the heat release rate per unit volume from a chemical reaction and $\dot{q}_b^m$ is the energy transferred to the evaporating droplets; and the term represents the conductive and radiative heat fluxes. Note that the use of the material derivative $D(\ )/Dt = \partial(\ )/\partial t + \boldsymbol{u}.\mathrm{grad}(\ )$ holds in the last equation.

Other two equations, the pressure equation and the equation of state,

$$\nabla^2 H = -\frac{\partial}{\partial t}(\nabla \cdot \boldsymbol{u}) - \nabla \cdot F \ \text{ and } \ p = \frac{\rho R T}{W} \tag{4}$$

are added to the previous four equations. The pressure equation is obtained applying the divergence on the momentum equation. In this equation, the value H represents the total pressure divided by the density. R is the universal gas constant, T is temperature and W is the molecular weight of the gas mixture.

Thus, we have the set of six equations for six unknowns, which are functions of three spatial dimensions and time: the density ρ, three components of $\boldsymbol{u} = (u, v, w)$, the temperature T and the pressure p. These equations must be simplified in order to filter out sound waves, which are much faster than typical flow speed. The final numerical scheme is an explicit predictor-corrector finite difference scheme, which is second order accurate in space and time. The flow variables are updated in time using an explicit second-order Runge-Kutta scheme.

Boundary conditions are prescribed on walls and vents. All input data for simulation are required in the form of a text file in prescribed format, which describes the coordinate system, geometry of domain and its location in given coordinates, mesh resolution obstacles, boundary conditions, material properties and other different simulations parameters. Important limitations of the system is that the domain should be rectilinear, conforming with underlying grid. The domain is filled with rectangular obstructions representing real objects, which can burn, heat up, conduct heat, etc. Simulation outputs include quantities for gas phase (temperature, velocity, species concentration, visibility, pressure, heat release rate per unit volume, etc.), for solid surfaces (temperature, heat flux, burning rate, etc.), as well as global quantities (total heat release rate, mass and energy fluxes through openings, etc.). These outputs are saved during simulation with desired format for visualization and can be visualized by the Smokeview program.

As it is mentioned in [11], the overall computation can either be treated as Direct Numerical Simulation (DNS), in which the dissipative terms are computed directly, or as Large Eddy Simulation (LES), in which large-scale eddies are computed directly and subgrid-scale dissipative processes are modelled. The numerical algorithm is designed so that LES becomes DNS as grid is refined. Description of the numerical schemes used for the solution of all equations is completely described in [11].

The aim of FDS is to solve practical problems in fire protection engineering, as well as to provide a tool to study basic processes in combustion and fire dynamics. In recent years, it has become a widely used and well tested system by various research teams in the world. It is well known that the accuracy of simulated fires highly depends on grid resolution. Therefore, in many papers authors investigate effects of grid size on different fire characteristics, such as the flame height, radiative heat fluxes, temperature distribution, and so on. In papers [12, 13], the effect of computational grid size on predicted characteristics of thermal radiation for fire is investigated. It was observed for different grid sizes that predicted flame heights for 20, 30 and 38 cm pool fires increase with increasing ratio $D^*/\Delta d$ (i.e., with decreasing grid size), where D^* is the characteristic diameter and Δd is the grid size, and would approach to a certain value. In addition, some studies had shown that the radiative heat transfer is one of dominant heat transfer mechanisms associated with such fires. Therefore, the accurate simulation of radiation strongly influences the prediction of fuel burning rate, smoke management flame inhibition effect, etc. However, the accurate prediction of these distributions depends on the choice of numerical treatments that include also the mesh size.

Another serious problem is the computation of total pressure H which fulfills the pressure equation. This equation solved by numerical scheme gives the Poisson equation, which is solved by a fast Fourier transform. The precision of this solution is very important and has significant influence on simulation outputs.

3. Computer simulation of automobile engine compartment fire (Audi 80)

Simulation of automobile engine compartment fire belongs to the most complex FDS simulation problems. To the best of our knowledge, we do not know any published paper addressed this problem. Due to complex geometry of burning space and objects inside the engine compartment, which affect the fire development and then have to be accurately captured, such a simulation requires very fine mesh resolution and therefore significant computational power for calculation. That is why the design of engine compartment geometry and components in the input FDS file is of great importance. In order to properly model the engine compartment as well as all relevant flammable components in its interior, the corresponding input geometry of simulated space was elaborated using available 3D scans and direct measurements of distances and proportions of detected flammable components. The simulation domain includes plastic, rubber and metallic components which influence the direction of fire and smoke spread in time (see Fig. 1). Engine compartment fire simulation is just the situation in which certain geometric features of engine compartment components do not conform to rectangular mesh, and have to be represented in a different way (electrical cables, tubes, hoses, etc.). The shape of plastic tanks and air filter can be captured almost realistically. However, the rubber tube (small thickness and cylindrical shape) has to be represented by a cluster of thin stripes where the total mass of stripes is equal to the mass of the tube itself. Moreover, the surface to volume ratio of the stripes is the same as that of the tube. Both these parameters, which are crucial for heating up and burning of material, were maintained. By this way some other components, such as paper interior of the air filter box, were modelled.

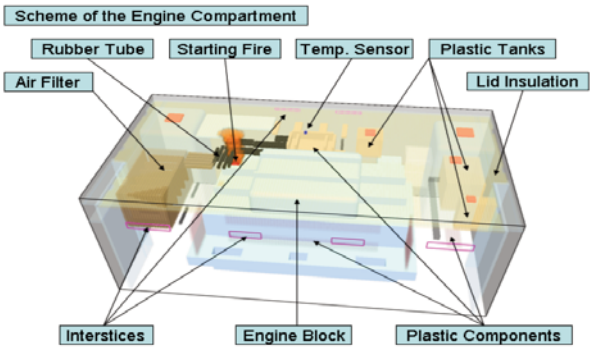

Fig. 1 Computer e model of automobile engine compartment

Proper determination of material properties (physical parameters describing burning properties of materials) in engine compartment was another essential task to be solved. There were four prevailing types of materials identified: aluminium alloy (metallic components), rubber (rubber tube), paper (air filter interior) and mixture of polyethylene (plastic components). Some material parameters for automobile varnish were estimated (e.g. the heat release rate per unit area) and some of them were derived from observations (e.g. the ignition temperature was determined from recorded infra-red camera observations) during the full-scale fire experiment.

In the simulation, the fire ignition source (the small burning cloth placed on the engine block under the rubber tube) is represented by a burning surface with the dimensions of 4 × 4 cm and total heat release rate set to 2.1 kW for the period of 60 s (see Fig. 1). Computational domain consists of two meshes including the interior of engine compartment as well as additional space above the engine compartment bonnet. *The first mesh* includes the interior of engine compartment and 3 cm space above the engine compartment bonnet, in order to show also the temperature distribution on the upper surface of the bonnet. The mesh boundary conditions are given by the material properties of bodywork (aluminium alloy). The mesh size was 132 × 72 × 53 cm with 1 × 1 × 1 cm resolution (503,712 cells total). The second mesh placed above the bonnet includes the space in which potential varnish fire occurs during the simulation. Its size is 172 × 112 × 80 cm with the resolution decreased to 2 cm (192,640 additional cells). Each of two meshes was assigned to one CPU core. The simulation of 720 s of fire required 65 hours of CPU time at Intel Q9550, 2.83 GHz CPU. More detailed comparison between full-scale experiment of the engine compartment fire of Audi 80 and computer simulation is described in [14].

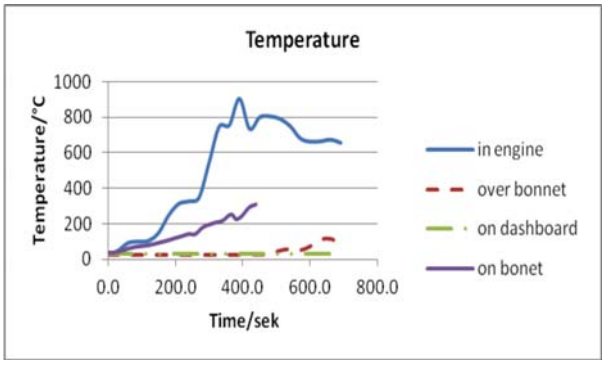

Fig. 2 Temperature in engine compartment obtained by full-scale experiment (IR)

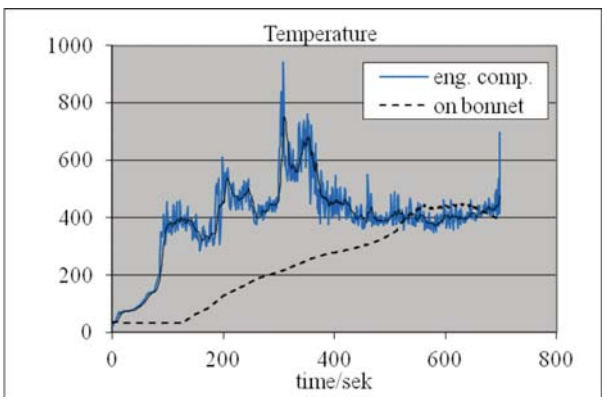

Fig. 3 Temperature in engine and on the bonnet obtained by FDS simulation

4. Computer simulation of additional types of car fires

A simple case of the simulation of ignition of a near-standing automobile from burning vehicle is shown in Fig. 4. We used two identical automobiles of the same type as in the previous simulation.The first automobile represents a source of fire similar to that in the previous case. The distance between the automobiles was 60 cm, what is in actual practice usually an upper border. Wind direction was chosen to accelerate the spread of flames from first to the second automobile. The size of computational domain was 510×540×210 with 3 cm computational mesh resolution. The total number of cells was equal to 2 142 000. The domain was split into four meshes which were assigned to four CPU cores of Intel Q9550 CPU, 2.83 GHz CPU. The simulation in the 4th minute of fire, a short time after ignition of the second car, is shown in Fig. 4. By this way we are able to simulate and analyze ignition of near-standing automobile from burning vehicle depending on the distance between the automobiles in different conditions in open and closed area for miscellaneous car category.

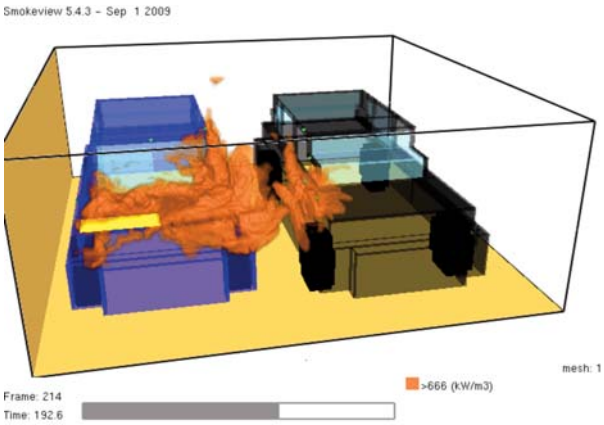

Fig. 4 Ignition of near standing automobile

Fires of automobile seating and/or luggage compartment are not very frequent. However, if they occur (e. g. as a result of arson), they can be very dangerous particularly in urban conglomeration. Such fires can cause large damages especially in the case, when the interior of automobile is sufficiently supplied with oxygen during fire (for example, if it flows through a broken window or ajar door). Computer simulation of such a case is illustrated in Fig. 5.

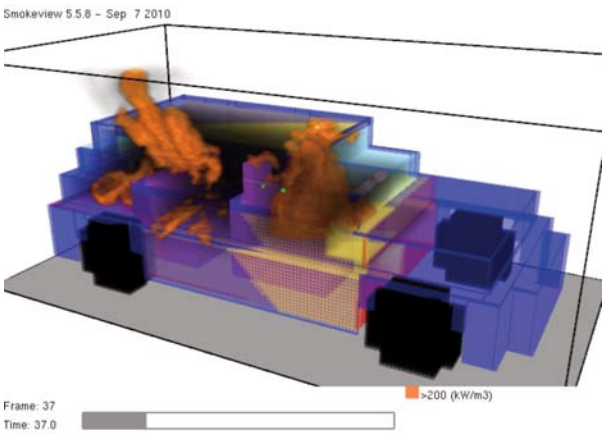

Fig. 5 Fire of automobile seating and luggage space

In order to show the FDS simulation of automobile fire in tunnel, we constructed a model of road tunnel with dimensions 10 × 180 × 7 m (width × length × height, XYZ) with a simple ventilation system consisting of two fans located under the ceiling 50 m far from both tunnel ends. The Cartesian coordinate system for the tunnel was chosen as X × Y × Z ∈ [−5.0, 5.0] × [0.0, 180.0] × [−4.8, 2.2] in meters. The mean gas temperature was measured by the top detectors T1, T2 and T3 in the position [0.0, 20.2, 1.8], [0.0, 125.2, 1.8] and [0.0, 160.2, 1.8], respectively and by the bottom detectors B1, B2, B3 in the positions [0.0, 20.2, −3.1], [0.0, 125.2, −3.1] and [0.0, 160.2, −3.1], respectively (see Fig. 6). The first wall position is exactly over the fire, while the second one is located about 30 m downstream the air blown by fans.

The fire was simulated by burning of combustible block with dimensions [0.0, 2.0] × [97.0, 100.0] × [−3.8,−3.7] with the maximum heat release rate 1000 kW. The initial temperature of air in the whole tunnel was set to 20°C. The total simulation time was 150 s and the dynamics of fire and fans was simulated as follows. At the beginning, the fans started to blow the air with the velocity of 5 m/s in Y-direction. At 40th second, the fire started with linearly increasing power, so that the maximum intensity was achieved at the 45th second and was not changed until the end of simulation. Simultaneously, the fans started to increase the air velocity linearly from the 50th second onwards, whereby the final velocity of 20 m/s was achieved at the 55th second and was not changed afterwards.

Computations were performed in parallel using FDS, version 5.4.0 on the Woodcrest Cluster at Regionales Rechenzentrum Erlangen, Erlangen – Nuernberg University (Germany). This cluster consists of 217 computational nodes, each with two Xenon 5160 Woodcrest chips (4 cores organized in 2 dual cores) running at 3.0 GHz. Each dual core contains 4 MB shared Level 2 cache, 8 GB of RAM and 160 GB of local scratch disk. The Infiniband interconnection network has the bandwidth of 10 Gbit/s per link and direction.

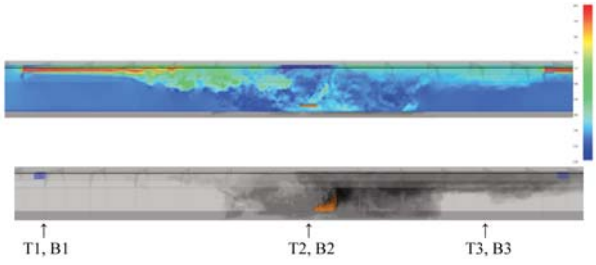

Fig. 6 Distribution of gas velocity (top) and smoke movement (bottom) in the tunnel at the 80th second

5. Conclusion

In this paper, it is shown how the computer simulation can be useful for visualization and analysis of automobile fire processes. Four types of automobile fire simulations are presented. Firstly, the FDS simulation of automobile engine compartment fire, validated by results of the full-scale fire experiment in the testing facilities of Fire Protection College of the Ministry of Interior of Slovak Republic in Povazsky Chlmec, is described. A good similarity between the simulation results and experimentally measured variables was confirmed. Next, the FDS simulations of automobile fires ignited in seating and luggage compartments, as well as the ignition of near standing automobile and the automobile fire in tunnel are illustrated. The simulation results will be also validated by the data obtained from the full-scale fire experiments. The presented simulation results show the great potential to model even relatively very complicated fire scenarios in very different environments.

In [15], some basic objectives how to achieve higher level security from legislative and civil point of view in Slovakia were briefly formulated. We would like to remind that the increase of security and safety in each economically and technically developed country includes also a number of technical and tactical issues which crisis management must take into account [16, 17].

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Dj. N. Dihovicni *

CONSTRUCTING KNOWLEDGE DATABASE IN DECISION MAKING

The paper describes solving problem of constructing knowledge database of a decision making in process safety. It provides analyses of the requirements as well the analyses of the system incidents caused by specification, design and the implementation of the project. Main focus of this scientific paper is highlighted on practical stability problem and conditions for optimal performance of safe fault-tolerant controllers, I/O, engineering and pressure transmitters. Algorithm of decision making in process safety is developed and the system has been realized taking into account C# approach in Windows environment.

Key words: decision making, safety, process

1. Introduction

One of the most important tasks in the safety engineering lies in the construction of a knowledge database of decision support for the chemical plants, and that way to ensure optimal conditions, improve quality and boost efficiency. Methods of analysis of control systems and simulation methods, which are used for observing dynamic behavior of linear systems with time delay, and distributed parameter systems, based on linear algebra, operation calculus, functional analysis, integral differential equations and linear matrix non-equations showed long ago that modern electronic components can be used to achieve more consistent quality at lower costs in safety engineering. The main idea to do so is that the quality service is maintained and controlled. Applying the Fuzzy theory in decision making has given very good results, and provided a flexible framework and over the years numerous mathematical models have been developed.

There are two basic problems to solve in decision making situations: obtaining alternative, and achieving consensus about solution from group of experts. First problem takes into account individual information which existed in collective information units. The latter usually means an agreement of all individual opinions. Usually two approaches are considered for developing a choice process in solving decision making problems: a direct approach where solution is derived on the basis of the individual relations and as well indirect approach where solution is based on a collective preference relation. In safe engineering using of the PLC has shown technical and economic benefits over hard-wired components. A main problem in process engineering is practical stability of the system. The chosen system should be stable in required period of time, and this important task is obtained by using practical stability theory for distributed parameter systems. Most systems in chemical engineering as chemical plants for instance, are described by partial different equations and they belong to a group of distributed parameter systems.

2. Practical Stability

During the process of analysis and synthesis of control systems a fundamental problem is stability. It is a well-known fact, that we can share stability definitions to Ljapunov and non-Ljapunov concepts that have arisen from various engineering needs. The most often case for consideration of control systems is Ljapunov approach, where the system behavior is considered on infinite interval which in real cases has only academic importance. From strictly engineering point of view it is very important to know the boundaries of the system trajectory in state space. These practical technical needs are responsible for non-Ljapunov definitions, and among them is extremely important behavior on finite time interval- practical stability. Taking into account that the system can be stable in the classical way lacking appropriate quality of dynamic behavior, and because of that it is not applicable, it is important to take the system in consideration in relation with sets of permitted states in phase space which are defined for such a problem. In theory of control systems there are demands for stability on finite time interval that for strictly engineering point of view has tremendous importance. The basic difference between Ljapunov and practical stability is set of initial states of system (S_α) [2], and set of permitted disturbance (S_ε) in state space, for every opened set S_β permitted states the equilibrium point of that system will be totally stable,

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instead the principle of practical stability where are sets (S_α, S_ε) and set S_β which is closed, determined and known in advance.

Taking into account the principle of practical stability, the following conditions must be satisfied:

- determine set S_β- find the borders for system motion
- determine set S_ε- find maximum amplitudes of possible disturbance
- determine set S_α of all initial state values.

In case that these conditions are regularly determined it is possible to analyse the system stability from practical stability view of point.

3. Definitions and Conditions of Practical Stability

Let us consider first order hyperbolic distributed parameter system, which is decribed by the following state- space equation:

$$\frac{\partial \underline{x}(t,z)}{\partial t} = A_0 \cdot \underline{x}(t,z) + A_1 \frac{\partial \underline{x}}{\partial z} \tag{1}$$

with appropriate function of initial state

$$\begin{aligned} &\underline{x}_0(t,z) = \underline{\psi}_x(t,z) \\ &0 \le t \le \tau,\ 0 \le z \le \zeta \end{aligned}, \tag{2}$$

where $\underline{x}(t,z)$ is n-component real vector of the system state, A is the matrix appropriate dimension, t is time and z is space coordinate.

Definition 1: The distributed parameter system described by equation (1) that satisfies initial condition (2) is stable on finite time interval in relation to [$\xi(t,z)$, β, T, Z] if and only if:

$$\begin{aligned} &\underline{\psi}_x^T(t,z) \cdot \underline{\psi}_x(t,z) < \zeta(t,z) \\ &\forall t \in [0,T],\ \forall z \in [0,\zeta] \end{aligned} \tag{3}$$

then it follows

$$\begin{aligned} &\underline{x}^T(t,z)) \cdot \underline{x}(t,z) < \beta \\ &\forall t \in [0,T] \forall z \in [0,Z] \end{aligned} \tag{4}$$

where $\xi(t,z)$ is scalar function with feature $0 < \xi(t,z) \le \alpha$, $0 \le t \le$ $\le \tau$, $0 \le z \le \zeta$ where α is real number, $\beta \in R$ and $\beta > \alpha$.

Let us calculate the fundamental matrix for this class of system:

$$\frac{d\Phi(s,\sigma)}{d\sigma} = A_1 \cdot (sI - A) \cdot \Phi(s,\sigma), \tag{5}$$

where after double Laplace transformation the fundamental matrix is given by the equation, Dihovicni *et al.* [4]:

$$\Phi(t,z) = \exp(A \cdot t \cdot z), \tag{6}$$

$$\text{where } A = \frac{I - A_0 \cdot A_1}{A_1}.$$

Theorem1: The distributed parameter system described by equation (1) that satisfies internal condition (2) is stable on finite time interval in relation to [$\xi(t,z)$, β, T, Z] if and only if:

$$e^{2\mu(A)\cdot t \cdot z} < \frac{\beta}{\alpha}. \tag{7}$$

Proof: Solution of equation (1) with initial condition (2) is possible to describe as:

$$\underline{x}(t,z) = \Phi(t,z) \cdot \underline{\psi}(0,0). \tag{8}$$

By using the above equation it follows:

$$x^T(t,z) \cdot \underline{x}^T(t,z) = \left[\underline{\psi}_x^T(0,0) \cdot \Phi(t,z)\right] \cdot \left[\underline{\psi}_x^T(0,0) \cdot \Phi(t,z)\right]. \tag{9}$$

By using well-known ineqality

$$\left\|\Phi(t,z)\right\| = \left\|\exp[A \cdot t \cdot z]\right\| \le \exp\left\{\mu(A) \cdot t \cdot z\right\} \tag{10}$$

and taking into account that:

$$\begin{aligned} &\underline{\psi}_x^T(0,0) \cdot \underline{\psi}_x(0,0) < \alpha \\ &\left(\left\|\underline{\psi}_x^T(0,0)\right\| = \left\|\underline{\psi}_x^T(0,0)\right\| < \alpha\right) \end{aligned} \tag{11}$$

then it follows:

$$\underline{x}^T(t,z) \cdot \underline{x}(t,z) \le e^{2\mu(A\cdot t\cdot z)} \cdot \alpha. \tag{12}$$

Applying the basic condition of theorem 1 by using equation (7) to further inequality we obtain Dihovicni *et al.* [4]:

$$\underline{x}^T(t,z) \cdot \underline{x}(t,z) < \left(\frac{\beta}{\alpha}\right) \cdot \alpha < \beta. \tag{13}$$

Theorem 2: The distributed parameter system described by equation (1) that satisfied initial condition (2) is stable on finite time interval in relation to [$\xi(t,z)$, β, T, Z] if and only if:

$$\begin{aligned} &e^{\mu(A)\cdot t\cdot z} < \frac{\sqrt{\beta/\alpha}}{1 + \tau \cdot \zeta \|A\|}. \\ &\forall t \in [0,\tau] \forall z \in [0,S] \end{aligned} \tag{14}$$

The proof of this theorem is given in Dihovicni *et al.* [3].

Let $|\underline{x}|_{(\cdot)}$ be any vector norm and any matrix norm $\|\cdot\|_2$ which originated from this vector. Following expresions are used:

$$|\underline{x}|_2 = (\underline{x}^T \cdot \underline{x})^{1/2} \text{ and } \|\cdot\|_2 = \lambda_{\max}^{1/2}(A^* \cdot A),$$

where * and T are transpose-conjugate and transport matrixes.

It is important to define the matrix measure as:

$$\mu(A) = \lim_{\varepsilon \to 0} \frac{\|1 + \varepsilon \cdot A\| - 1}{\varepsilon}. \tag{15}$$

The matrix measure μ may be defined in three different forms according to the norm which is used:

$$\mu_1(A) = \max\left(\mathrm{Re}(a_{kk}) + \sum_{i=1, i\neq k}^{n} |a_{ik}|\right)$$

$$\mu_2(A) = \frac{1}{2}\max\lambda_i(A^T + A)\ . \tag{16}$$

$$\mu_\infty(A) = \max\left(\mathrm{Re}(a_{ii}) + \sum_{k=1}^{n} |a_{ki}|\right)$$

Definition 2: The distributed parameter system described by equation (1) that satisfies initial condition (2) is stable on finite time interval in relation to [ξ(*t,z*), β, *T*, *Z*] if and only if, Dihovicni *et al.* [3]:

$$\left|\underline{\psi}_x(t,z)\right|_2 < \xi(t,z) \tag{17}$$

then follows

$$\left|\underline{x}(t)\right|_2 < \beta\,, \tag{18}$$

where ξ(*t,z*) is scalar function with feature $0 < \xi(t,z) \leq \alpha$, $0 \leq t \leq$ $\leq \tau$, $0 \leq z \leq \zeta$) α is real number, $\beta \in R$ and $\beta > \alpha$.

Theorem 3: The distributed parameter system described by equation (1) that satisfies initial condition (2) is stable on finite time interval in relation to [α, β, *T*, *Z*] if and only if:

$$e^{\mu_2(A)\cdot t\cdot z} < \frac{\sqrt{\beta/\alpha}}{1 + \mu^{-1}{}_2(A)}\ . \qquad \forall t \in [0,T] \forall z \in [0,Z] \tag{19}$$

Proof: Solution of equation (1) with initial condition (2) is possible to describe by using fundamental matrix as:

$$\underline{x}(t,z) = \Phi(t,z)\cdot\underline{\psi}_x(0,0)\,. \tag{20}$$

By using the norms of left and right side of the equation (20) it follows:

$$\underline{x}^T(t,z)\cdot\underline{x}(t,z) \leq e^{2\mu(A\cdot t\cdot z)}\cdot\alpha \tag{21}$$

and by using well-known inequality

$$\left\|\exp(A\cdot t\cdot z)\right\|_2 \leq \exp\left\{\mu(A\cdot t\cdot z)\right\} \tag{22}$$

$t \geq 0,\ z \geq 0$

it follows:

$$\left|\underline{x}(t,z)\right|_2 \leq e^{\mu_2(A)\cdot t\cdot z}\left|\underline{\psi}_x(0,0)\right|_2 \tag{23}$$

and by using equation (17) it is obtained:

$$\left|\underline{x}(t,z)\right|_2 \leq e^{\mu_2(A)\cdot t\cdot z} \tag{24}$$

so finally it is obtained:

$$\left|\underline{x}(t,z)\right|_2 \leq \alpha\cdot e^{\mu_2(A)\cdot t\cdot z}\left\{1 + \mu_2^{-1}(A)\right\}. \tag{25}$$

Applying the basic condition of theorem 3 by using equation (19) it is obtained:

$$\left|\underline{x}(t)\right|_2 < \beta \tag{26}$$

$$\forall t \in [0,T],\ \forall z \in [0,Z]\,.$$

Theorem 4: The distributed parameter system described by equation (1) that satisfies initial condition (2) is stable on finite time interval in relation to [α, β, *T*, *Z*], if and only if Dihovicni et al. [3]:

$$e^{\mu(A\cdot t\cdot z)} < \frac{\beta}{\alpha}\,. \tag{27}$$

$$\forall t \in [0,T],\ \forall z \in [0,Z]\,.$$

Theorem 5: The distributed parameter system described by equation (1) that satisfies initial condition (2) is stable on finite time interval in relation to [t_0, *J*, α, β, *Z*], if and only if:

$$\left[1 + (t - t_0)\cdot\sigma_{\max}\right]^2\cdot e^{2(t-t_0)\cdot z\cdot\sigma_{\max}} < \frac{\beta}{\alpha},\ \ ,$$
$$\forall t \in [0,T],\ \forall z \in [0,Z]\,. \tag{28}$$

where σ_{max} represents the maximum singular value of matrix. The proof of this theorem is given in Dihovicni *et al.* [4].

4. Practical Part of Realization

There are few well known stages in developing computer decision support systems based on knowledge which include choosing suitable mathematical tools, formalization of the subject area [4], and development of the corresponding software. In the first phase the problem lies in making the right diagnosis and in analyses of the requirements and as well the analyses of the system incidents caused by specification, design and the implementation of the project. The problem of diagnostics may be stated such as finite number of subsets Herrera *et al.* [5], or classical investigation methods should be applied Thayese *et al.* [6].

The system architecture consists of the following modules:

- Stability checking module. This module is designed as a program for checking the practical stability of the system. If the system passes this check it goes further to other modules.
- Analysis module of safe fault-tolerant controllers, I/O, engineering and pressure transmitters.
- Diagnostics module.
- Knowledge Module of all possible situations and impacts to chemical plants.
- Optimal solution- decision making module.
- Presentation module.

For system realization an object oriented programming approach has been used, and the program has been developed

using the C# language. Each module has a supportive library and the logical structure is based on the classes, which are described below for ustration.

- Main classes are:
- **Analyses** group whose primary task is to collect necessary facts about the system.
- **Practical stability** group which determines whether the system is stable or not. If the system is unstable in view of practical stability, then it is automatically rejected.
- **Diagnosis group** describes all possible casualities for not required results or potencial casualities for not optimal costs.
- **Performance group** is used for the optimal performance.
- Cost group is used for the optimal cost effect.
- Decision making algorithm for optimal performance and cost consists of two phases:
- **Phase 1** is used for input Analyses class, Practical stability class and diagnosis class.
- **Phase 2** is used for output Performance and Cost group.

5. Conclusion

By analysing process systems from safety and optimal cost perspective, it is important to recognize which systems are not stable in real conditions. From engineering state of view we are interested in such systems which are stable in finite periods of time; so our first concern should be to maintain stable and safe systems. Our knowledge database is created in DB2 and it involves all possible reasons for non adequate performance. Key modules for obtaining the best performance, safety and low costs are a good base for the program support in C# programming language and the UML representation.

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ASSESSMENT AND MANAGEMENT OF LEVEL CROSSING RISKS

The goal of the project "Assessment and Management of Level Crossing Risks" was to make a comprehensive analysis of safety of level crossings in the Moravian-Silesian Region. The project is divided into several phases including technical and legislative aspects as well as issues of human factor affecting the occurrence of incidents related to level crossings. In individual chapters, results of questionnaire survey concerning the given problems are processed, the analysis of level crossing risks is made and measures to reduce the risks associated with level crossing traffic are proposed.

1. Introduction

In the Czech Republic many casualties and injuries are still connected with level crossings. The high death and injury rates of level crossing traffic in the Czech Republic are given above all by the historical development of the number of level crossings, i.e. places where a railway line crosses a road or path, and by the present-day increase in road traffic. For this reason, the Union for the Development of the Moravian−Silesian Region and the Czech Technology Platform on Industrial Safety gave impetus to the project *Assessment and Management of Level Crossing Risks* in which also the Railway Infrastructure Administration (henceforth referred to as SŽDC) participated.

Level Crossings

(1) A level crossing according to Act No. 266/1994 Coll., on rail systems as subsequently amended [1] is defined as a point of a railway crossing with a surface road at the level of rails. In the mentioned Act, Section 6, it is stated that if the railway is crossing a road at the level of rails, the rail transport operation shall have the right of way over the transport on road communications. Each level crossing regardless the type of level crossing must be equipped with a crossbuck or another type of crossing safety device. If all standards, decrees and regulations on the design, construction and maintenance of level crossings are fulfilled, level crossings can be regarded as safe. In spite of the fact that the above-mentioned legal aspects are satisfied, many people die annually of just level crossing accidents.

Rate of Level Crossing Accidents in the Moravian-Silesian Region

One of regions with a high risk of railway accidents is the Moravian-Silesian Region (furthermore referred to as MSR). In the territory of MSR 647 level crossings falling within the scope of SZDC Ostrava are there (see Table 1).

Overview of level crossings in MSR — Table 1

Overview of level crossings on lines in MSR – by type of safety device		
Crossings equipped merely with a crossbuck		398
Crossings equipped with a crossing safety device (CSD)		249
• Crossings equipped with warning lights - total	235	
• Crossings equipped with a mechanical CSD	14	
Total number of crossings	647	

In the years 2005–2009, 101 accidents occurred at these crossings; 56 persons were injured, 19 persons died and altogether the value of damage to property was more than CZK 16.5 . 10^6 [2, 5, 6]. The numbers of accidents in individual years in the given area are presented in Table 2.

Number of collisions at level crossings in MSR in the years 2005–2009[2] — Table 2

Number of collisions at level crossings in MSR in the years 2005–2009						
Means	Year					
	2005	2006	2007	2008	2009	total
car	22	20	9	11	13	74
lorry	2	1	2	2	0	7
motorcycle	0	0	1	1	1	3
cyclist	1	1	1	0	2	5
pedestrian	2	4	0	1	4	11

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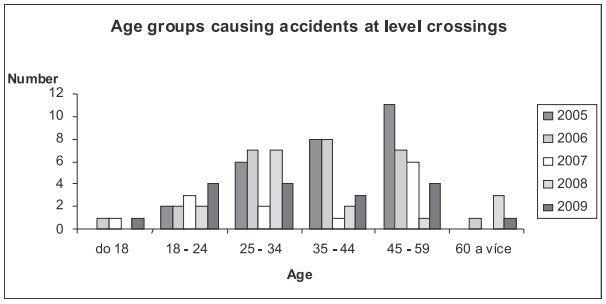
To assess the accident rate in this region, rather detailed analyses for the period of last five years, i.e. the years 2005–2009, were carried out. As an example, Graph 1 is given below.



Graph 1: Age influencing the number of accidents at level crossing in the years 2005–2009 [2]

2. Perception of Level Crossing Risks

Each road traffic participant knows what traffic lights look like, what the meaning of their signalling is, and knows what to do when the red, yellow and green lights are on. However what is the cause of that fact that red lights at level crossings are not perceived and respected in the same degree as red lights at crossroads? If we think about this, consequences of showing little respect for them at level crossings are usually more serious than at crossroads [6, 7].

This behaviour and perception of possible risks to drivers and also other road traffic participants at level crossings and at crossroads became a stimulus to conducting a questionnaire survey.

Questionnaire Survey

The aim of questionnaire survey was to define and specify the road traffic participants at level crossings who took part in the questionnaire survey, to evaluate the knowledge of road traffic participants in the area of level crossings, to evaluate the influence of external conditions and stereotype on the satisfaction of level crossing regulations and the view of road traffic participants of perception of level crossing risks.

To accomplish the set objectives, the method of sociological survey, namely written questioning, was used. The questionnaire was anonymous and comprised 13 closed questions.

Results of Questionnaire Survey

Altogether 340 questionnaires were sent to respondents in the period from the beginning of July to the end of September in the year 2010; 175 questionnaires were returned completed.

Participants in the survey were men and also women of various age groups, with different lengths of driving experience. From the evaluation of the questionnaires it followed that two thirds of respondents were men; the 25–34 year old group was the largest. The most of respondents met level crossings mainly as drivers having more than 5 years of driving experience; also other level crossing users participated (pedestrians and engine drivers).

From the questionnaire it has been found that respondents e.g.

- consider a level crossing to be a crossroads
- have most frequently failed to notice and crossed a level crossing equipped with a crossbuck
- know the speed with which they are permitted to enter a level crossing
- state that the most frequent cause of failing to notice signs and markings and of passing through a level crossing is the fact that the driver is in a hurry and ignores traffic signs and markings
- do not know any campaign focused on level crossing safety.

3. Analysis of Level Crossing Risks

The first step in the process of reducing risks is naturally the analysis of the risks. The risk analysis is usually understood as a process of determination of threats, probability of implementation of these threats and their consequences, i.e. the determination of risks and severity of the risks. The risk analysis becomes the decisive basis for the process of elimination of level crossing risks.

Risk Analysis Procedure

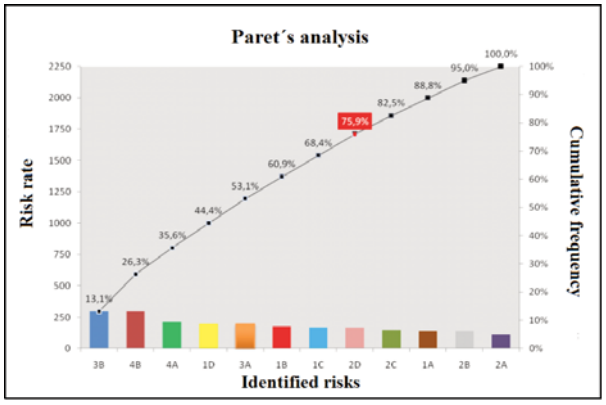
In the first stage, it was necessary to define the boundaries that would be used for the risk analysis. For the needs of risk analysis, these boundaries were divided into 2 areas: legislative framework x level crossing itself, its borders. Furthermore, level crossing traffic participants had to be defined generally, i.e. road traffic participants as well as railway traffic participants. The following step was the specification of dangerous substances (toxic, combustible, explosive, and others). For the needs of the risk analysis, substances were divided into liquid and gaseous substances. The kind and type of chosen substances correspond best to materials transported by road as well as by rail. The last step was the determination of the order of individual methods in making the risk analysis. The following procedure was proposed:

1. application of What – If method,
2. application of FMEA method,
3. application of FTA method.

Results of Risk Analysis

When making the risk analysis, the following scenarios were evaluated:

a) an accident between a tank lorry transporting a dangerous substance and a passenger train (in combination with the injury of participants and release of dangerous substance – 1A – 1D),
b) an accident between a tank lorry and a goods train – both transporting dangerous substances (in combination with the injury of participants and release of dangerous substance – 2A – 2D),
c) an accident between a car and a passenger train (with / without the injury of participants – 3A – 3B)
d) an accident between a bus and a passenger train (with / without the injury of participants – 4A – 4B)



Graph 2: Paret's analysis

From the above-mentioned and made analyses it has followed that the most severe risks are:

A crash between a tank lorry transporting dangerous substances and a passenger train:
- involving the injury of participants and involving no release of dangerous substance – 1B
- involving no injuries of participants and involving the release of dangerous substance – 1C
- involving the injury of participants and the release of dangerous substance – 1D

In this part it is clear that the most important factor is the number of directly affected people as a consequence of potential accident/traffic accident at the level crossing (either direct endangering passengers' health, or endangering the health of driver of the tank lorry due to the accident or the release of dangerous substance).

A crash between a tank lorry transporting a dangerous substance and a goods train transporting a dangerous substance:
- involving the injury of passengers and the release of dangerous substance – 2D

In this case it is necessary to consider two factors, namely the probability of the collision between the tank lorry transporting a dangerous substance and the goods train transporting a dangerous substance. This probability is quite small, but consequences that may occur in case of crash may be fatal for both the driver/engine driver and the surroundings of the level crossing (population in the vicinity of the level crossing and contamination of the environment).

A crash between a car and a passenger train:
- involving no injury of accident participants – 3A
- involving the injury of accident participants – 3B

Here the important factor is the high probability of accident occurrence, because the frequency of cars is the highest of those of all the above-mentioned transport means, and also because in the evaluation of data on level crossing accidents the majority of level crossing accidents were caused by drivers of cars.

A crash between a bus and a passenger train:
- involving no injury of accident participants – 4A
- involving the injury of accident participants – 4B

As a consequence of crash between a bus and a passenger train, a high number of people are potentially endangered. Many passengers may be injured and killed. With such incident, a difficult intervention of fire brigades and the emergency treatment of injured persons by emergency medical service are connected. People who are participants in such an accident may suffer psychical injury/trauma that will accompany them for their whole lives. As a consequence they will not be able to go by such means (bus, train) any more in order to avoid the same situation.

4. Proposed Measures

The proposed measures following from the comprehensive solving of problems of level crossings could be divided, according to their character, into the following three groups: technical measures, organisational measures and educational measures. The specific groups are characterised and analysed below.

1) Technical Measures

Technical measures are such measures that eliminate the occurrence of a fault. They should be as cheap as possible, but yet effective.

a) Replacement of Gate

An effective way to prevent the entry to the crossing is to replace the existing protection gate by another type of barrier that should completely prevent the entry. This is of course very expensive but proven, e.g. in Spain. Crossings are protected here by means of rising posts. The level crossing is equipped with an optical and an acoustic signalling device; after their activation, the posts become to rise from the ground. This type of protection has replaced the existing gate (barrier).

In the Czech Republic this type of protection is not entirely unknown. It can be met on roads, but not at level crossings. The advantages of application of such protection equipment to level crossings are an increase in safety and the prevention of entry of

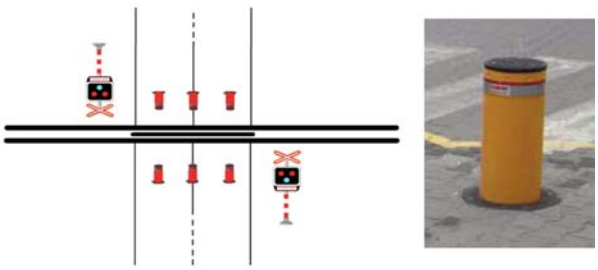


Fig. 1: Rising posts

vehicles to level crossings. The disadvantages of this piece of equipment are the costs of purchase and assembly.

b) Change in Type of Optical Signalling Device

As for light signalling devices, it would be suitable to use diodes instead of present-day lights. Diodes can be seen better even when blinded by sun glare, in fog, in conditions of poor visibility, and others.

New indicators using LED technology have already been tested in the Czech Republic. By testing it has been found that the lights can be seen in sharp sunshine much better; even from the extreme angles of view, when the light of lamps is less visible. The advantages are the longer life of LEDs and the fact that each of three lights of the indicator is fitted with 137 LEDs that are electronically divided into three independent circuits – segments. In case of fault in one circuit, the remaining LEDs (about 90 pcs) emit light sufficient for fulfilling standards and regulations on the luminous intensity of indicators. [3]

c) Change in Traffic Signs

For the selected level crossings with an increased number of traffic accidents we recommend using a warning traffic board "Caution, frequent accident level crossing" (see Figure 2) similarly to road traffic, where in the selected parts there are traffic signs warning of frequent accident points. The designed traffic sign could be classed to the group of warning traffic signs and designated as sign No. A 34; in combination with the traffic sign No. A 31c it could (80 m ahead of crossing) warn of a level crossing at which traffic accidents occur frequently.

Fig. 2 Design of traffic sign "Caution, frequent accident level crossing"

d) Making Traffic Signs More Conspicuous

An important point is also making level crossing signs more conspicuous. It would be suitable to use red reflex reflectors, which can be seen better by drivers in conditions of poor visibility, instead of red stripes.

e) Additional Markings

To additional markings, light guide strips (cat's eyes) belong. A light strip would either draw the attention of drivers to the level crossing permanently, or the lights would be switched on after activation of the crossing safety device by a coming rail vehicle. Before the level crossing, drivers would be warned by means of a row of high-intensity LED warning lights placed across the road. Another possible way of road marking would be the use of so-called "optical-psychological brake" with acoustic effect, such as several stripes running across the road before a level crossing. These manners have already been dealt within a project of Ministry of Transport [4].

f) Camera System and Dummy Cameras

An effective way to prevent passing through level crossings after activation of signalling devices is the installation of cameras that begin recording simultaneously with the activation of signalling devices or shortly before the activation. If the driver is aware that his/her behaviour is being observed, his/her behaviour is more responsible and in accordance with regulations. This manner of prevention is already utilized in some places; however, this way is very difficult from the organisational point of view (records must be checked, drivers breaking regulations must be identified and fined), from the financial point of view and also the point of view of safety. The proper purchase and operation of a camera system is expensive, despite the fact that cameras may be stolen or destroyed. For this reason, cameras could be replaced by dummy cameras, and from time to time, moved from level crossings where they are used to other selected level crossings.

g) To Execute Changes

The purpose of this measure is to execute such changes in a signalling device and in its immediate surroundings that will be able to disturb the driver's stereotyped acting, such as change in the sound of the signalling device, etc., but that will be in accordance with relevant standards and regulations.

2) Organisational Measures

Organisational measures should be divided according to their scope of competence and powers.

a) Police of the Czech Republic, Municipal Police

- rather frequent inspection of traffic at level crossings, fining of drivers breaking the road traffic regulations,
- interpretation of camera records,
- organisation of educational actions for children in schools.

b) Employee of SŽDC – Rail Transport Engineer

- to keep regular checks of signs and markings,
- to keep regular checks of sight conditions,
- to keep regular checks of functionality of signalling devices
  - all checks should be conducted by a person unfamiliar with the given level crossing and its surroundings to avoid ignoring possible worsened conditions owing to the good knowledge of local conditions and stereotype.

c) In General

- formation of a database on hazardous crossings in the region,

- clarification of competence, authorities and responsibilities of organisations as for individual safety devices, signs and markings, and others,
- making legislation and recourse stricter in the case of not obeying the regulations of road traffic at level crossings,
- preparation of publications, leaflets on *"How to behave at level crossings?" and "How to behave at a level crossing in case of accident?"*
- media pressure, better awareness, e.g. of accident rate statistics,
- not to carry out nationwide media campaigns, but to focus on specific areas, regions, because people are more sensitive to and interested in things that happen in their surroundings than at the other end of the country.

3) Educational Measures

Educational measures are to increase the awareness of people on hazards associated with level crossings, on prevention of these hazards and on how to behave in the case of accident at a level crossing.

The proposals are divided into groups according to the target groups for which they are intended:

- *basic schools*
- inclusion of educational actions and traffic education in the teaching-learning process in basic schools;
- distribution of instructional films on behaviour at level crossings to schools;
- *driving schools*
- to increase attention paid to level crossing problems in teaching in driving schools;
  - by driving simulators, instructional films drawing attention to hazards by means of information on road traffic regulations when passing through level crossings and information on how drivers and other persons are to behave if being a participant in an level crossing accident (where to call, what to report, etc.);
- *the public*
- information on behaviour at level crossings intended for drivers and also for pedestrians;
- fining pedestrians, cyclists for going around the closed gate at level crossings.

In the course of implementation of the measures, attention should be paid especially to feedback. This means that after a given time period, tests and surveys will be carried out that will verify the efficiency of measures implemented.

5. Conclusion

The goal of the project on the topic "Assessment and Management of Level Crossing Risks" dealt with for several months was to make a comprehensive analysis of safety of level crossings in the Moravian-Silesian Region, covering technical as well as legislative aspects and also human factor issues.

Of the above-mentioned proposed measures to reduce risks, the following measures are recommended preferentially:

- *Increase in the level of protection of level crossings* (installation of gates);
- *Making level crossing additional signs and markings more conspicuous* (optically and acoustically);
- *Improvement of awareness and education of road traffic participants* (campaigns, driving schools, pupils of basic schools and students of secondary schools).

This contribution was prepared as part of the grant project of Student Grant Competition of VŠB – Technical University of Ostrava, No. SP/2010126 "Assessment and Management of Level crossing Risks".

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DETERMINATION OF TEMPERATURE CONDITIONS FOR A DESIGN OF ENGINEERING CONSTRUCTIONS DURING A FIRE

The problem of an engineering constructions design for effects of fire results from contemporary knowledge and procedures used in technical practice, however, is not limited only to norm recommendations, but looks also for other suitable methods of design. To examine fire endurance of engineering constructions by computation it is necessary to perform the determination of temperature in the area through models for follow-up thermal analysis. This article therefore presents principles of choice of appropriate design fire scenario by determination of the whole conception of safety and then presents a valiant solution of determination of the thermal action though the design fire by the form divergent from norm procedures. In addition, in the text it is alerted to deficiency and limitation in work used norm principles.

Keywords: design, thermal effect, fire scenario, design fire

1. Introduction

Every examination of fire protection of buildings requires forming of an expert opinion. This opinion predicts not only possible fire and smoke source and expansion, reaction of installed fire protective equipment but also characteristic behaviour of building constructions during a fire. On this basis rises, considering input data and analytical methods used, fire protective design built by the designer, who, in relation to possible hazards, determines such strategies of fire protection that have risk on commonly acceptable level.

From the view of examination of building constructions fire resistance is for the present typical the "trend" of fire building constructions resistance determination with the usage of the *Eurocodes.* In terms of fire protection is the most important the CSN EN 1991-1-2 Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire [1].

By designing of building constructions on effects of fire it is also possible to use *principles of fire protection engineering*. Their application doesn't follow the common procedure of determination of thermal conditions (for example fire curve). In these cases the relevant fire characteristic is determined so that it represents one or more fire scenarios, which may occur by particular building.

The procedures for determination of building constructions fire endurance mentioned above are very close in some details, may concur or eventually be complementary to each other.

2. Requirements and demonstration of building constructions fire resistance

Fire resistance of building constructions is collectively expressed ability of constructions to resist the effects of fire. Evaluation of fire resistance consists in proof of given requests fulfilment.

Constructions fire resistance requirement in relation to fire risk of fire compartments is determined *according to the code of standards about building fire safety* (series CSN 73 08xx) *or according to other data* (for example according to CSN EN 1991-1-2). The fire resistance is on regular basis determined for *standard fire process* or *probable* (parametrical) *fire process*. To the standard fire process correspond fire resistances determined by calculate fire load or by equivalent period of fire duration. The probable fire process is determined according to the specific conditions of considered part of building or technological object, generally with variant temperature course in burning area from standard fire development. Probable fire development is determined by probable period of fire duration and by probable gases temperature [2] or by temperature analysis of parametrical fire development [2].

Constructions fire resistance is determined (demonstrated) by *classification* according to results of tests according to appropriate test standards or by *standard value* (for example based on CSN 73 0821), *eventually by evaluation* (in cases when all factors affecting the fire resistance can be numerically defined) or it is possible to determine it by test *and evaluation* (in cases when not all factors affecting the fire resistance can be covered by test or when the results of tests require for particular application farther examination) [2].

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3. Load of constructions exposed to the fire effects

By building constructions designing for effects of fire it is necessary to analyze their heat and mechanical load [1].

Procedure of design for fire effects takes into account:
- choice of a particular design fire scenario,
- definition of design fire,
- evaluation of temperature in carrying elements,
- evaluation of mechanical behaviour of construction (of mechanical response).

The procedures of design can be divided into element analysis, construction part analysis and the whole construction analysis.

The heat load of the construction can be determined based *on nominal or parametric fire curves or fire models* (see Fig. 1).

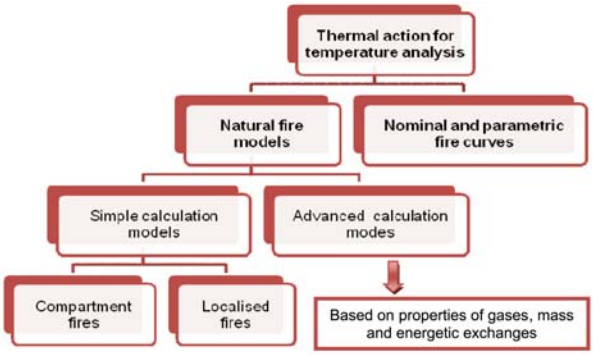

Fig. 1 Thermal action for temperature analysis of the construction (adopted from [1])

Simple fire models are based on specific physical parameters with limited application field. By fires of fire compartment area it is supposed a uniform temperature distribution as function of time, by localised fires it is supposed a non-uniform temperature distribution.

	Fire model	Fire development	Temperature in the space
Simple calculation models	Localised fire	Before flashover	Axial temperature of Fire Plume
	Nominal fire curves	After flashover	Uniform temperature in the whole space
	Parametric fire curves		
Advanced calculation models	Zone model	Whole fire development	Uniform temperature in the layer (zone)
	Field models		Time and space dependence

Fig. 2 List of fire models for determination of temperature in the space

Advanced fire models assume using one-zone and two-zone fire models and field models that are based on dynamical fluid and gas models (see Fig.2).

4. Choice of design fire scenario and design fire

A choice of fire scenario and design fire is a part of *qualitative analysis,* which can be called first step in examination of buildings fire safety, when the designer gathers design parameters needed to be able to subsequently examine the fire risk and to determine strategies region for risk maintenance at the acceptable level. *Fire scenario* describes the development of particular fire in time and space (see Fig. 3). Generally, it is possible to define the fire scenario as a time behaviour description of fire influenced by factors such as environment, human behaviour, fire safety equipment etc.

Fig. 3 Fire scenario scheme [9]

In the qualitative analysis it is necessary to choose suitable fire scenarios. Usually are chosen these with less propitious variants of fire development and at the same time with enough high probabilities of their occurrence. At the determination about importance of fire scenarios the high stress lays on expert assessment.

In practice we could determine almost infinite number of possible fire scenarios. But it is impractical and unreal to analyse all the scenarios. In terms of qualitative study it is chosen a final set of so-called design fire scenarios suitable for analysis. Results of these scenarios need to represent an acceptable fire risk upper boundary. In other words these are the most unfavourable fire scenarios with satisfactory occurrence probability with consequences that the society is capable to hold.

Every *design fire scenario* is represented by a unique appearance of events and is a result of particular set of circumstances associated with fire safety controls

By the selection of design fire scenarios suitable for analysis it is necessary to proceed systematically and to choose such scenarios, in order that at least one of them assess the perspective of material damage risk and other one the perspective of human health and life hazard. As the most suitable way to determine design fire

scenario is considered the procedure establishing the *risk classification*, which takes into account consequences and also the probability of fire scenario.

By the risk classification the procedure below can be used:
- selection of possible fire scenarios,
- consideration of scenario appearance probability based on data available and/or on an expert opinion,
- consideration of scenario consequences with using an expert opinion,
- analysis of relative risk of fire scenarios (i.e. product of fire appearance probability and its consequences),
- distribution of fire scenarios by relative risk.

Substeps of procedure for determination of fire scenario risk rating are illustrated in Fig. 4.

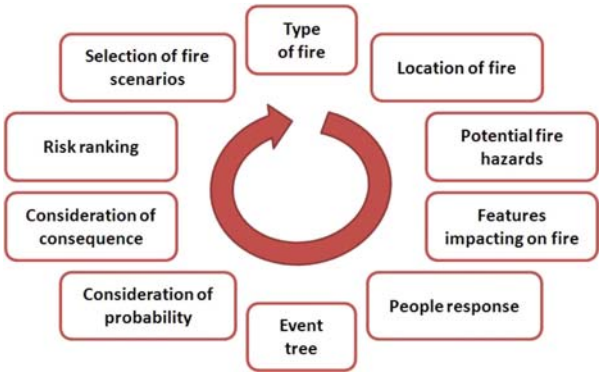

Fig. 4 Fire scenario design scheme (adopted from [10])

Important basis of determination of initial set of possible design fire scenarios are statistical data about fires, their occurrence cause, direct and consequential damages, number of evacuated and saved subjects, number of dead people etc. Data could be used for determination of most probable and also most hazardous fires for a particular (specific) kind of object and character of its usage (purpose).

Usage of event tree and after choice of fire scenarios always depends on an expertise of designer who has to have field experience to be able with certain accuracy to determine probabilities of occurrence of particular phenomena. In particular objects and situations must they, however, decide according to their experience or collective dealing with other experts.

5. Localised fire

Localised fire represents the situation when the total ignition of substances is unlikely and a non-uniform temperature distribution in the area is assumed.

Two basic situations are distinguished in term of expansion and spread of flame (see Fig. 5):
- blaze that doesn't affect ceiling; ($L_f < H$, flame length is lower than distance between source of fire and ceiling),
- blaze that affects ceiling; ($L_f \geq H$, flame length is equal or greater than distance between fire source and ceiling). In this case it is necessary to determine horizontal fire length L_h, which sets out the area of flames radial spread under the ceiling.

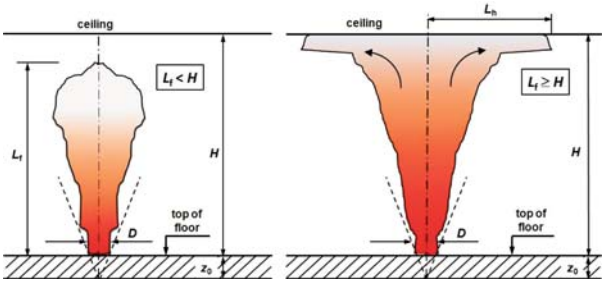

Fig. 5 Spread of flames by the fire in a bounded space [7]

Input data for examination of localised fire effects on engineering structure are flame length L_f, virtual axis origin z_0, convective part of heat release velocity Q_c and other. Computational process of localised fire expanded in Eurocode 1 is one of the common, but at the same time also simplest, methods for Fire Plume axial temperature determination and for determination of heat flow laid across engineering construction. Modesty of solution is also the reason of significant limit of described method usage. Above all it is about the *evaluation limitation considering the height position in space* (more precisely in Fire Plume position) and about the *accumulative smoke influence*.

Relations listed in Eurocode 1 are usable for determination of Fire Plume axial temperature in its final part, thus in smoke zone[1]. Application of calculation methods in other parts of Fire Plume leads to unreal optimistic results [4], [5].

Computing method is, among others, based on presumption that there is a suction of surrounding air with temperature corresponding to the standard conditions of environment (generally 20 °C) into the developing combustion gases column. But in real situations during the fires in bounded spaces there is in most cases a creation of smoke layer under ceiling or suspension ceiling construction which goes down. By the Fire Plume passage through the hot gases layer its axial temperature is affected on grounds of ambient conditions changes. In the shape taking Fire Plume there is a suction of gases, whose temperature is higher than the ambient temperature and thereby is the temperature drop with increasing distance above the surface more gradual. Final values of Fire Plume axial temperature without or with consideration of hot gases layer may radically differ and the results obtained by using of Eurocode 1 may be in case of hot gas layer misleading (significantly undersized) [6].

The technique by determination of Fire Plume axial temperature (possible application of localised fire according to the Eurocode 1) is illustrated in Fig. 6.

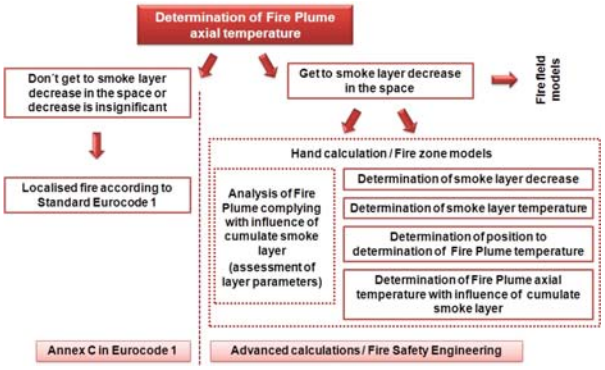

Fig. 6 Technique of determination of Fire Plume axial temperature

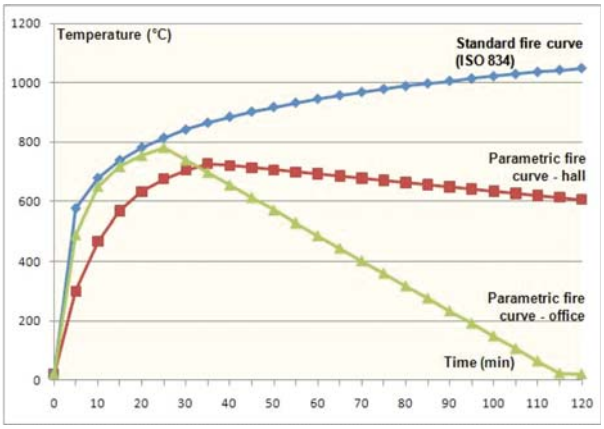

Fig. 7 Parametric fire curves vs. standard fire curve

The procedure of localised fire according to the standard Eurocode 1 is possible to apply in practice for design of building constructions during the fire conditions without farther related calculation methods rather sporadically. Only by cases of building objects with large geometrical measurements where the smoke layer decrease is very slow and short application period of calculation procedure.

6. Parametric fire curve

Flashover may be defined as a transition from localised fire to the combustion of all unprotected flammable gases in the room. The flashover is taken rather as a transition between two states than as a precisely determined event. The initial conditions for flashover appearance are sufficient fuel and sufficient aeration to development of the fire to size needed.

The fire in a bounded space after the flashover (in the phase of fully developed fire) is most frequently described by fire curves with characteristic quick increase of temperature (conventional graphic illustrations of fire intensity). Illustration of afterburning (cooling) by a fire curve is more difficult.

Fire curves of by ventilation controlled fire for different coefficients of ventilation, different thicknesses of fire load and different physical characteristics of constructions bounding fire compartment are generally called parametric fire curves. Equations for determination of parametric fire curves developed from equation of thermal equilibrium. Typical parametric fire curve is divided into two parts (Fig. 7). The first part describes exponential phase of fire development and the second one the linear part of cooling. The line between these phases makes maximum achieved temperature. Maximum achieved temperature information is important for consideration of building construction behaviour during the fire. The course of parametric fire curve is positively affected by fire safety equipment (for example automatic fire extinguishing system).

Parametric fire curve according to the Eurocode 1 (annex A CSN EN 1991-1-2) is valid only for fires with cellulosic type fire load and for relatively small fire compartments (with size under 500 m^2 of floor area with maximum ceiling high 4 m). Especially for common hall objects as sales or storage halls this fire curve is unsuitable. It can't be applied by fire compartments with horizontal openings in floor or ceiling (or roof) too.

7. Fire models

Most widespread fire models are *deterministic models* that predict fire development and with it associated processes on the basis of solution of mathematical equations describing physical and chemical processes during the fire. Physical conditions, which determine development and results of fire, are called *fire scenarios* by these models. Fire scenarios include amount and organization of flammable substances, disposition and character of object, design of fire safety systems, fire origin area, position and other parameters which influence resultant values describing fire. These data differ a little according to particular purpose of the model. Despite, it is possible to create a basic division of input parameters into several groups relating to fire load, gas exchange with environment and the space (room) description, in which the fire takes place.

Deterministic models are divided into two independent subsets: zone models and field models (based on computer technology CFD, see Fig. 8).

The most important feature of computational fire models is their ability to realistically predict the process of design fire within the range of their set parameters. The main disadvantage of these fire models in engineering practice are, however, relatively high set input parameters requirements and the time needed for the evaluation (especially by field models).

8. Conclusion

Building constructions fire resistance assessing using methods according to Eurocodes or using engineering principles is without

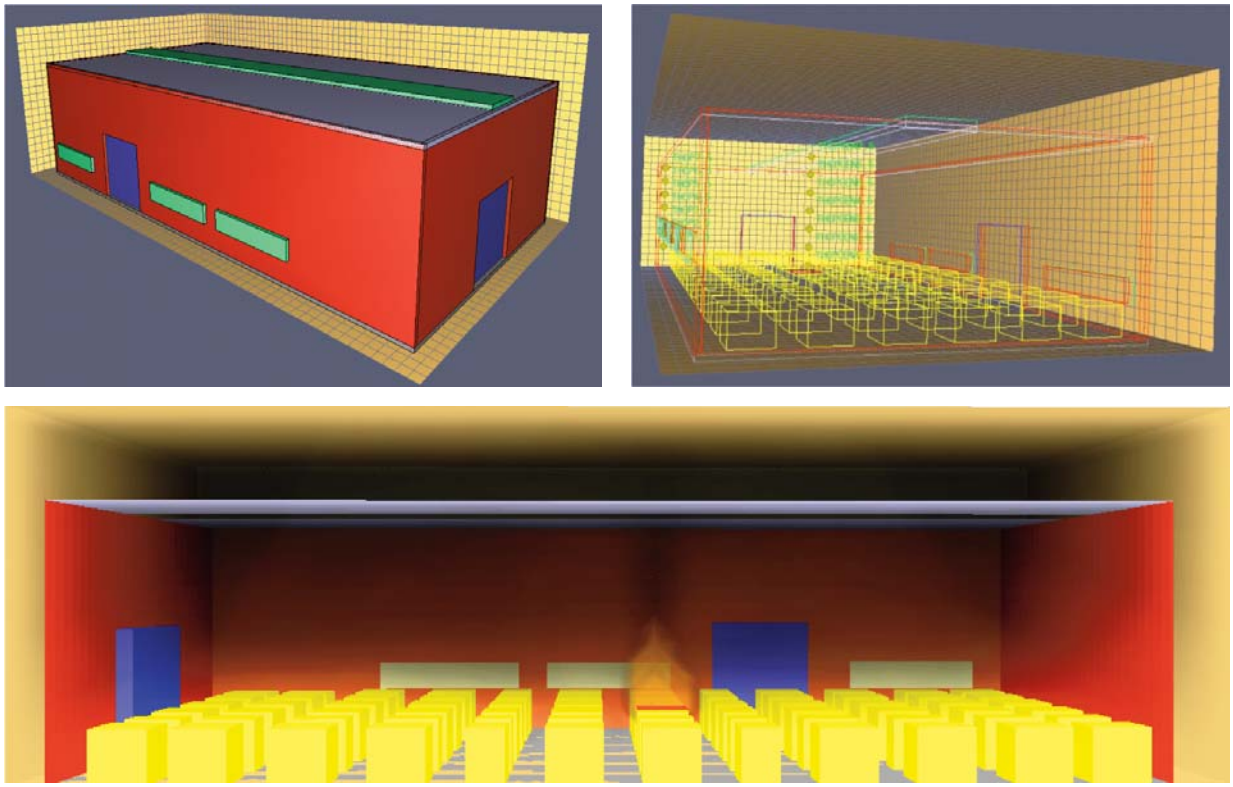

Fig. 8 Example of fire field model visualization (CFD model)

doubt a sunrise area which will also in future find constantly wider use.

Also through variety of procedures for thermal analysis of area, where fire development take place, and building construction, it is obvious that many of them (for example localised fire methods, parametric fire curves), have their significant limitation. It is necessary to respect the limits of evaluative methods by assessing building constructions fire resistance.

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Katarina Kampova *

FOUNDATIONS OF IMPLEMENTATION OF RISK MANAGEMENT PROCESS WITHIN PROJECT MANAGEMENT

Nowadays, most organisations are experiencing unprecedented levels of change. Change has become a way of life for organisations that need to remain effective and competitive in order to thrive. It is essential to manage the inherent risk associated with change and innovation. Project brings together resources, skills, technology and ideas to deliver business benefits or to achieve business objectives. Good project management helps to ensure that these benefits or objectives are achieved within budget, within time and to the required quality.

Project management must control and contain risks if a project is to stand a chance of being successful and ensure the security of the project. Without an ongoing and effective risk management procedure it is not possible to give confidence that the project is able to meet its objectives. This paper covers the main aspects of the management of risk as they apply to project management and proposes the methodology, which is applicable in implementation of risk management within a project.

1. Risk in context of a project

The term risk is often elusive, because its interpretation is commonly based on the specific aspect and goal of its utilization. Therefore, there are many definitions and approaches to cover this term. However, the situations in which we perceive risk have certain common elements. The first one is that we do not know what will happen. The second one is that specific interests are exposed to consequences in such situations [1]. Thus, there are essentially two components needed for risk to exist – an uncertain event and its adverse consequences (see Fig. 1). Risk can be defined as an uncertain event that, should it occur, will have an effect on the achievement of objectives. A risk is measured by a combination of the probability of a perceived threat and the magnitude of its consequences on objectives [11].

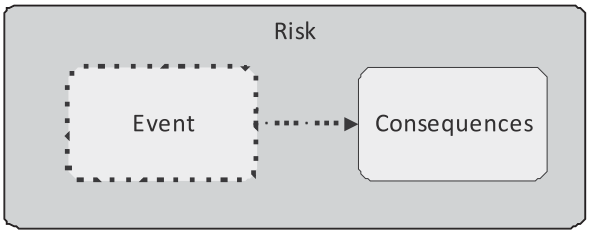

Fig. 1 Elements of risk (source: author)

The risk is very abstract concept in its essence, because it reflects two different observable entities – potential event and its consequences. Such abstractness is the reason, why the risk is often perceived intuitively, which leads to frequent identification of this term with one of its elements, either with its negative event or with its consequences.

The risk does not exist, until there is an uncertain event together with its impacts on objectives. If this combination does not exist simultaneously, there is no risk and the combination as such is not the subject of risk management [8]. Therefore the uncertain event with irrelevant impacts on project objectives cannot be considered as project risk, as well as the event, which has adverse impacts but its occurrence is either impossible or certain.

The risk essentially models causal relation between uncertain cause or event and its consequence. The consequences of the risk represent adverse impacts on specific values or interests. In context of project, the impacts are represented by influence of project objectives. In case the risk event is imminent, indicating an impending impact, the risk is commonly referred to as threat. There are basically two types of impacts within the context of the project [4]:

- not delivering the project's outcome that can achieve expected benefit; and
- not achieving the project's end result within required quality, time and costs.

From the project point of view, it is necessary to ascertain types of relations, whose consequences can be identified with mentioned two types of project's consequences.

The occurrence of event associated with risk is not isolated, but it is always a result of the complex causal relations between various events and attributes of environment, in which the project is carried

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out. Individual components (issues, topics, or concerns) of the project environment that form its properties and may ultimately drive its behaviour and hence affect the probability of risk event occurrence are designated as the risk factors [5]. The monitoring of risk factors, changes and trends of development of the risk environment can indicate the dynamics of risk intensity changes.

For the identification of the project's risks, it is important to recognize the context, in which the risk is assessed. The context of the risk determines which event is considered as the risk event and which as the risk factor. The project risk management should recognize the whole context of the risk and therefore it is necessary to identify these relations as a complex sequence of the different events, which occur within the certain project environment and lead to peril of the project (See Fig. 2).

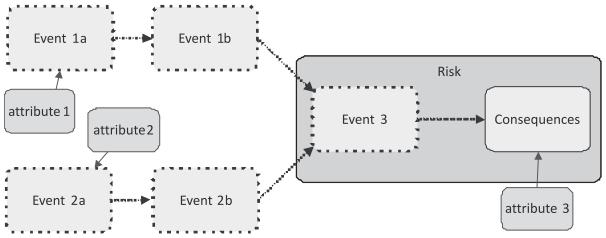

Fig. 2 Causal relations within the risk context (source:author)

The risk management within this broad context of causal relations may be illustrated on IT project considering the risk of deprivation of the project's source code (Event 3) with negative impact on time and costs of the project (Consequences). The loss of source code is in this case immediate event preceding the adverse consequences. This event can occur as a result of theft of project servers (Event 1b) or damage to the server (Event 2b). The theft can result from overcoming the physical protection of servers (Event 1a) and damage can occur as a result of the natural disaster – lightning, fire, flood, etc. (Event 2a).

The risk can be generally managed through the control of various attributes of the environment. The consequences of risk event can be mitigated regardless of having knowledge about the event and its causal relations. The consequences in the example can be moderated by a backup procedure implemented on the independent servers (attribute 3). However, the knowledge of the causalities facilitates the effective control of risk probability and thus prevents the risk event from occurring. The risk in the example can be prevented by ensuring higher level of physical protection of assets of the project (attribute 1) or by securing hardware equipment of the project against natural disaster with surge protectors, appropriate choice of location, etc. (attribute 2).

Generally, it is not possible to compile a list of risks, which would be universally applicable to every project. Nevertheless, the project risks can be broadly classified under two categories, based on distinguishing types of consequences as follows [4]:

- business risks; and
- direct project risks.

Business risks cover the threats associated with a project's end result not fulfilling business expectations and not delivering required benefits. It is the responsibility of the project board or project steering committee to manage business risks and to keep the validity and viability of the business case within the business strategy.

Direct project risk includes the collection of threats to the management of the project and hence to the achievement of the project's end results within cost and time. These risks should be managed on a day-to-day basis during all phases of the project life cycle, from initial idea to project close-out.

2. Managing risk

Every project takes place in an environment that is constantly changing [3] and project itself is subject to constant change too. Fast changing environment with many interested parties and external influencing factors and changes in a project due to unanticipated occurrences require reconsideration of project's priorities and relative importance of risks. The risk is inseparable aspect of the whole project life cycle and in a way, risk events are a result of bad planning [2]. Therefore, it is necessary to introduce a risk management process, which continually provides reassessment of changes within the project environment and proposes the suitable responses to the risk.

Boardly, the management of risk comprises two main parts (Fig. 3):

- risk analysis; and
- risk management.

The risk analysis and risk management phases must be treated separately, to ensure that decisions are made objectively and based

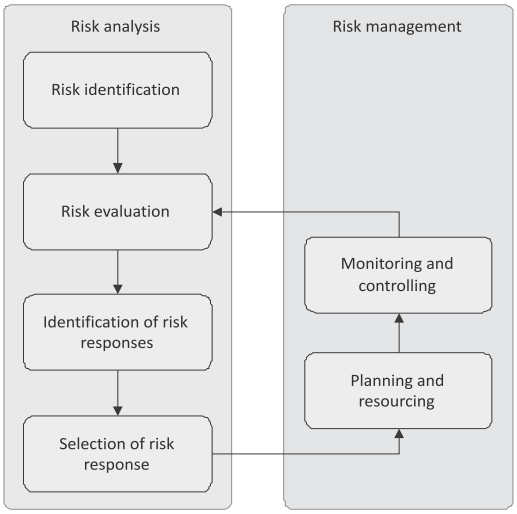

Fig. 3 Activities in the management of risk (source: author)

on all the relevant information. These processes are, however, interrelated and undertaken iteratively. The formal recording of information is an important element in risk analysis and risk management. The documentation provides the foundation that supports the overall management of risk [4].

Risk analysis is a process that should be conducted continuously throughout the project as information becomes available and as circumstances change. Risk analysis consists of overlapping activities:

- risk identification,
- risk evaluation,
- identification of risk responses; and
- selection of risk response.

The objective of risk identification is to uncover various potential risk events that could be faced by the project and also to identify their determining circumstances. This step is focused on revealing as many risks and their causal relations as possible, regardless the judgment of the likelihood or magnitude of impacts. Once identified, risks are all entered in the risk log. The risk log is a control tool for the project manager, providing a quick reference to the key risks facing the project, what monitoring activities should be taking place and by whom [1].

Risk evaluation is the activity concerned with assessing the level of each risk within the risk log. The level of risk is determined by quantification of risk uncertainty. The risk uncertainty means that we do not know what will happen, when it will happen and what actual size of impact it will have. This uncertainty chiefly comes from insufficient knowledge, inaccurate information or by natural variability of the risk factors [12]. Probability is often used as a metric of uncertainty [7].

Another aspect of probability considerations is when the risk might occur. Some risks are predicted to occur further away in time than others. This prediction is called the risk's proximity [1]. Risk proximity is an element of risk uncertainty, which depicts the period of time within which the risk event is most likely to occur [6]. It can be quantified by means of exponential probability distribution, which describes the time between risk events.

After evaluating the risks, many people stop, believing that knowledge will protect them. However, awareness and assessment do not change risk exposure, unless they lead to action [9]. Therefore, ensuing step of risk evaluation focuses on the identification of suitable risk responses. The result provides an insight into the possibilities of actions, which might be carried out in order to appropriately respond to the risk. The actions break into broadly five types: prevention, reduction, transference, acceptance and contingency [4].

Prevention terminates the risk. It is the type of action, where countermeasures are put in place that either stop the risk event from occurring, or prevent it having any impact on the project [1]. Reduction treats the risk and reduces either the probability of the risk developing or limits the impact on the project to acceptable levels. Transference is a specific form of reduction, which reduces impacts only and often only financial impact [11]. Transference passes the risk to a third party via insurance policy or penalty clause. Acceptance tolerates the risk either because nothing can be done at a reasonable cost to mitigate it, or because the risk is so small the effort to do anything is not worthwhile [13]. Contingency prepares for the risk by actions planned and organized to come into force as and when the risk occurs.

The last step of risk analysis is the selection of the most appropriate actions, based on the preceding steps. For each possible action it is a question of balancing the cost of taking that action against the likelihood and impact of allowing the risk to occur.

The process of risk management logically follows risk analysis. Once the risks have been identified and evaluated, attention needs to focus on managing them. The objective of this process is planning, organizing and controlling of risk responses selected in the risk analysis. Risk management consists of two major phases:

- planning and resourcing; and
- monitoring and controlling.

The phase of planning and resourcing is focused on developing a detailed plan of actions required to carry out and on identification and allocation of the resources to be used for the implementation of actions. The monitoring and controlling phase identifies signs of a change in the status of the risk after the amelioration actions have been put into effect. The objective of this phase is to check and report whether the overall management of risk is being applied effectively.

3. Conclusion

In the past thirty years project management has been a discipline which has developed tremendously and increased in visibility [3]. The projects are more numerous, more complex and more varied in nature. Project management faces the fast changing context driven by the business striving to deliver demanded benefits. Such conditions challenge the project managers to effectively manage the substantive risk associated with rapidly developing environment.

In order to manage risks and deliver successful project it is necessary to provide a mechanism to harness the resources and enable the project to achieve business objectives. This paper has introduced a fundamental framework covering basic principles of perception of risk within the context of the project and activities required to manage the risks during the project. The approach focusing on risk environment was introduced together with the classification broadly segmenting the project risks. The management of risk procedures stemmed from the understanding of risk environment was described. The risk management is comprehended as continuously carried out actions arranged in two overlapping phases. The phase or risk analysis identifies the project risks as well as the options for treating them and the phase of risk management plan, resource, control and monitor the implementation of actions dealing with the project risks.

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Zdenek Dvorak – Pavel Fuchs – Jan Novak – Radovan Sousek *

INDIVIDUAL AND SOCIAL RISK DURING TRANSPORTATION OF DANGEROUS SUBSTANCES

This article aims to present new views on risk assessment, primarily individual and social risks during transportation of dangerous substance. Included are modelling procedures and methods applied to calculate dangerous substance exposure to the biodiversity of the environment, solved in project BIOTRA. New procedures and methods applied for calculation of environmental exposure by dangerous substance outflows in road transport are also presented.

1. Introduction

The Technical University of Liberec began working on the project "BIOTRA" in 2008. This project is part of the National research program in the Czech Republic. Experts from other institutions cooperate on project solving tasks. The "BIOTRA" project is aimed at producing methodology for ecological risk evaluations associated with dangerous goods transport with special focus on environment and its biotic elements. The main result of the project "BIOTRA" should be the designing of decision making software tools for the ecological transportation alternatives selection, which will also allow determining recommended routes for dangerous goods in road transport.

2. Threat evaluation regarding road transport

The investigation of threats regarding road transport is currently one of the central tasks. There are thousands of people dying on the roads every year. The EU has defined in the White book the tasks for membership countries to lower numbers of mortal accidents to the half. According to a statistical annual report, the results of mortality on Slovak roads as followed:

The development of mortality on Slovak roads in 2000 - 2009 Table 1

Year	2000	2003	2006	2009
Fatalities	628	645	519	386
Percentage according to plan	100%	102.7%	82.6%	61.4%

Source: [9]

Investigation of accident causes is based on statistical data. The methods are focused on the identification of particular elements in the transport system. Therefore, we evaluated each of following parts separately: Road infrastructure, transport means, transport technology, specific management and information systems in road transport. The findings show that the most crucial deficiency was in the quality and capacity of road infrastructure.

3. Potential escape of dangerous substances

The significant threat for transport, human health and the environment is the transport of dangerous substances. There are certain characteristics of such accidents:

- Escape time is limited by the vessel discharge; the worst case is assumed to be the instantaneous outflow of whole tank volume to the environment,
- Substance quantity is limited by transport vessel capacity (road tank, tank car, etc.),
- Outflow location is not known in advance, it may be situated wherever on the transport route.

The bandwidth exposure assessment is simpler if a risk map compilation in the surrounding of the single outflow source or of whole transport route is available. The problem is simplified to risk assessment in the profile perpendicular to the route. In a general case all present conditions are not known, especially atmospheric stability and wind speed. It is necessary to calculate the probability of standard meteorological conditions and these probabilities to an average according to their representation in locality [1], [7].

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3.1 Explosions

Explosion - probability of the leaking of unconfined gas cloud into the atmosphere is considerably smaller than the probability of fire. The basic presumption for explosion is that the concentration of gas must exceed the lower explosion limit.

The explosion sets in a shock wave. The negative effect is overpressure on the shock front expressed in pressure units (kPa or bar). Duration of action is by its effects mostly neglected during the evaluation.

The recommended methods of effect calculation are based on trinitrotoluene equivalents. The results from the geometric similarities are that the parameters of shock waves for a given explosive system are identical to the equal value of reduced distance :

$$Z = \frac{R}{W^{1/3}} \tag{1}$$

Where
Z = reduced distance [m],
R = distance from the explosion epicentre [m],
W = explosion system weight [kg], formulated by an equivalent TNT.

From the calculated reduced distance it is possible to figure out the overpressure (Pa) on a shock front. This can be founded on dependence due to the reduction of distance from an explosion epicentre. Various formulations of this relation can be found in many different sources. An example of one of many formulas for calculating overpressure is presented below:

$$\Delta p = \left(\frac{93{,}2}{Z} + \frac{383}{Z^2} + \frac{1275}{Z^3}\right) \tag{2}$$

Where Δp is overpressure [kPa].

Probit function for human death has a formula:

$$Y = -16.7 + 2.03 \cdot \ln(\Delta p) \tag{3}$$

This relation can be used to find probit parameters, e.g. for eardrums break, building destruction or window break. This helps to define different types of environment elements damage.

3.2 Fire

In comparison to toxicity, fire takes place in a relatively small area. It is given by the fact that for the gas ignition there are necessary concentrations between the upper and lower ignition limit. The lower ignition limit is mostly higher than the concentration of dangerous gases [2].

Heat radiation is one of the main consequences which affect the surrounding area of an accident.

Energy released by combustion is given by the formula:

$$E = Q \cdot \Delta H_c \cdot \eta \tag{4}$$

Where
E = released energy [kJ],
Q = combustible quantity [kg],
ΔH_c = gas heating power [kJ/kg],
η = radiation ratio of total released energy [-].

In the case of instantaneous outflow the effect depends on the ignition time because the cloud location, geometry and the gas quantity change over time.

For the effect evaluation it is possible to use probit functions. In the case of fire we can use Eisenberg's formula for human death probability:

$$Y = -14.9 + 2.56 \cdot \ln V \tag{5}$$

The parameters k_1, k_2 in the general probit function are not dependent on any particular substance whose characteristics are calculated in regards to the amount of energy released.

Heat exposure dose V depends on thermal radiation. Thermal radiation evoked by point source in distance r is given by the following formula:

$$I = \frac{E}{4\pi \cdot r^2 \cdot t} \tag{6}$$

Where
I = thermal radiation intensity [kJ],
t = duration of action [s],
r = distance from source [m].

This formula can be used for the case of instantaneous outflow where the cloud has a semi-ellipsoid form.

From the radiation intensity level and exposure duration it is possible to assess the received thermal radiation dose V:

$$V = I^{4/3} \cdot t \tag{7}$$

Where
I = heat flux [J/(m^2·s)],
t = exposure time [s],
V = received dose (tdu – thermal dose unit, 1 tdu = 1 (kW/m^2)$^{4/3}$.s).

Human death probability can be determined using a probit function that results in thermal dosage. According to the thermal dosage, the probability of different types (burn of 1. and 2. instance) of injury can also be determined. In a similar manner can it be specified for fire consequences for fauna. For stationary objects i.e. buildings, constructions, woods, and plants the probable consequences can be determined on the basis of heat flux whose specific value evokes wood ignition.

3.3 Gas dispersion in the atmosphere

The Pasquill – Gifford model "PUFF" is designed for dispersion modelling in instantaneous outflow conditions. It is a dispersion model with normal (Gauss) distribution of concentrations and Lagrange approach. Focus is placed on monitoring gas element movement in a particular wind field. The gas cloud spread in relation to the wind direction. At first the cloud expands and the gas concentration sinks. Later the cloud volume decreases because more and more gas disperses in insignificant concentrations outside the cloud [2].

Gas dispersion is affected by wind speed and atmospheric stability. The atmospheric stability relates to a vertical temperature drop. It generally holds that when the atmospheric stability grows then escaped substances travel longer distances until their concentration sinks. On that ground the higher stability classes are regarded as "bad" weather conditions for dangerous substance dispersion.

3.4 Bandwidth for liquids

Defining bandwidth assessment of negative effects for liquids is more difficult than defining bandwidth for gases. There are more scenarios of liquid spread and also a wider spectrum of potentially threatened environmental elements. On the other hand, the bandwidth is considerably smaller.

The diagram of risk evaluation by dangerous liquid outflow is shown in Fig. 1. After the liquid flows onto the earth's surface, three different processes accompanied with different intensities begin: Flushing, imbitition and vaporization. These processes are necessary to simulate simultaneously, because imbitition and vaporization depend on the surface of a created pool. Whereas the flushing is affected by reduction of liquid, which was absorbed or evaporated. The situation is schematically shown in Fig. 1.

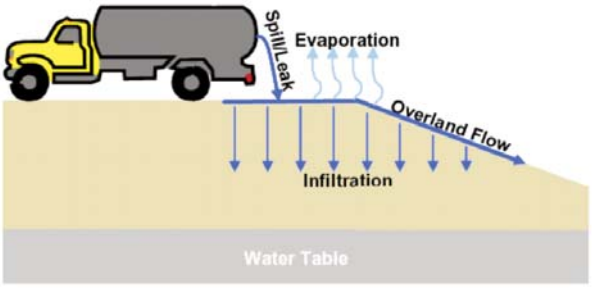

Fig. 1 Diagram of processes by liquid outflow to the terrain

Flushing depends especially on liquid parameters, grade and surface quality, which in general is the width and depth of a pool sink when the grade grows. However, the depth depends on the surface types in discussion. The typical depth on a relatively smooth surface (asphalt, concrete) is so minimal that it can be expressed in millimetres. Vegetation greatly increases the effect of contamination. This creates further surface damage which results from remaining toxic liquids.

For reasons given it is clear that the solution includes two basic types of problems:

- physical problems evaluation,
- finding of necessary area characteristics.

4. Road transport risk assessment

Standard methods of traffic effect evaluation of the environment and are oriented towards exhaust and noise assessment. It is also possible to analyse case studies of vehicle accidents connected with dangerous substance outflow. The probability of a major accident is low; however the consequences may be large. Presently there are no methods which allow complex road transport risk assessments to focus on dangerous substance potential outflow consequences for the environment.

The risk is possible to quantify and for its acceptability decision making is this quantification even necessary. Quantitative assessment represents exposure. A numeric value or numeric function can be used to describe the relation between probability and consequences of existing hazards. Various hazards may include machines, activities or technologies. These hazards may also include different objects or processes that endanger humans as well as the environment. Generally, the risk is the product of dangerous event probability and its consequences [3], [4], [8].

4.1 Outflow calculation and display from stationary sources

The dispersion models result (air-borne spread, fire, explosion, spilling) is time variable concentration field of escaped substance. Generally, they are calculated in several concentration fields for chosen condition combinations. Concentration field and substance danger parameters are inputs for respondent answer models to negative impact. Negative impacts (toxicity, thermal radiation, shock wave, radioactive radiation) are necessary to be quantified. This is possible by exposure dose calculation which represents physical, chemical and biological effects that depend on substance concentration and action time [2].

4.2 Social risk

Social risk = Accident probability x consequences.

Consequence = exposed human death probability x the number of threatened people.

Unit individual risk = Individual risk for ever-present unprotected person by unit accident probability.

Unit social risk = Individual risk modified according to presence period, protection level and number of threatened people by unit accident probability.

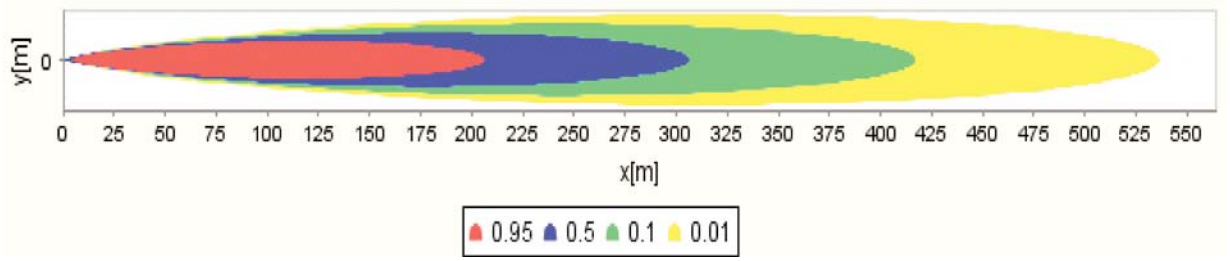

Fig. 2 Example of human death probability by toxic exposure in dependence on source distance x and y (instantaneous outflow 1000 kg NH3, atmosphere stability class E, wind speed 1.7 m/s)

Death probability is different for group of people according to their protection level (reduced individual risk according to categories).

4. 3 Unit social risk

$$SR_j = \sum\left(IR_j \cdot \sum\left(H_i \cdot h_i\right)\right) \quad (8)$$

Whereas

IR_j Represents an individual risk unit in the j-partial area,
H_i = number of people i-category in j-area,
h_i = people protection level coefficient i-category

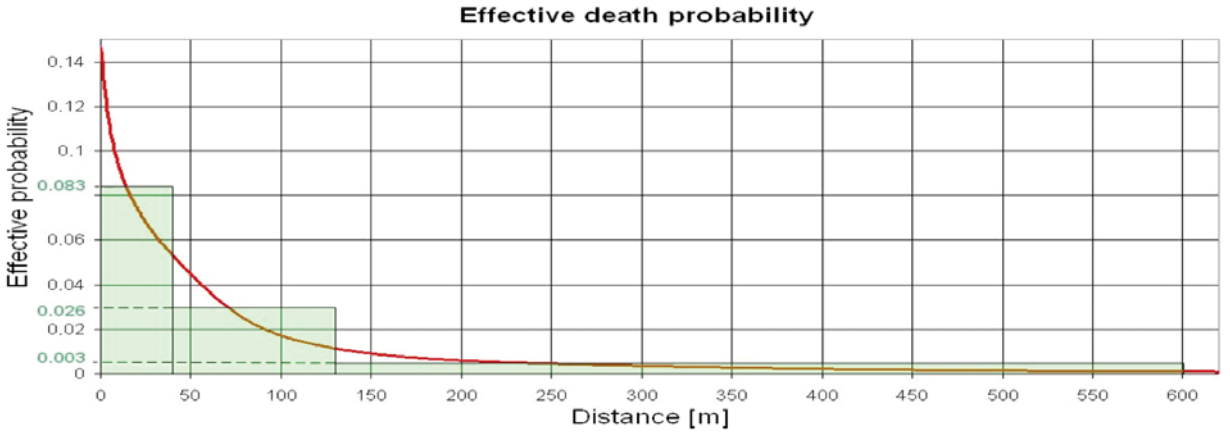

Fig. 3 Effective death probability depending on the distance from the source

Fig. 4 Schema of segments road distribution and reference point network lay-out.

5. Data import to GIS

Importing data to the GIS software is it useful to define areas with an approximate identical individual risk value. Individual risk decreases from the accident source. If we do not consider wind direction, individual risk is uniformly distributed around a specific source [4].

5.1 Outflow calculation and display from mobile sources

Mobile sources move on a defined trajectory. An accident can happen at any point on a trajectory, but only at one point for a particular type of transport. Individual risk at certain point can be expressed as a sum of risks from single road segments. The situation is systematically shown in Fig. 5 [5].

The road is divided into small segments s so that the distance r between reference points $[x_s, y_s]$ and each point of a defined segment can be assumed as constant. The cloud width $E(r)$, probability $P(r)$ for a single meteorological situation and average (total) probability $P_\varphi(r)$ is constant for a defined segment. The road segmentation should be taken into consideration that the accident probability $P_h(si)$ is constant inside a segment. Then:

$$P(x_s, y_s) = \sum_i P_h(s_i) \cdot P_\varphi(r)_i \cdot s_i \tag{9}$$

Where

$P(x_s, y_s)$= total death injury (lethal dose) probability in a single point $[x_s, y_s]$,

$P_h(s_i)$ accident probability in a single segment expand to the route unit length $[m^{-1}]$,

s_i length of route a single segment i [m],

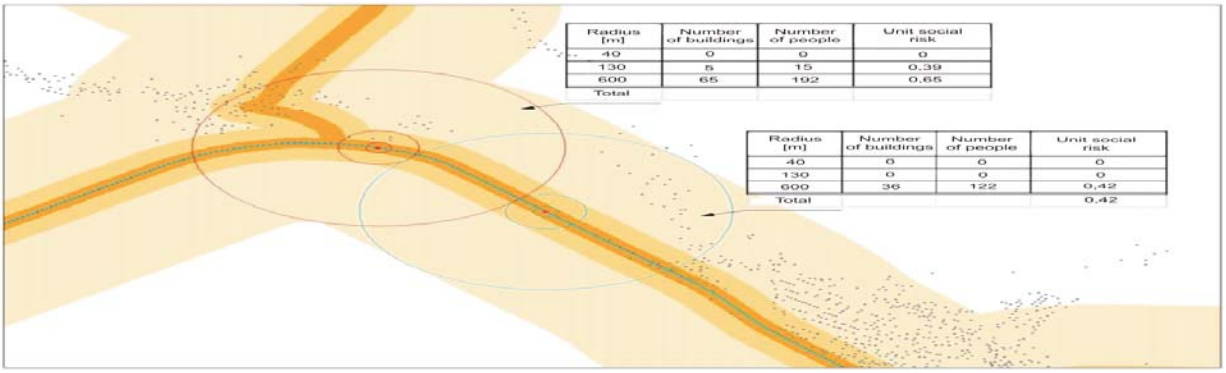

Fig. 5 Individual risk distribution nearby the traffic route

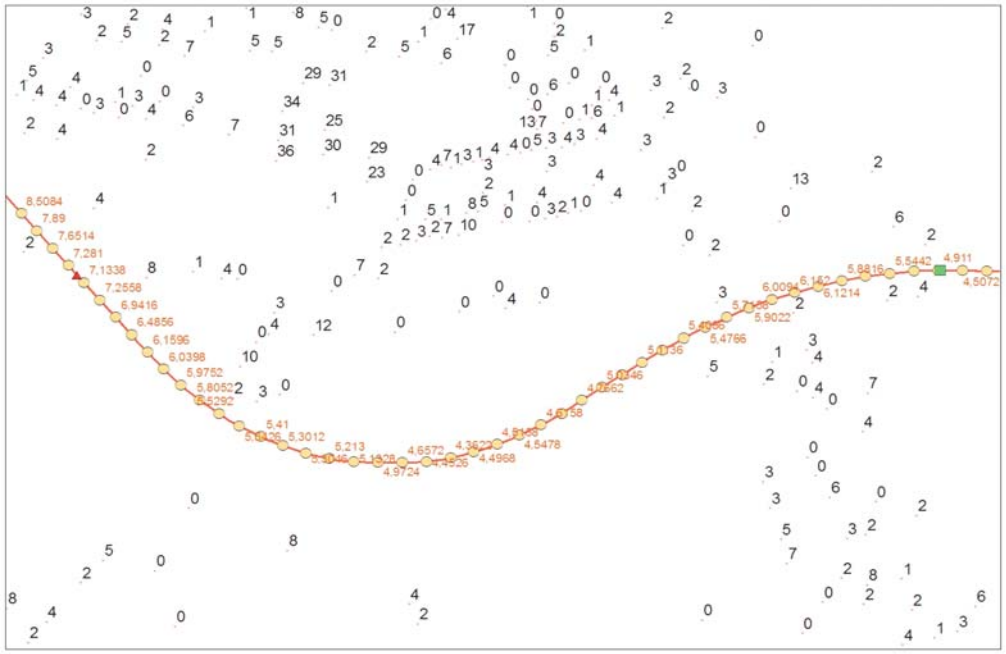

Fig. 6 Address points, number of people, unit social risk for single road parts (20 m)

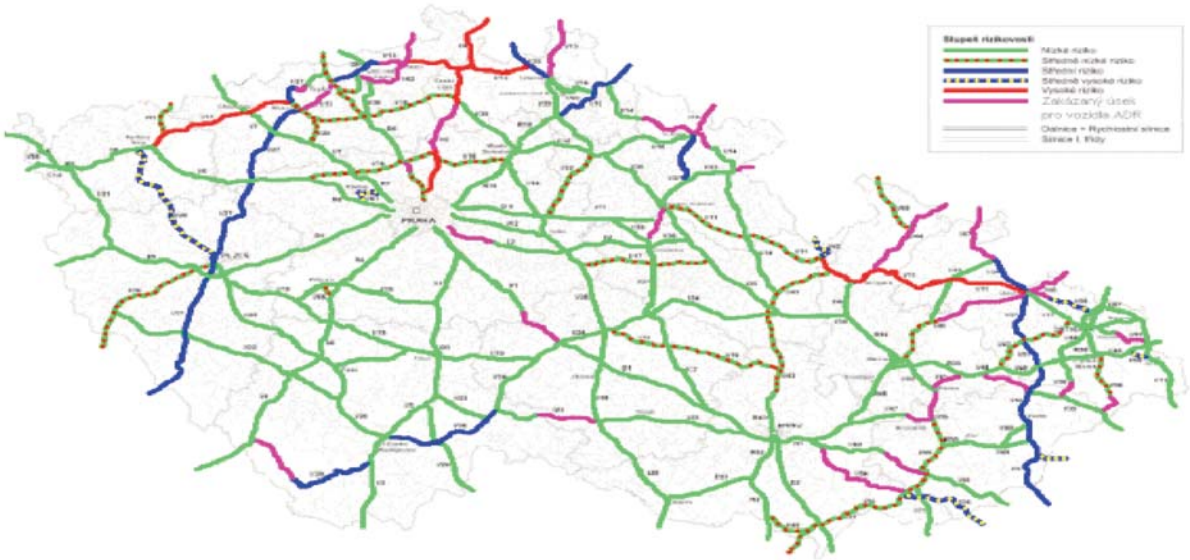

Fig. 7 Possible version of selected road network segments for dangerous goods transport with implemented exposures in the Czech Republic (pink colour – dangerous goods transport ban according to law)

$P_{\varphi}(r)_i$ average death (injury) probability/(lethal dose) in a cloud axis,
i route segment index.

Individual risk can be determined in point network according to the death or injury impact contours, which surround the traffic route. The illustration of network distribution and final individual risk maps can be found in the next figure below. It is evident that the enhanced risk is the curve inside the meandering road where the interest point can be affected by accidents in more parts of the traffic route.

5.2 Road network assessment for the transportation of dangerous goods

According to the risk maps, the road segments can be determined [6], [7]. Based on those road segments is it possible to define a route with minimal social and individual risks. It is possible to:

1. Displays risk maps
2. Uses the data/maps for assessment in the transportation of dangerous goods and to find recommended routes.

6. Conclusion

This paper represents the present status of the project BIOTRA (2B08011). Currently half of the research was conducted therefore partial outcomes have been presented. Soon it will be possible to present complex software tools, which would enable users to compile route maps for the transport of dangerous goods as well as to simulating the risks connected to transport and to determine individual and social risks.

It is important to note that the simulation model will include solutions for all parts and at the same time support cooperation between its parts with minimal demand for "manual" operation with the data. According to evaluated consequence (toxicity, fire, and explosion) is it possible to precede to the individual risk calculations. Toxicity defines human death or injury probability presented via cloud axis and effective cloud width. The fire effects depend on cloud dimensions within combustion limits, heat flux and thermal exposure dosage. The system will be designed with the focus placed on the shock front calculations for after a possible explosion.

The software tool enables the user to get the data in a form which can be used for probability averaging through the use of frequencies of particular meteorological situation. This system can also be used for the creation of individual risk maps. The output possibilities are designed to correspond with different demands for following graphic and tabular proceedings.

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Milan Majernik – Jana Pankova Jurikova *

THEORETICAL-METHODOLOGICAL ASPECTS OF INTEGRATED RISK MANAGEMENT STANDARDIZATION

The authors are submitting a system model for integrated risk management. Results and conclusions of the paper are based on analysis of development, current status and progressive trends in standardization and risk management aspects of quality, safety, environment etc. Originality of the solution lies "in an enclosure" of quality management systems, safety management system and environmental management system according to standards, under the ISO standard ISO 31000 in the Slovak version of the upcoming STN. Solution is based on the philosophy of a single audit of compliance for the accreditation of certification bodies - they will certify risk management system. First audit can be realized for the certification system and the second for implementation system. The prepared standard ISO 31000 would be certification's standard.

1. Introduction

Enterprising at European and worldwide globalized markets is now inconceivable without acceptance of ISO standards and EU regulations for environmental management, management aspects of quality, safety, social responsibility, but also others.

An increasing number of socially required and maintained management systems and the associated burden on their certification, respectively registration (especially auditing) is forcing organizations (businesses, CO, AO) to seek new approaches to assess their compliance with worldwide standards.

Many organizations (companies) are now separate implementation of management systems (quality, environment, safety, etc.) enormously burdened (rising costs, an excessive burden on employees and specific documentation and necessary training, the requirements of communication with stakeholders, internal and external audits, etc.). The question arises inevitably, how many separately implemented enterprise management systems is company still able to sustain. Separately maintained and developed if there are constantly emerging new requirements and specific ISO standards (e.g. 16949, 22000, 26000, etc.).

One way to solve these problems is the integration of management systems. But the problem is that for conformity in the IMS (while the internal, certificated, supervised, recertificated auditing) there is no standard among ISO standards covering requirements for sub-systems.

It turns out that such a solution could be based on approach to risk management application (a prepared group of standards ISO 31000). Slovak Office of standards, metrology and testing (SOSMT) is preparing a basic version to ISO 31000 "Risk Management – Principles and Guidance" at present. This standard is not intended for certification such as the ISO 9000, 14000, 27000 and so on. This fact is in custody on the reported problems with auditing positive.

If you manage to modify the ISO 31000 into a Deming cycle of continuous improvement of risk management (quality, environmental, safety, social, project, investment ...) by including the requirements of sub-systems of course, their integrated auditing will be real.

The inspiration for such scientific routing solution is also the fact that within Slovak national accreditation services (SNAS) is now the Technical Committee of "Accreditation risk management" constituted and SOSTM prepares issue of the ISO 31000 "Risk Management".

2. Integrated Enterprise Risk Management System

With the ever increasing demands on the current market and technical development it is very challenging to maintain, respectively manage quality of product at a level as the company requires. This management requires relatively high effort to adapt to new changes and understand that quality of product means the achievement of a lot of criteria in many areas, either environmental protection, health protection of workers or other criteria. [5] Management of various aspects represents the core of the current management system, which can be implemented within the organization by using appropriate standards (Fig. 1).

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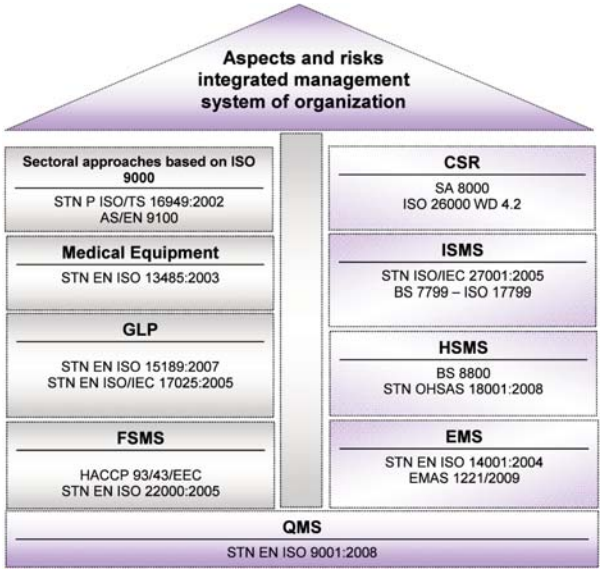

Fig. 1 Management systems in the organization

At present, generally the effort applies to put these related systems to a common basis – the modern management processes. Neither certified QMS nor certified EMS lead to high productivity and competitiveness if they are treated as isolated systems. The current trend is thus clearly intended to "comprehensive business integration", where the other business subsystems access to the most frequently constructed systems without which it is impossible to ensure the competitiveness of the organization.

In terms of method and procedure it is significant to focus on the Deming cycle of continuous improvement. It also appears that the change in behavior (improvement) is impossible without changes in thinking and attitudes of all stakeholders in the management system.

The problematic area of integration of management systems (and the fact that there are still many new appearing) remains an area of "authorization" (accreditation, certification) and related audits in compliance with relevant standards (ISO 9000, 14000, 27000, OHSAS 18000...).

In this context there is no doubt that further development should be directed not only to implementation of integrated management systems (IMS), but also to integrated (single) auditing for various types of audits (pre-certificated, certificated, inspected, supervised, internal).

3. Authorization of an integrated risk management

The processes of accreditation and certification are an inherent part of implementation, maintenance and authorization management systems.

Methodical guidelines developed by SNAS for accreditation of management systems have undergone fairly significant changes and do not always have such a form that could be used only one methodical guideline for accreditation of certifying an integrated system of risk management.

SNAS accredited bodies certifying quality management systems, quality assurance systems in accordance with NATO requirements, quality management systems for welding, systems of sustainable forest management, quality management systems for medical devices, environmental management systems, management systems and safety health, safety management systems and information management systems, food safety, on the basis of methodical guideline for accreditation of certification bodies certifying management systems. This methodical guideline is not usable for integrated risk management system too.

New, original idea is that SNAS will proceed based on only one methodical guideline during the accreditation process. This guideline will become usable in the accreditation process of bodies certifying risk management system. (Fig. 2). The basis of the risk management becomes risk register. It would solve significant aspects of organization.

Deeper analysis of processes shows the authorization process for consistency with respect to demonstrating compliance with relevant ISO standards (9000, 14000, 27000, 18000) to the sequence of steps and time limits and frequency of audits. The problem can be in terms of audits of separate implementation of individual management systems (Surveillance, control, internal and re-certificated). The advantage of risk management system from this point of view is the single audit of management partial aspects in accordance with relevant standards, broader audit team CO.

All of the requirements for risk management system certification, that the organization must ensure, are defined in the prepared standard ISO 31000 "Risk Management – Principles and Guidance"

4. Risk management systems in the enterprise

Risk management has a very important role in many business areas. It is now understood as a systemic and comprehensive tool to manage all processes of risk assessment. The base is to document policy as a management liability. It must correspond to strategic areas, goals and business character of organization. [13]

Risk management is a term that implies a logical and systematic method for determining the context, identification, analysis, evaluation, treatment, monitoring and communicating risks associated with any activity, function or process. It also deals with the identification of opportunities, as well as reduction of loss.

The basic requirements of risk management are: [11]

- definition of risk management policies (define, document commitment and goal setting – focusing on the character of the business),

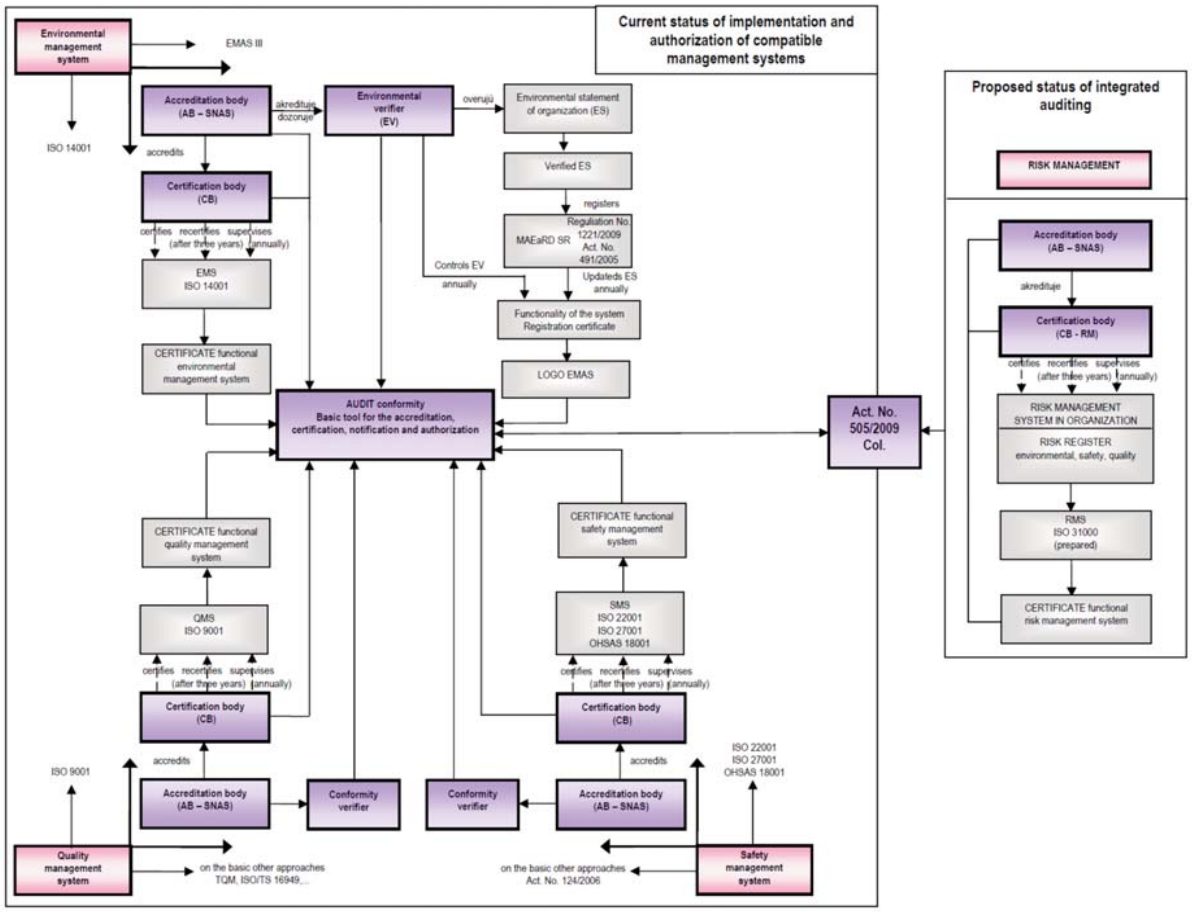

Fig. 2 Relationships in the process of accreditation, certification and authorization of management systems

- planning and provision of resources (developing, implementing and maintaining a system of risk management in accordance with this standard, the assessment of performance management and review of the organization as a basis for improvement),
- responsibility and authority,
- resources,
- program implementation,
- management review.

As currently prepared standard is not intended to encourage risk management, we must take into account the changing needs of a particular organization, its particular goals, structure, operations, processes, functions and products. It is assumed that the standard can be used in the harmonization of risk management practices within existing standards.

The goal of risk management is, therefore, the reduction of various kinds of risks relating to the matter at a socially acceptable level. It can be the amount of risk whose source may be the environment, technology, human, organization and others. Risk management will solve integrated risk assessment process and also the integrated process of accreditation and certification in the future.

4.1. Framework of STN ISO 31000

4 Framework for managing risk
4.1 General
4.2 Mandate and commitment
4.3 Design of framework for managing risk
4.3.1 Understanding the organization and its context
4.3.2 Risk management policy
4.3.3 Accountability
4.3.4 Integration into organizational processes
4.3.5 Resources
4.3.6 Establishing internal communication and reporting mechanisms
4.3.7 Establishing external communication and reporting mechanisms
4.4 Implementing risk management
4.4.1 Implementing the framework for managing risk
4.4.2 Implementing the risk management process
4.5 Monitoring and review of the framework
4.6 Continual improvement of the framework
5 Process for managing risk
5.1 General
5.2 Communication and consultation

5.3 Establishing the context
5.3.1 General
5.3.2 Establishing the external context
5.3.3 Establishing the internal context
5.3.4 Establishing the context of the risk management process
5.3.5 Developing risk criteria
5.4 Risk assessment
5.4.1 General
5.4.2 Risk identification
5.4.3 Risk analysis
5.4.4 Risk evaluation
5.5 Risk treatment
5.5.1 General
5.5.2 Selection of risk treatment options
5.5.3 Preparing and implementing risk treatment plans
5.6 Monitoring and review
5.7 Recording and improvement the risk management process

4.2. Transformation of the key elements of risk management system according to ISO 31000 to the Deming cycle

Common methodical tool of implementation, maintenance and assessment of management systems of partial aspects (quality, environment, security, information security, etc.) and integrated management system is the Deming cycle of continuous improvement (PDCA – plan – do – check – improve).

The prepared standard can be used as a substitute for ISO standards for partial aspects, if the structure and processes for risk management are united with these standards.

There are key elements of risk management system assigned (Fig. 3) according to the forthcoming ISO 31000 in each stage of Deming cycle of continuous improvement.

5. Conclusion

Standardization of various aspects of management processes also places increased demands on the auditing process for accreditation (CO, environmental verifiers), certification of management systems (quality, environment, security) and the mandatory internal audits within the implemented management system.

IMS accreditation process must be based not only on the experience and knowledge of practice, but must rely primarily on the results of scientific research studies, the results of forecasting the development (a process of accreditation and environmental management) and the European and global progress in these areas.

Properly analyzed the structure of the upcoming structure of process standardization of risk management of organization in general, ISO 31000, refers to the fact that from the structure' s point of view and also the process of implementation there are no significant differences from the standards for the management of partial aspects (Quality – ISO 9000, Environment – ISO 14000, Safety – OHSAS 18000, etc.). It seems that the organization could use (and many even did) the implemented standards, address the issue of risk management. A fundamental question then is whether the forthcoming standard will not just be another "duplicate" in the IMS standards organization, also causing the indicated problems with auditing.

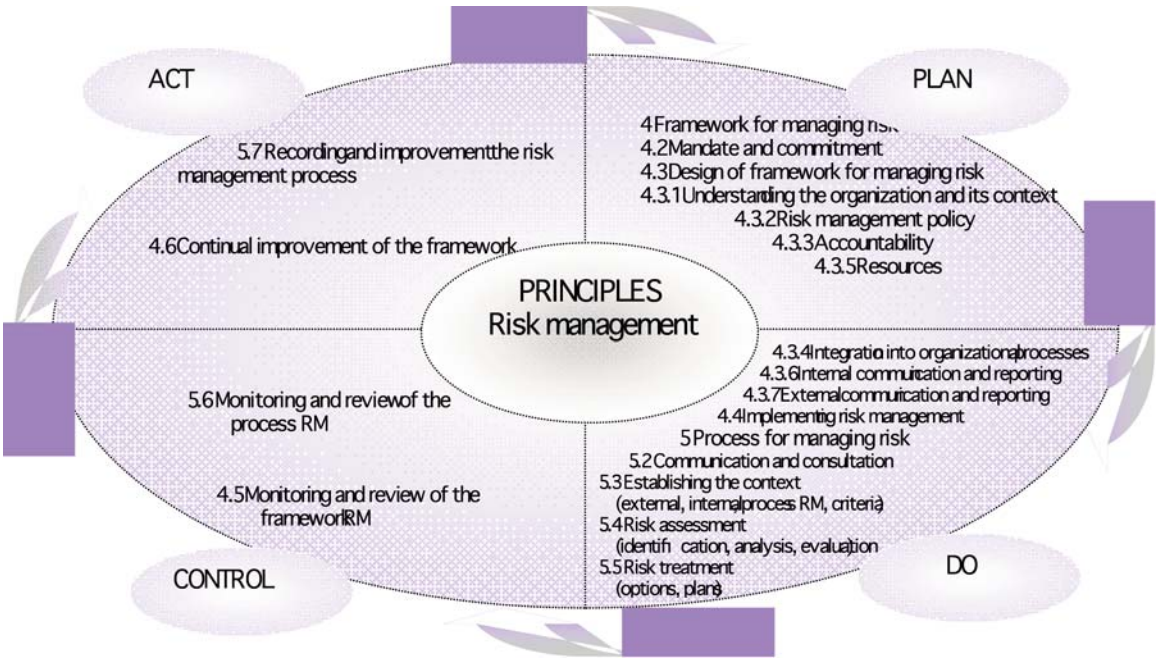

Fig. 3 The key elements of risk management system according to ISO 31000 in the Deming cycle of continuous improvement

Transformation of the structures of the forthcoming standard for Deming cycle of continuous improvement and adjustment separately proposed PDCA management process, risks and structures of risk management (particularly in the – Check audit) creates a space for its use as an "umbrella" standard management of partial aspects.

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Bojan Ticar *

ENVIRONMENTAL RISK REGULATION IN THE ENVIRONMENTAL PROTECTION LAW OF THE REPUBLIC OF SLOVENIA

The purpose of this paper is to present an overview of the regulation of environmental protection in force in administrative law in the Republic of Slovenia. The author analyses basic environmental protection principles which are contained in the EU regulation. These principles are: (1) the precautionary principle (le principe de précaution, der Grundsatz der Vorsorge), (2) the principle of preventive action (le principe d'action préventive, der Grundsatz der Vorbeugung), (3) the principle of correction at source (le principe de correction à la source, der Grundsatz, Umweltbeeinträchtigungen mit Vorrang an ihrem Ursprung zu bekämpfen), and (4) the polluter pays principle (le principe de pollueur-payeur, das Verursacherprinzip).

In order to accede to the EU, the Republic of Slovenia in Article 3a of the Constitution of the Republic of Slovenia allowed the supremacy of the primary legislation of the EU over Slovenian national regulations. The above-mentioned principles of the EC Treaty are transposed into the legal system of the Republic of Slovenia by means of its environmental legislation and implementing regulations. In this paper the author analyses the public law regulation contained primarily in the Environmental Protection Act (Official Gazette RS, Nos. 39/2006, 20/2006, and 70/2008). In addition to the general regulation implemented already by the Environmental Protection Act of 2006, the last amendment to the Environmental Protection Act transposed into the Slovenian legal order the provisions of Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage.

The paper focuses on the administrative legal regulation of the prevention and reduction of burdens on the environment, the conservation and improvement of the quality of the environment, the remedying of the consequences of burdens on the environment, as well as the improvement of the disrupted natural equilibrium and the recovery of its regenerative capacity. The paper furthermore analyses the application of the Environmental Protection Act as a general substantive law, as well as the special application of the procedures provided for in the Environmental Protection Act against subsidiary regulation of general administrative procedures in cases in which public and private interests are in collision or in potential collision.

Key words: administrative law, environmental protection, the precautionary principle, the principle of preventive action, the principle of correction at source, the polluter pays principle

1 Introduction

The substantive foundation of contemporary transnational and national regulation of environmental protection in administrative law in democratic societies in recent decades is no longer an anthropocentric perception of nature, i.e. that nature is exclusively subordinate to humans (Greek: *anthropeioi nomos*), but rather a new, ecocentric perception of nature (Greek: *nomos theios*). According to ecocentrism, the centre of legal protection is nature and not the exploitation of nature by humans. In light of the fact that anthropocentrism (i.e. in the sense of exploitation by humans) as a basis for human interaction with nature has led to the damaging and in some places even to the complete destruction of nature, there is no doubt that the ecological reasoning which lies within the anthropocentric perception of nature cannot lead to its protection. Legal protection of nature can only be achieved by establishing an ecocentric foundation in positive law regulation. This direction must also be followed by contemporary national and transnational legislation – Greek *nomos* (see *Pličanič, 1999; 16-30; Kirn 1992, 5-22*).

The ecocentric foundation of the regulation of nature has been followed in the last two decades by cogent (Latin: *ius cogens* – compelling law) regulation of European and Slovenian administrative law through the system of positive law (Latin: *ius positivum* – applicable law) institutional and *instrumental regulations*. The term institutional regulations primarily refers to the highest legal acts which establish a value framework for the legal system (see *Parsons, 1978*). These are especially the primary European legislation (i.e. the Treaty Establishing the European Community – hereinafter referred to as the EC Treaty) and the Constitution of the Republic of Slovenia (hereinafter referred to as the Constitution). The term *instrumental regulations,* on the other hand, refers to national laws and implementing regulations which implement the value-based aims established at the institutional level in positive law.

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The national regulation of environmental protection in administrative law in the Republic of Slovenia is a fairly new legal discipline that has existed and been developing only for the last two decades within the framework of graduate and post-graduate studies at Slovenian universities. Conceptually, this entails studying environmental law, which at the transnational and national levels enacts moderation in activities affecting nature.

With reference to such, it can be established that EU principles are also in conformity with the Slovenian Constitution, which in Section III, regulating economic and social relations, ensures everyone the protection of a healthy living environment (Article 72 of the Constitution) and the protection of the natural heritage (Article 73 of the Constitution). In this connection, the Constitution also addresses the concepts of national asset and natural resource (Article 70 of the Constitution). With reference to all the above-mentioned constitutionally protected values, the Constitution instructs the legislature to adopt the appropriate national legislation thereon. In addition, also Article 3a of the Constitution, which was added in 2003 as the basis, and one of the requirements of the EU, for Slovenia to join the EU, cannot be neglected. On the basis of this provision the Republic of Slovenia recognises the supremacy of the primary EU legislation over national legislation in the creation of the national legal order. The above-mentioned principles and constitutionally protected rights are implemented in the Slovenian legal order through national regulations, first of all through the Environmental Protection Act (hereinafter referred to as the EPA-1).

The above-mentioned Act introduced the institutional regulation of environmental protection, as laid down in the European treaty and the Slovenian Constitution, through thirteen fundamental principles. These are the following: (1) the principle of sustainable development, (2) the principle of integration, (3) the principle of cooperation, (4) the principle of prevention, (5) the precautionary principle, (6) the principle of the accountability of the person responsible for a burden on the environment, (7) the principle of payment for causing a burden on the environment, (8) the principle of subsidiary action, (9) the principle of incentives, (10) the principle of public access to information, (11) the principle of the protection of rights, (12) the principle of the admissibility of activities affecting the environment, and (13) the principle of the ecological function of property (Articles 4 to 16 of the EPA-1).

However, the EPA-1 is not the only Slovenian regulation that regulates the environment. There is a whole range, depending on the special regulation which each individual aspect of the environment requires. Slovenian environmental law can, in the broader sense, be divided into five parts related in terms of content (see *Scripta UL PF No. 35., 2008: 166–168*), namely: (1) the legal regulation of natural assets and the conservation of biotic diversity, (2) the legal regulation of water management, (3) the legal regulation of mineral matters management (non-renewable natural resources), (4) the legal regulation of wild animal management (hunting and fishing), and (5) the legal regulation of forests and barren land management.

This paper will not deal with specific and special regulations. It can be mentioned, however, that for a profound understanding of the structure of the national legal order in the field of environmental law, the rule *lex specialis derogat lege generali* must be applied. This entails that in the event of a collision of statutory rights and obligations, when two laws regulate the same legal relation, the regulation of the law which is more specialised – in the sense of Latin *lex specialis* – prevails. The EPA-1 is a general regulation. In individual specific environmental law fields the regulation determined in special regulations will thus prevail, inasmuch as they regulate specific environmental relations in a specific and special manner.

The central term of modern environmental law is the subjective law of persons subject to environmental law – their *legal rights and duties.* They are based on the general constitutional right of individuals to a healthy living environment. This is a general right which is followed by special rights and duties regulated by special laws in accordance with the principle of speciality. This right is in general a legally protected entitlement (Latin: *facultas agendi*) that a legal subject can act in a certain manner. This right is composed of two entitlements, namely of a fundamental entitlement and a claim. A fundamental entitlement enables subjects to fulfil their own interests if such are in compliance with the legal aim of the entitlement. A claim, on the other hand, contains the possibility that the state will impose a coercive sanction in the interest of the subject if another subject does not act in compliance with the obligation. The right thus contains, on one hand, an entitlement of one subject, and, on the other hand, the duty or obligation of another subject. Therefore, from a broader perspective (e.g. in interest-volition theory), a legal right is both – a right and a duty entitlement of the legal subject (*CZ, Pravo, 2003: 264*).

In what manner administrative law rights and duties of subjects to environmental law are implemented in accordance with the Slovenian EPA-1 will be discussed below. The paper will focus on the question of environmental protection permit as an individual administrative act and through this, the regulation of the supervision of state authorities regarding violations of administrative law statutory provisions from the field of environmental protection.

2 Environmental Protection Permit in Slovenian Legislation

The environmental protection permit is a central concrete and individual administrative act that every entity responsible for a planned activity must obtain in accordance with Slovenian legislation (Article 57 of the EPA-1). In order to operate an installation or plant where any activity that might cause large-scale environmental pollution will be carried out, the operator must obtain an environmental protection permit. However, the EPA-1 introduces various types of environmental protection permits which differ with regard to the scope of the requirements that must be fulfilled in order to be obtained, with regard to the time limits for issuing the permit, and with regard to the participation of the public; all types of permits are, however, issued by the Ministry of the Envi-

ronment and Spatial Planning or its affiliated body, i.e. the Environmental Agency of the Republic of Slovenia (hereinafter referred to as the EARS). An environmental protection permit must be obtained prior to the beginning of the operation of the installation or plant and for every substantial change in the operation of an installation or plant. A substantial change in the operation thereof is (1.) any change in the installation or its extension that modifies any principal technical characteristic of the installation or its capacity, which as a consequence causes a change in the quantity or type of emissions into the environment or the waste for which the environmental protection permit was obtained, (2.) a considerable increase in the quantity of a hazardous substance, (3.) a significant change in the chemical or physical properties of a hazardous substance, or (4.) any other change in the technological process in a plant where a hazardous substance is used. An environmental protection permit must be obtained in three instances (see *Viler-Kovačič, 2006: 6–7*), namely:

- For installations that may cause *large-scale* pollution, i.e. installations subject to the IPPC Directive. The abbreviation derives from the title of the EU directive, namely Council Directive 96/61/EC concerning integrated pollution prevention and control, abbreviated as the IPPC Directive. This directive regulates IPPC installations.
- For other installations that do not cause large-scale pollution (installations determined in Article 82 of the EPA-1):
  - if an activity is pursued in these installations that causes emissions into the air, water, or soil for which limit values are prescribed;
  - if an activity is pursued in these installations for which the obligation to obtain an environmental protection permit is prescribed in other regulations;
  - if in these installations waste is treated or disposed of.
- For installations that pose a major environmental risk.

Pursuant to the EPA-1, an installation is any stationary or mobile technical unit for which it has been established that it may cause an environmental burden as a consequence of one or more specified technological processes taking place in that installation, or of any other technology-related processes taking place at the same site (item 8 of Article 3 of the EPA-1). In accordance with the same Act, a plant is defined as the entire area managed by one operator where there are one or more installations, including the accompanying or associated infrastructure and technological processes related thereto in which hazardous substances are produced, stored, or used in any other way (item 9 of Article 3 of the EPA-1).

In what manner European legislation is applied at the national level will be demonstrated through the case study of the application of the Seveso Directive into the Slovenian EPA-1 (*Viler-Kovacic, 2006: 6–7*):

CASE STUDY: *A particularity of the environmental protection permit in the Slovenian legal system is also the transposition of the Seveso European Directive for plants into the EPA-1 (see Article 86 of the EPA-1). The Council of the European Union adopted the Seveso Directive (i.e. Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances) following a major accident in Seveso in Italy in 1976, when several kilograms of dangerous dioxin was suddenly and uncontrollably released from the chemical plant and contaminated more than 15,000 m2 of land and vegetation. As many as 2000 people were treated for dioxin poisoning and more than 600 had to be evacuated from their homes (see* http://europa.eu.int/comm/environment/seveso/#1*, 20. 11. 2009).*

The above-mentioned directive was transposed into the EPA-1 through the requirement that when operating a plant, the person posing a risk to the environment must implement the prescribed measures for the prevention of any major accident and for the mitigation of consequences therefrom for humans and the environment, and in particular draw up a scheme for the reduction of environmental risk and a safety report. A person posing a risk to the environment must obtain an environmental protection permit for the plant, which is named an environmental protection permit issued in accordance with Article 86 of the EPA-1 or a Seveso permit, in order to distinguish it from other environmental protection permits.

Operators of such plants are termed persons posing a risk to the environment, whereas a risk to the environment in accordance with the EPA-1 entails the probability that in certain circumstances or within a certain time interval an activity would harm, directly or indirectly, the environment, or human life or health. The measures that the plant operators must undertake for the prevention of major accidents and the mitigation of their consequences for humans and the environment, as well as safety measures connected therewith which plant operators must meet, are regulated by the Government Decree on the Prevention of Major Accidents and the Mitigation of their Consequences (Official Gazette RS, No. 88/2005). Pursuant to this Decree, plants are divided into plants posing a lower risk to the environment and plants posing a greater risk to the environment, regardless of the type and quantity of hazardous substances that are in the plant. A formula for the assessment of a plant posing a lower risk to the environment and those posing a greater risk to the environment is provided in the annex to the Decree.

In the procedure for issuing the environmental protection permit, the EARS must make the permit application and the draft decision on the environmental protection permit available to the public. The provisions that apply to entities subject to the IPPC Directive apply, mutatis mutandis, regarding the participation of the public. The time limit for issuing a permit is three months from receiving a complete application.

The environmental protection permit stipulates in detail measures for the prevention of major accidents and the mitigation of their consequences for humans and the environment; the environmental protection permit is issued for a period of five years from the day of the beginning of the operation of the plant (and not from the day this administrative act takes effect). In the event that it is assessed that the consequences of a major accident in a plant could have an impact on the environment of another state, or when the latter so requests, the competent authority of that state is to be informed of the environmen-

tal protection permit issued. If on the basis of such information another state so requests, it must be forwarded the safety report of the plant in question.

Such environmental protection permit may also be extended, updated, or withdrawn under the conditions and in the manner determined by the EPA-1.

3 Administrative Supervision of Environmental Protection

Administrative supervision, particularly inspection, is one of the administrative functions of the state that ensures supervision of the implementation of the adopted legal order and provides feedback so that administrative bodies can learn of the effects of the adopted regulations and introduce appropriate modifications and measures. The coercive nature of inspection tasks ensures that addressees of legal norms respect regulations, whereas at the same time these norms protect the rights and legal benefits of individuals that were recognised to them by laws and other regulations. Inspection supervision is thus supervision of the implementation of laws and other regulations. The tasks of inspection are performed by inspectors as officials with special authorisations and responsibilities (see *Likozar-Rogelj, 2006: 16–17*).

The nature of performing inspection tasks is repressive. Therefore, the primary task of inspectors is not to give advice or instruct parties to obtain the necessary permits, but to impose measures if addressees (i.e. persons subject to inspection) do not have the permits which they are required to have. This also applies to environmental protection permits regulated in the EPA-1.

If an environmental inspector establishes that a person liable for the operation of a plant or installation does not have the necessary environmental protection permit, he or she does not instruct the person liable to obtain such permit, as the author of the above-cited article erroneously thinks, but prohibits the operation of the installation or plant if it is operating without an environmental protection permit (see item 6 of the first paragraph of Article 157 of the EPA-1). As the legislature determined that the operation of a plant or installation without obtaining a prior environmental protection permit is prohibited, it provided for the imposition of sanctions; a legal entity may be imposed a fine in the amount of 1,200 to 360,000 EUR. Due to the fact that the amount of the prescribed sanction that can be imposed is high, accelerated minor offence proceedings are not allowed (*Likozar-Rogelj, 2006: 16–17*).

It thus proceeds from the above-mentioned that inspectors must respect the principle of legality when performing their tasks. They implement this fundamental principle through supervision, as they supervise in the public interest whether the adopted legal regulations are respected and take appropriate measures in cases in which they establish a violation of the regulations that they are authorised to supervise. The repressive nature of inspection tasks is demonstrated solely through measures which inspectors are obliged to impose if they establish that the legal order is not respected.

4 Conclusion remarks

In 2006 the Inspection Act (hereinafter referred to as the IA) introduced an amendment that authorises inspectors to apply preventive measures (see Article 33 of the IA) which concretise the principle of the protection of the public interest and the protection of private interests in order to ensure that the regulations are respected. Inspectors can namely only issue a warning if they establish irregularities when performing their inspection tasks and asses that such is an appropriate measure regarding the seriousness of the violation. They also determine a time limit in which the irregularities must be remedied. If the irregularities are not remedied, inspectors impose other measures in accordance with the law. The above-mentioned discretionary right of inspectors importantly influences the preventive action; depending on the seriousness of the violation, inspectors assess whether a warning will suffice and whether the person subject to inspection will respect the norms of the regulation and perform the omitted prescribed obligation or remedy the violation which they have caused with their operation. If, however, inspectors establish that after a warning has been issued, a person subject to inspection does not respect the imposed measure, they are to impose other, graver measures prescribed by law. A person subject to inspection is obliged to remedy the irregularities or deficiencies within the determined time limit; if they do not do so themselves, the inspectors force them to remedy such in execution proceedings with the execution carried out by a third person or by a fine. Inspectors thus do not only impose measures, but also ensure that such measures are implemented (*Likozar-Rogelj, 2006: 17*).

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EMERGENCY REPORTING PROCEDURE IN A MULTI-NATIONAL ENVIRONMENT

This article is aimed on reporting procedure in emergency situation used in multi-national environment. It is based on real procedures, documents and instructions, which are usually used in all kinds of emergency assets, especially during the activities of multi-national joint forces. The first impulse for creating this procedure started in armed task forces and due to the great effect fluently increased to the civilian sector. The article is a basic instruction how to simply ensure information flowchart among all the elements and secure quick reaction on developing crisis situation.

1. Introduction

Crisis management is a phenomenon of the present time. Nowadays, the increasing numbers of predicaments are solved in a multi-national environment. In the case of emergency quick reaction and efficiency are the fundamental characteristics in order to ensure a proper coordination of the rescue assets immediately. A precise, punctual and timely management of assets that effect through a simple chain of command, can only achieve this. Different operation procedures, capabilities and language barriers of the involved international assets brought about the need to create a common system of reporting procedure. The main purpose of this article is to create an overall summary of the multi-national standard operation procedures (SOP), information flowcharts (IF) and reporting procedures (RP) in order to explain its application in the real situation.

All these mentioned segments are the necessary parts of a decision making process (DMP) and the most important inputs in the process of gathering information in order to get enough relevant information for the general solution of the situation.

We can divide this problem into three parts:
- standard operation procedures (SOP)
- information flowcharts (IF)
- reporting procedures (RP)

2. Standard operation procedures

Aim of the SOPs is to clarify the procedures used by the crisis management. The main intent of each SOP is to support the members and managers of the crisis staff and incident commander in DMP and help them to make particular decisions aimed to reach the final goal.

The core of each SOP is a clear and simple direction, how to manage the situation in order to ensure a safe and secure environment in accordance with the official protocols and documents. SOP has to be clear and simple, but on the other hand, rich on the value.

The most important SOP for our work is the "Alert of Immediate Rescue Team (IRT) and Communication Procedures in Emergency Situation" used in the multi-national military IRT assets.

3. Information flowchart

The main intent of IF is to ensure the flow of information and reports to all the participants, especially between the IRT on the spot and the operation room (OPS room).

IRT assets have to react immediately and with a sufficient information flow during the incident. OPS room is responsible for the accurate and timely reporting of all information related to the incident to IRT. Each incident must be assessed individually and taken actions must be based on the received accurate information and any situational analysis from the incident site. IRT Asset Status Reports and Situational Picture are sent to the OPS room verbally through the assigned CIS (communication and information systems) systems minimum every 30 minutes.

The most widely used CIS system is the radio communication. There are several rules in the transmission in order to get the fluent flow of the information. The most important are:

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- Send the brief but precise message.
- Break the message into sensible passages with pauses between.
- Make sure no-one else is transmitting at the same time.
- By transmitting maintain the high standard of articulation, normal rhythm and moderate volume. Do not shout.
- Avoid excessive calling and unofficial voice procedures.
- Hold the microphone close to your mouth.

Phonetics

- The *International Phonetic Alphabet* [1] listed below shall be used.
- Numerals shall be transmitted digit by digit except round figures as hundreds and thousands.

International phonetic alphabet [1] Table 1

Letter	Phonetic Alphabet	Letter	Phonetic Alphabet	Numeral	Spoken as
A	ALFA	N	NOVEMBER	0	ZERO
B	BRAVO	O	OSCAR	1	WUN
C	CHARLIE	P	PAPA	2	TOO
D	DELTA	Q	QUEBEC	3	THREE
E	ECHO	R	ROMEO	4	FO-WER
F	FOXTROT	S	SIERRA	5	FI-YIV
G	GOLF	T	TANGO	6	SIX
H	HOTEL	U	UNIFORM	7	SEVEN
I	INDIA	V	VICTOR	8	ATE
J	JULIET	W	WHISKEY	9	NINER
K	KILO	X	XRAY	Examples: 12 WUN TOO 44 FO-WER FO-WER 90 NINER ZERO 136 WUN THREE SIX	
L	LIMA	Y	YANKEE		
M	MIKE	Z	ZULU		

Procedure Words (PROWORDS) [1]

- A *pro-word* is a word or phrase which has been given a special meaning in order to speed up the handling of messages.
- The only authorised pro-words are listed below:

PROWORDS [1] Table 2

PROWORD	Explanation
ALL AFTER	The portion of the message to which I have reference is all that which follows _____.
ALL BEFORE	The portion of the message to which I have reference is all that which precedes _____.
BREAK	I hereby indicate the separation of the text from other portions of the message.
CORRECT	You are correct, or what you have transmitted is correct.
CORRECTION	An error has been made in this transmission. Transmission will continue with the last word correctly transmitted.
FIGURES	Numerals or numbers follow.
FLASH	Precedence FLASH.
FROM	The address designator immediately following indicates the originator of this message.
I READ BACK	The following is my response to your instructions to read back.
I SAY AGAIN	I am repeating transmission or portion indicated.
I SPELL	I shall spell the next word phonetically.
I VERIFY	That which follows has been verified at your request and is repeated. To be used only as a reply to VERIFY.
MESSAGE	A message which requires recording is about to follow. Transmitted immediately after the call. (This PROWORD is not used on nets primarily employed for conveying messages. It is intended for use when messages are passed on tactical or reporting nets.)
OUT	This is the end of my transmission to you and no answer is required or expected.
OVER	This is the end of my transmission to you and a response is necessary. Go ahead, transmit.
READ BACK	Repeat this entire transmission back to me exactly as received.
RELAY (TO)	Transmit this message to all addressees (or addressees immediately following this PROWORD). The address component is mandatory when this PROWORD is used.
ROGER	I have received your last transmission satisfactorily.
SAY AGAIN	Repeat all of your last transmission. Followed by identification data means "Repeat _____ (portion indicated)".
SILENCE (Repeated three or more times)	Cease transmission on this net immediately. Silence will be maintained until lifted. (When an authentication system is in force, the transmission imposing silence is to be authenticated).
SILENCE LIFTED	Silence is lifted. (When an authentication system is in force, the transmission lifting silence is to be authenticated).
SPEAK SLOWER	Your transmission is at too fast a speed. Reduce speed of transmission.
THIS IS	This transmission is from the station whose designator immediately follows.
TIME	That which immediately follows is the time or date time-time group of the message.
TO	The addressees immediately following are addressed for action.
UNKNOWN STATION	The identity of the station with whom I am attempting to establish communication is unknown.
WAIT	I must pause for a few seconds.
WAIT – OUT	I must pause longer than a few seconds.
WILCO	I have received your signal, understand it, and will comply. To be used only by the addressee.

WORD AFTER	The word of the message to which I have reference is that which follows _____.
WORD BEFORE	The word of the message to which I have reference is that precedes _____.
WORDS TWICE	Communication is difficult. Transmit (transmitting) each phrase (or each code group) twice. This PROWORD may be used as an order, request, or as information.
WRONG	Your last transmission was incorrect. The correct version is ____.

4. Emergency reporting procedure

In the multi-national reporting procedures *reporting forms* are usually used. These ones make the information flowchart about the situation easier. Each form must be very strict and comprehensible.

Advantages of the reporting form:
- time saving
- well arranged information
- elimination of the missing information
- easy use for everyone
- low level of the needed language skills

"Request for IRT support" is the most important reporting form in the emergency reporting procedure. Forms and examples (in accordance with SOP: "Alert of Immediate Rescue Team (IRT) and Communication Procedures in Emergency Situation") of these requests are described below.

When reporting any accident/incident or emergency situation comply with the Medical Emergency Aide Memoire known as METHANE Report [2]:

Fig. 1 METHANE Report [2]

M-E-T-H-A-N-E	
DTG	**Date, Time, Group *** 29 0935B SEP 2009
M	**My call sign (name, team)** ECHO 21
E	**Exact location (GRID – or describe location)** GRID: EN 12300 35400
T	**Type of incident (e. g. RTA)** RTA (route traffic accident) of bus and vehicle.
H	**Hazard at the scene (e. g. Traffic, fire)** Possible burning vehicle, unknown liquid and hard traffic
A	**Access (route in, GRID of RV *, HLS *)** Main route in vicinity of village XY. South route to main junction. Possible HLS at GRID: EN 009 135 with no hazards, marks with blue smoke.
N	**Number and type of casualties** Approximately 9 casualties. Number of wounds. Impacts, external bleedings, possible wound of backbone, burns and trauma injuries. (2 - urgent, 7 - priority precedence) (2 - litter, 7 - ambulant)
E	**Emergency assets present and needed (e. g. IRT, firemen)** Medical teams and FIREMEN. Medical assets and extraction equipment required. Urgently. Police to secure the area and provide bypass. No assets currently present. BPT (be prepared to) HELIVAC.

In Mass Casualty Situation (MASCAL) incident commander requests helicopter medical evacuation (Heli MEDEVAC) if required, for evacuation of injured persons. Make the request usually using *9-Line MEDEVAC REQUEST* [3], in this type of situation.

1. **Required Information [5]**
   a. Header Message
      (1) Date-Time Group (DTG)
      (2) Identifier/Unit Name/Name
   b. 9-Lines Test as follows:
      (1) *Pickup Zone (PZ) Grid Reference*
      Provide the 6-figure grid reference and any other pertinent landmarks, town location, etc, that will help identify the location of the casualties.
      (2) *Radio Call Sign (C/S) and Frequency (Freq)/Phone number*
      Fill in the call sign of IRT (on-site commander, incident commander, reporting person who are still in touch) and primary and alternate frequency or phone number.
      (3) *Number of Patients and Precedence (Patients by precedence)*
      Provide the number of casualties awaiting the evacuation by category.

      A/P1 *Priority 1 / URGENT*
      Emergency patients who require speedy evacuation that is necessary to save life, to prevent complications or to avoid serious permanent disability.
      B/P2 *Priority 2 / PRIORITY*
      Patients who require specialised treatment not available locally and who are liable to deteriorate unless evacuated with the least possible delay.
      C/P3 *Priority 3 / ROUTINE*
      Patients who require immediate treatment that is available locally but whose prognosis would benefit from air evacuation on routine scheduled flights.

* DTG: 29 0930Z SEP 2009 means 29 SEP 2009, 09:30, Z: local time
* GRID of RV – exact location of rendezvous (meeting) point marked with 6-figure grid reference
* HLS – Helicopter landing site

Fig. 2 9-line MEDEVAC REQUEST [3]

MEDEVAC " 9-Line" REQUEST			DTG		UNIT (NAME)
1	LOCATION (GRID OF PICKUP ZONE)		(1)		
2	CALLSIGN & FREQ (PHONE NUMBER)		(2)		
3	NUMBER OF PATIENTS/PRECEDENCE		(3) A ..... B ..... C		
	A – URGENT; to be at hospital facility (R2 or R3) within 90 minutes of first notification (P1)		B – PRIORITY; to be at hospital facility (R2 or R3) within 4 hours of notification by "9-line" (P2)		
	C – ROUTINE; to be at hospital facility R2/R3 within 24 hours of notification by '9-line" (P3)				
4	SPECIAL EQUIPT REQ'D		(4)		
	A – NONE	B – HOIST (Winch)	C – EXTRICATION	D – VENTILATOR	
5	NUMBER TO BE CARRIED LYING/SITTING		(5) L ..... A ..... E		
	L – LITTER (Stretcher)	A – AMBULATORY (WALKING)		E – ESCORTS (e.g. for child patient)	
6	SECURITY AT PICKUP ZONE (PZ)		(6)		
	N – No threat		E – Explosion		
	L – Unknown liquid		X – Nuclear, biologocal and chemical dangerous		
7	PICKUP ZONE (PZ) MARKING METHOD		(7)		
	A – PANELS	B – PYRO	C – SMOKE	D – NONE	E – OTHER (explain)
8	NUMBER OF PATIENTS BY STATUS		(8) A ..... B ..... C		
	A – IRT MEMBER		B – CIVILIAN (ADULT)		
	C – CHILD				
9	PICKUP ZONE (PZ) TERRAIN/OBSTACLES (describe terrain, obstacles and weather)		(9)		
DO NOT DELAY LAUNCH OF MEDEVAC – SUPPLY FURTHER INFORMATION ONCE AVAILABLE:					
M	MECHANISM OF INJURY (and at what time if known)		(M) (Time: .....)		
I	INJURY OR ILLNESS SUSTAINED		(I)		
S	SYMPTOMS AND VITAL SIGNS A – airway B – breathing rate C – pulse rate D – conscious/unconscious E – other signs		(S) ..... A ..... B ..... C ..... D ..... E		
T	TREATMENT GIVEN (e.g. Tourniquet and time applied, Morphine)		(T)		

(4) *Special Equipment Required*
The classification defines specialized equipment to be aboard the aircraft.
A – None
B – Hoist (Winch)
C – Extrication
D – Ventilator

(5) *Number of Casualties Carried Lying or Sitting (Patients by type):*
The classification defines the patient's requirement for space in the aircraft.
L – Litter (stretcher) Borne Patients
A – Ambulatory (walking) Sitting Patients
E – Escorts Sitting Passengers

(6) *Security at Pickup Zone*
N – No threat
E – Possible explosion
L – Liquid (type or unknown)
X – NBC dangerous

(7) *Pickup Zone Marking Method*
The classification provides information how the PZ will be identified and marked.
A – Panels
B – Pyrotechnics
C – Smoke
D – None
E – Other (explain)

(8) *Number of Patients by Status*
A – IRT member
B – Civilian (Adult)
C – Child

(9) *Pickup Zone Terrain/Obstacles*
The classification provides an assessment of any obstacles and the type of terrain located adjacent or at the PZ.
Terrain: – slope
– elevation
– surface

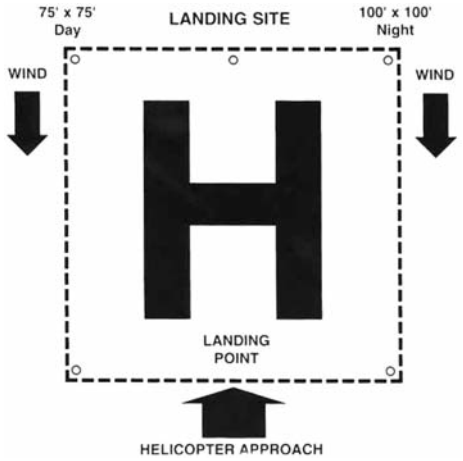

Fig. 3 Landing zone preparation [6]

Obstacle: – pylons, pillars, trees, building etc.
– wiring
– FOD (foreign object damage)

Weather: – visibility
– weather status
– wind (strength and direction)

Conclusion:

The article discuss about information flowchart and reporting procedure in multi-national environment in order to speed up the handling of information. The main effort is put on creation of reports about incidents/accidents in accordance with reporting forms, which are usually used in international emergency management. The article clarify the basic terminology and summarize gathered information gained by information research and own experiences. The main purpose was to create an overall summary of available information about reporting procedure into common document in order to explain its application in the real situation and help to emergency personnel in their daily routine work.

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UTILIZING KNOWLEDGE OF PHYSICS IN SAFETY ENGINEERING

Any technician working in safety engineering needs certain knowledge of physics. This knowledge includes physical quantities and units of measurement, physical properties of substances, various formulae and equations, etc. It is also very important to possess knowledge enabling general – and often highly complex – processes to be simplified. This paper discusses two such possibilities for simplification.

Key words: physical field, heat transfer

1. Introduction

When solving various practical problems of safety engineering, general solutions may be highly complex [5]. It is therefore of key importance whether the solution may be simplified, and if so under what conditions, as well as whether certain processes may be disregarded. This paper presents and discusses two such possibilities for simplification.

2. Point sources and non-point sources of physical fields

The solutions to a range of physical and technical problems involve various physical fields (gravitation, electrical, thermal, acoustic, etc.). In most cases it is the intensity and potential of these fields that are used in calculations.

When carrying out such calculations it is important whether the source of the physical field is a point source (in which case the calculation is simple) or a non-point source (which complicates the calculation).

A point source of a physical field is a source whose dimensions and shape can be disregarded when solving the given problem. The dimensions and shape of a non-point source cannot be disregarded. Non-point sources of physical fields include linear sources (e.g. wires), surface sources or general sources (bodies).

The condition for simplification is determined depending on the accuracy with which the calculation is to be carried out. It is usually sufficient if the difference between the quantity calculated for a field produced by a point source (x_b) and the quantity calculated generally for a non-point source of a field (x) is no larger than one percent, i.e.

$$x_b = 1.01x \tag{1}$$

The following examples show how it is possible to work with the concepts of point sources and non-point sources of physical fields.

2.1 Electrical fields

Intensity of electrical fields

The intensity of an electrical field produced by a point electrical charge in a vacuum is calculated by the equation

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\left(NC^{-1}, Vm^{-1}\right) \tag{2}$$

where
ε_0 – permittivity of vacuum
Q – charge (C)
r – distance from charge (m)

However, this equation is only accurate for point charges or charged homogeneous balls (the distance is measured from the centre of the ball).

If the charged body is not a point source, the situation is somewhat more complicated, and the intensity of the electrical field must be calculated according to the equation

$$E = \frac{1}{4\pi\varepsilon_0}\int\frac{dQ}{r^2} \tag{3}$$

where
dQ – element of electrical charge.

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Electrical field of a charged ring

A thin wire is formed into a ring with radius a, and the total electrical charge of the ring is Q. The intensity of the electrical field is determined at point P on the axis of the ring at distance b from the centre of the ring (Fig. 1).

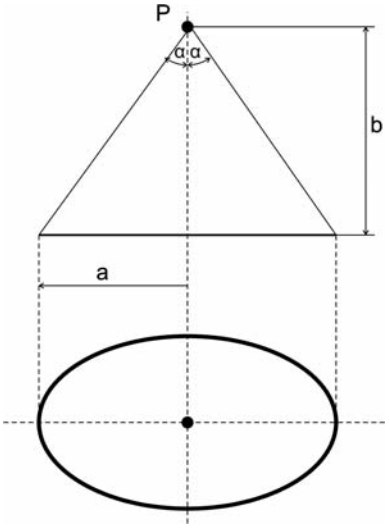

Fig. 1 Calculation of the intensity of the electrical field of a charged ring

Using equation (3), it is possible to derive for the given intensity the equation [1] and

$$E = \frac{Q}{4\pi\varepsilon_0}\frac{b}{(a^2+b^2)^{\frac{3}{2}}} \tag{4}$$

The quantities are marked as in Fig. 1.

If distance b is much larger than the radius of the ring a – i.e. $b >> a$ – then equation (4) can be simplified to

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{b^2} \tag{5}$$

which corresponds with the equation for the intensity of a point charge located in the centre of the ring.

The condition for simplification for a 1% difference in intensity calculated generally (equation 4) and in a simplified manner (equation 5) can be determined from the following equation (according to equation 1):

$$\frac{1}{4\pi\varepsilon_0}\frac{Q}{b^2} = 1.01\frac{Q}{4\pi\varepsilon_0}\frac{1}{(a^2+b^2)^{\frac{3}{2}}} \tag{6}$$

The solution of this equation gives us the result

$$b = 11.9a \doteq 12a$$

Thus, if the distance from the centre of the ring is over 12 times more than the radius of the ring, the calculation of the intensity of the electrical field can be carried out using the equation for the calculation of the intensity of the electrical field of a point charge located in the centre of the ring.

2.2 Light fields

Illumination with a surface source

The illumination of point P, which lies on the axis of a circular disc with radius a and luminance L at distance g from the centre of the disc (Fig. 2), is calculated according to equation [2]

$$E = \frac{LS}{a^2+g^2} \tag{7}$$

where $S = \pi a^2$

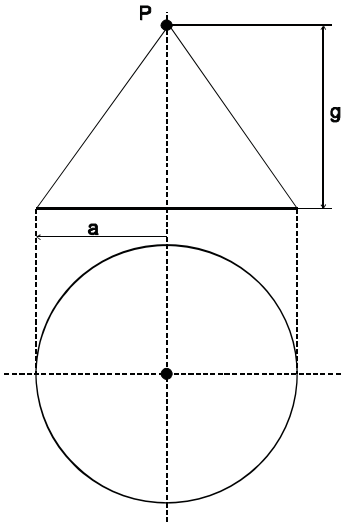

Fig. 2 Calculation of illumination from a surface source

Due to the sufficient distance of point P from the disc, we can consider the disc as a point source of light, and calculate the illumination on the basis of the equation

$$E = \frac{LS}{g^2} \tag{8}$$

The condition for simplification for a 1% difference in the the quantity of illumination calculated generally (7) and in a simplified manner (8) can be determined from the following equation (according to equation 1):

$$\frac{LS}{g^2} = 1.01\frac{LS}{a^2+g^2} \tag{9}$$

The solution of this equation gives us the result

$$g = 10a$$

Thus, if the distance g from the centre of the ring is 10 times larger than the disc radius a, the disc can be considered a point source of light.

3. Heat transfer

Heat transfer plays an important (though often neglected) role in the solution of thermokinetic problems [6]. It is a process which occurs on the boundary of gas or liquid and a solid substance, i.e. on the boundary where convection changes to conduction (or vice versa).

At this boundary there is a sharp jump in temperature. In the liquid (or gas) the temperature is approximately constant except for a very thin layer adjacent to the wall, in which the temperature drops significantly, so the wall has a lower temperature than the temperature of the liquid. This occurs in cases where the heat is transferred from the liquid to the wall. In the opposite case, when the heat is transferred from the wall to the liquid, the wall has a higher temperature than the liquid.

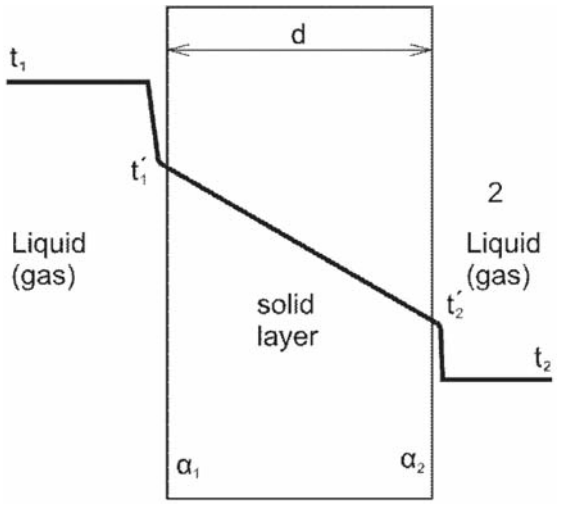

Fig. 3 Temperature change during heat transfer from liquid to liquid via a solid layer

If the liquid (Fig. 3) has temperature t_1 and the surface of the solid wall has temperature t'_1, then the heat transferred during time τ through surface S from the liquid to the wall is given by Newton's equation

$$Q = \alpha S \tau (t_1 - t'_1) \tag{10}$$

The proportionality constant α is known as the heat transfer coefficient ($Wm^{-2}K^{-1}$).

In practice, we usually determine the penetration of heat from one liquid (gas) to another liquid (gas) via a flat wall. In a stationary state, it is easy to derive the equation

$$Q = kS\tau (t_1 - t_2) \tag{11}$$

The quantities are marked as on Fig. 3.

Constant k is known as the heat penetration coefficient ($Wm^{-2}K^{-1}$).

$$\frac{1}{k} = \frac{1}{a_1} + \frac{d}{\lambda} + \frac{1}{a_1} \tag{12}$$

where

α_1, α_2 – heat transfer coefficient from liquid 1 to the wall or from the wall to liquid 2 ($Wm^{-2}K^{-1}$)

d – wall thickness (m)

λ – thermal conductivity coefficient of the wall material ($Wm^{-1}K^{-1}$)

At first sight it may appear that heat transfer is not a particularly complex problem. However, the reality is different. Unlike the thermal conductivity coefficient, which is a material constant, the heat transfer coefficient is not a material constant. It depends on a range of parameters, e.g. density, viscosity, thermal conductivity of the medium, convection speed, geometric and shape parameters, etc. It can reach highly divergent values depending on circumstances (Table 1):

Approximate range of values of the heat transfer coefficient [3] Table 1

Coefficient without phase change		α ($W m^{-2}K^{-1}$)
Natural convection	gases	3 – 20
	water	100 – 600
Forced convection	gases	10 – 500
	water	500 – 10000
	highly viscous liquids	50 – 500
Coefficient with phase change		
liquid boiling		1000 – 20000
vapour condensation		1000 – 100000

For this reason, equations (10), (11) and (12) are simple only in formal terms. Determining the heat transfer coefficient (and thus also the heat penetration coefficient) is a complex problem, and exceeds the scope of this paper.

As an illustration, we can calculate the heat flow (the heat flowing through a surface of $1m^2$ in 1s) for the following conditions (markings according to Fig. 3).

1. t_1 = 5 °C, α_1 = 7.5 W m^{-2} K^{-1}, copper layer, d = 1 cm, λ = 372 W m^{-1} K^{-1}, α_2 = 50 W m^{-2} K^{-1}, t_2 = 45 °C.

2. $t_1 = 5$ °C, $\alpha_1 = 7.5$ W m^{-2} K^{-1}, polystyrene layer, d = 1cm, $\lambda = 0.06$ W m^{-1} K^{-1}, $\alpha_2 = 50$ W m^{-2} K^{-1}, $t_2 = 45$ °C.

In the first case (a) we calculate the heat flow including heat transfer; in the second case (b) the heat transfer on both sides of the solid layer is disregarded.

The results can be summarized as follows:

1a ..... $q = 267$ W m^{-2} 1b ..... $q = 1.48$ MW m^{-2}
2a ..... $q = 125$ W m^{-2} 2b ..... $q = 240$ W m^{-2}

It is evident that heat transfer plays a major role in the solution of thermokinetic problems – even those problems which seem simple. Analysis [4] shows that the influence of heat transfer is particularly significant in the case of highly conductive solids, growing as the solid layer becomes thinner. If we intend to disregard this phenomenon, there must be very good reasons for doing so. Otherwise, calculations may be burdened with significant error.

4. Conclusion

When solving complex practical problems, we search for opportunities to simplify. However, it is essential to consider in which conditions such simplifications may be made, and what effect this will have on the resulting solution of the problem.

This contribution was prepared in the framework of dealing with the grant project of the Ministry of the Interior of the Czech Republic, Security Research Programme, under the No. MV0400511, “Influence of Terrorist Attack on Selected Industrial Technologies with a Dust Explosion Hazard”.

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CONTROL AND NAVIGATION OF MOBILE ROBOTS IN SAFETY AND FIRE PROTECTION

This paper presents the actual situation of mobile robots (MRs) application in the field of safety and fire protection. At the beginning are described the basic structures and subsystems of each MR, reasons for their applications and some design examples of mobile robots applied for safety and fire protection. The second part of this paper presents several different conceptions of MR control systems with respect to dangerous applications. The last part of this paper is oriented on the methods of MR navigation and path planning. This part is related with maps and localization problem and describes why it is necessary to have a map in MR control system. There are presented some basic map types with their advantages and disadvantages.

1. Introduction

Generally, the mobile robot is a complicated mechatronic cognitive system consisting of many subsystems with different levels of complexity. The most distinguished characteristic mark of mobile robots is their locomotion in space. The problem of design process of a mobile robot integrates the knowledge from many science fields as cybernetics, automation, mechanical engineering, electronics, informatics, artificial intelligence and bionics. Selection of appropriate navigation method in workspace is one of the fundamental problems, which is solved by the design process of all autonomous mobile robots (AMR).

The reasons for mobile robot application:
- safety – the elimination of human contact with danger objects or environment,
- exploration of unknown terrain,
- inaccessibility and unavailability – survey by landslides and earthquakes,
- reliability – elimination of human error from the processes.

The application of mobile robots in natural disasters, various rescue operations and fires can help increase the efficiency and safety of rescue work. It can reduce the risk that people have now to undergo during similar actions. The minimization of risk for human in danger environment is also the reason why the researchers around the world deal with development in the field of mobile robotics. In this paper we want to describe some problems associated with the application of mobile robots under these very specific and hard conditions.

AMRs contain several subsystems:
- mechanical subsystem (locomotion subsystem) – undercarriage,
- sensoric subsystem – internal and external sensors,
- control subsystem – control of all subsystems of AMR,
- communication subsystem – data transfer and communication with operator.

2. Application of mobile robots in fire protection

One of the authors had within practical Erasmus training the chance to participate in the project oriented on development of a mobile robot named Guardian (Fig. 1a). This robot is designed for firefighters and developed by the company Robotnik Automation (Valencia, Spain). The main task was to run real time Linux on embedded PC together with drive subsystem. The second task was implementation of a laser range finder to the SLAM (Simultaneous Localization and Mapping) algorithm. Another subject of development was the system enabling to automatically follow a walking firefighter without teleoperation. The new Guardian is a high mobility robot with modular architecture. It is able to integrate several sensors – indoor/outdoor laser, cameras, microphones, stereohead, GPS, IMU (Inertial Measurement Unit) and actuators for modular robot arms, tilting camera, etc. The robot weighs 75 kg and its load capacity is approximately 50 kg. Guardian is an all-terrain vehicle, able of climbing up and down steps thanks to the hybrid undercarriage (combination of wheels and belts). The robot is small enough to be transported in a conventional car boot and light enough to be loaded into a lift. The mobility and high speed of the robot allows it to rapidly access to buildings.

Guardian is controlled by embedded PC with operational system Linux Real Time. On this platform the Player/Stage is running thus enabling the navigation of the robot through the corridors inside the buildings and also building its own map of environment. The system WiFi/WiMan is used for the communication

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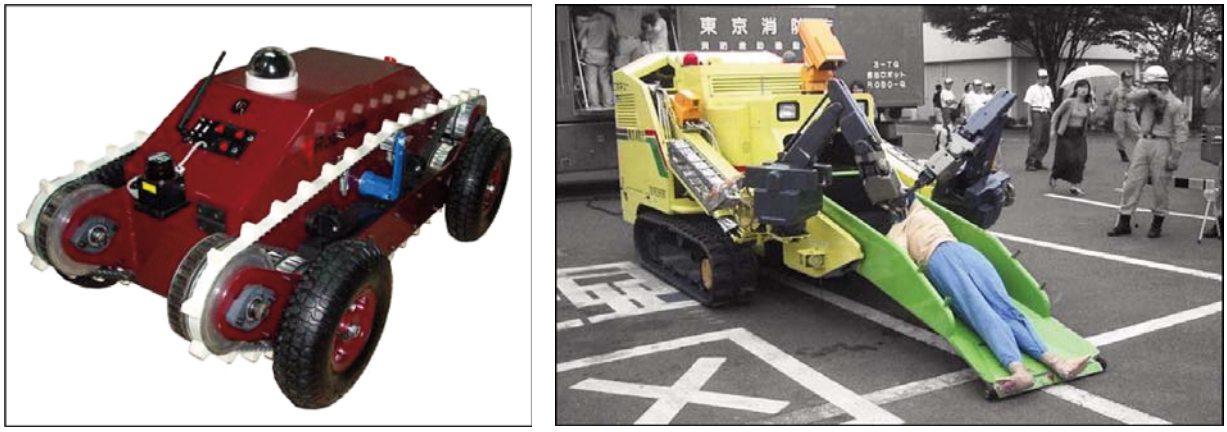


a) b)

Fig. 1 Mobile robots applied for rescue systems
a – Guardian (Robotnik Automation, Spain) [4], b – Robo-Q (Tokyo Fire Department, Japan) [5]

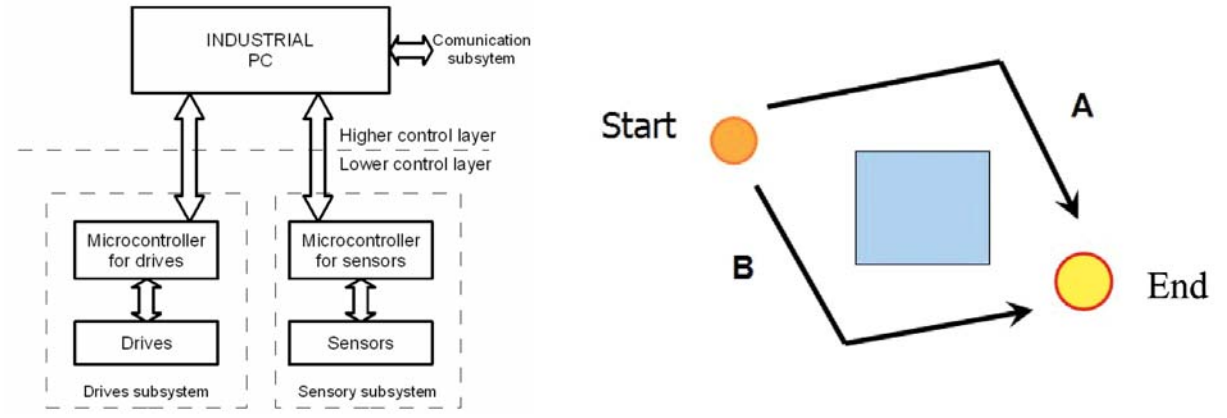
with the operator. As an optional device the system can be applied for manipulation with objects by two independent arms.

Another example of the mobile robot for the rescue systems is the Robo-Q used in firefighting (Fig. 1b). Now, it is working for the Tokyo Fire Department. This robot uses its arms to identify and pick up any people who might have passed out from the smoke and fumes generated by fires. The practical side of this robot is that firemen no longer have to run into thick smoke or chemical fumes to perform the rescue.

3. Control systems for mobile robots for application in fire protection

The control system of the mobile robot together with a control program is one of the most important parts of the mobile robot. Hardware of the control system should be able to retrieve information from the sensoric subsystem – in qualitative and also in quantitative meaning. The control program must handle and analyze this information in real time and provide the appropriate reaction of actuators. It is necessary to take into account the planned usage of the mobile robot during the selection of a suitable type of a control system – if it is a mobile robot for indoor or for outdoor environment. This leads to requirements for operating temperature, humidity and vibrations. Another requirement, which affects the concept of the control system, is also the question what the control system will monitor and handle (drives, sensors, communication with operator) – all within relatively small periods. The autonomy of the mobile robot significantly affects the final configuration of the control system where there are several possibilities. Roughly speaking, the mobile robot control system can be based on the a personal computer, industrial computer (IPC – Industrial PC) or on a microcontroller.

The control system based on a standard personal computer is not very suitable for mobile robots applied in safety and fire protection. These applications require the control system with some special characteristics (resistance to high temperature, humidity and vibrations). All of these requirements and some others can be



a) b)

Fig. 2 The basic scheme of control system for AMR (a) and path planning (b)

met using the control system based on IPC or based on the microcontroller.

Control system based on microcontroller can be developed exactly for concrete application. We can set up the number of inputs, outputs, communication interfaces, etc. Also the final size of the control system can be smaller than in case of IPC. It is necessary to use a special container for the control system. The microcontroller is not the best solution for a control system with high computing power requirements, but it is good to combine the microcontroller with IPC.

Control system based on combined architecture can provide us with advantages from both industrial PC and microcontroller (Fig. 2a). The lower control layer can control only some processes, for example, a drive subsystem or sensoric subsystem. In case of the drive subsystem, it is necessary to drive motors depending on information from the higher control level. It means to compute the parameters for a motor driver with feedback from incremental sensors using PID (Proportional Integral Derivate) algorithm which gives us higher control accuracy. The sensor subsystem based on a microcontroller processes data from sensors. The higher layer of control system then does not have to use computing power on those tasks and can work, for example, on the path planning and map building.

The navigation of AMR focuses on the three basic tasks (three key questions) which the control system of mobile robot has to solve (Fig. 2b) [3]:
- Where am I?
- Where am I going?
- How do I get there?

To answer these questions the robot has to [3]:
- have a model of the environment (given or autonomously built),
- perceive and analyze the environment,
- find its position within the environment,
- plan and execute the movement,

4. Navigation and path planning of mobile robots

The navigation strategies can be classified into several groups from the viewpoint of method of sensors' data processing, representation and type of environment and level of path planning.

At the bottom is the *pure reactive control* oriented only on obstacles avoidance when the nearest space surrounded the robot is scanned. The robot tries to detect all obstacles in front of it and avoid the collision with them. Next level is *local navigation* which solves also localization. When the robot knows the environment and it has its own map, we can speak about a tactic level of global navigation. In this case the robot can find the path between two points located somewhere in the map. The highest level is often called the strategic level of global navigation.

The selection of appropriate navigation strategy depends on required level of mobile robots autonomy, on kind of fulfilled tasks and on character and level of environments cognition. For the classical task "Safety browsing of environment" (for unknown environment) the local navigation is used whilst for the task "Coordinated movement between two points of environment" (for known environment) the global navigation is used. For complex solution of mobile robots movements control both navigation methods are therefore used (Fig. 3).

For exploring the surrounding environment the system of proximity sensors is the most commonly used. Tactile sensors are used only as a backup safety element to activate the emergency stop. Proximity detecting of obstacles may be principally based on image sensors handlers or distance measuring sensors (optical and ultrasonic). Only the combination of different processing methods and the application of various types of sensors can increase the quality of output information.

Local navigation

Local navigation is based on execution of elementary steps providing a collision-free robots path within the environment. The movement is executed without considering the global "End" position (Fig. 2b). For the local navigation data from different kinds of sensors (optical, ultrasonic) are used, most frequently in the form of the information about obstacles presence or absence in assumed course.

Global navigation

Global navigation is the control of mobile robots movement between the entered global "Start" and "End" position. In comparison with local navigation, in the case of global navigation the importance of end position is markedly greater. The basic task in

Basic functions and basic types of mobile robots' navigation Table 1.

Navigation strategies	Methods of sensors' data processing	Representation of environment	Type of environment	Level of path planning
Global navigation – strategic level *(Environment exploration)*	Environment modeling	Topological, hybrid or multilayer maps (Voronoi diagram)	Known	Planning of the path between several places
Global navigation – tactic level *(Environment exploration)*	Environment modeling	Metric or topological maps (Potential fields)	Known	Finding the path between two points
Local navigation *(Course planning)*	Localization and obstacles avoidance	Metric maps (Occupation grid)	Unknown	Course planning
Reactive control *(Obstacles avoidance)*	Obstacles avoidance	—	Unknown	—

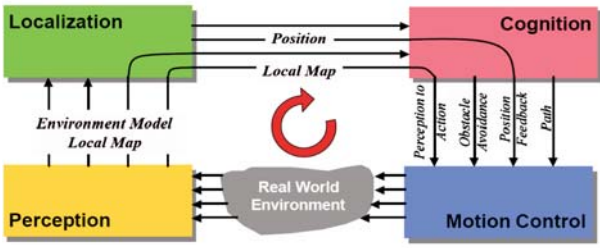


Fig. 3 Activities of mobile robot control system [8]

this case is the determination of a global path. This kind of navigation is called "the planning".

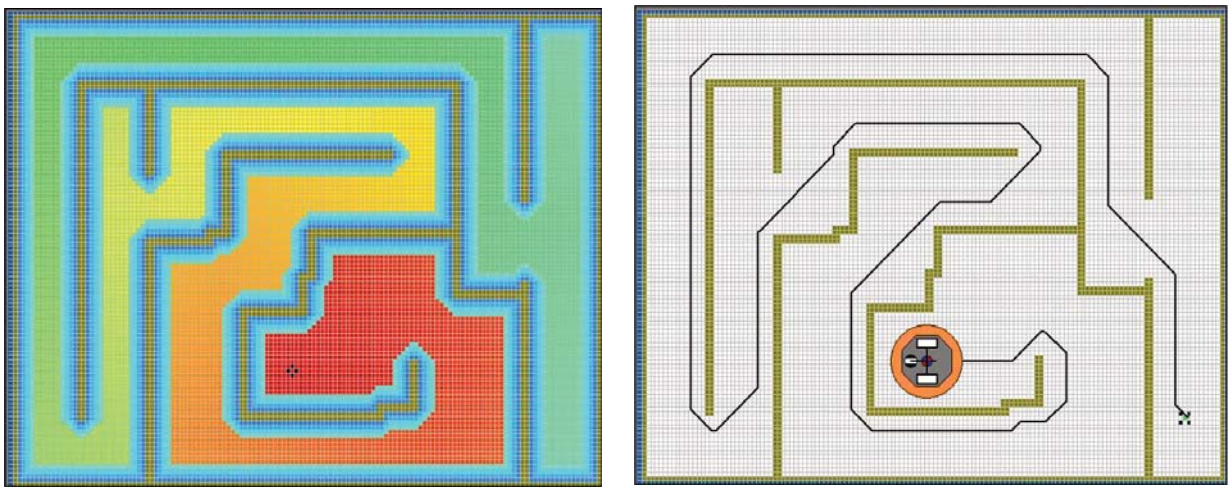
The tactic level of global navigation (the path planning) is often solved with the method of potential fields (Fig. 4), which is based on the principle of cooperation of so-called attractive and repulsive fields (or forces). Generally, the metric maps are applied for generating these fields. Specific selection is dependent on the map size, type of obstacles, etc. [2, 3, 6].

5. Maps and localization

Due to a high level of danger it is necessary to ensure a higher level of the system security. In the buildings on fire a huge problem is with the smoke and dust concentrated inside the closed rooms, so it is difficult to apply the standard method of localization and navigation. Also the connection with the human operator can be lost. Then, it is better when the robot has its own map of environment and also algorithm describing "what it must do" in emergency. When the robot loses the connection with an operator, the robot itself can find the right way. Therefore, it is important to choose an appropriate map type which will help the robot to find the right way in this case.

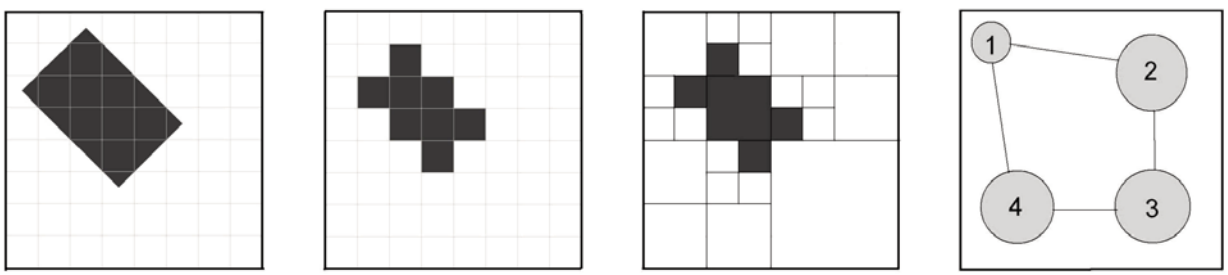
Metric maps

Objects are described by their shape and dimensions. This group is very often represented by raster maps. As an example we can consider so-called Occupancy grid, Polygonal map or the Quadtree representation (Fig. 5). The Occupancy grid looks like a grid where the columns and rows have constant width or height.



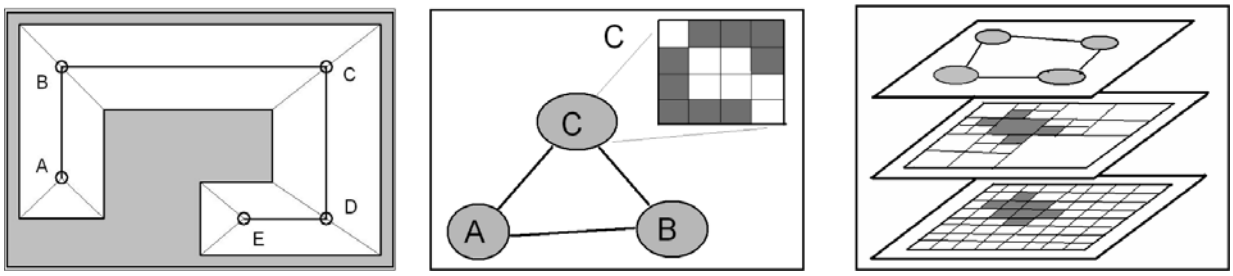
a) *b)*

Fig. 4 Methodology steps by global navigation – outputs from simulation software designed at authors workplace
a – generated final form of potential field, b – planned path



a) *b)* *c)* *d)*

Fig. 5 Representation of object O in metric (a, b, c) and topological (d) maps
a – object O (in our case "an obstacle"), b – representation of object O in 2D-raster, concretely in Occupancy grid,
c – representation of object O by Quadtree, d – representation of object O in topological map



a) b) c)

Fig. 6 Other map systems for mobile robot path planning
a – transformation of the metric map into the topological map, b – hybrid map system, c – principle of multilayer system

Each cell can get the status "obstacle" or "free cell" (in mathematical meaning for example "1" or "0"). It is easy to build a grid, but there is a problem with huge amount of data hence it is also memory space-consuming.

Topological maps

In this case the path between points are described by a graph where the nods represent the rooms or places which are important for the robot movement and the lines represent the path between these places. It leads to a smaller amount of data and smaller requirements for memory space. On the other hand, the description of space is not very precise.

To topological maps we can assign the Potential fields and also Voronoi diagrams or Generalized Voronoi diagram (GVD).

Hybrid maps

The basic structure of a workspace is described by a graph but the structure of any node is for more details described by a metric map. The whole structure provides us with the possibility to have an optimized description free of losses of sufficient resolution in important places.

Multilayer map system

Multilayer map system is based on concurrent working with several different map types. Each map is placed in one layer. It means that we have the system of different kinds of data structure and we can transform the structure of data from one layer to another one. Then it is possible to choose the most appropriate map for each task (Fig. 6).

6. Conclusion

This paper presents the current situation of mobile robots application in the field of safety and fire protection. Nowadays the application of mobile robots is very often and the number of developed robots still grows. Mobile robots are used especially in the environments, which are dangerous for human. They can be found in firefighting, bomb disposal, chemical operations, underwater operations, etc. Several concrete mobile robots are described in the paper. The second part of this paper presents different conceptions of mobile robot control systems with respect to dangerous application. The control system can be developed as a simple control system based on a microcontroller, but also as a complex control system based on industrial PC combined with PLC and microcontroller. The development of mobile robot control system depends on many factors, e.g. on environment parameters, EMI, required battery running time, computing power, operating range etc.

Acknowledgement

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Svetla Fiserova *

APPLIED ERGONOMIC METHODOLOGY FOR CURRENT ENGINEERING PRACTICE

A human factor is part and parcel of each work system. The current ergonomic methodology enables applications related to the evaluation and design of work systems that take into account both basic aspects of each work system, namely the technical and human aspects. The contribution focuses on the hierarchical classification of methods intended for the use in work systems under the conditions of current engineering practice.

1. Introduction

Ergonomics, or the study of human factors is defined by a valid international standard as the scientific discipline concerned with the study of interactions among humans and other elements of a system, and the profession that applies theoretical knowledge, principles, empirical data and methods to design orientated towards the optimization of human well-being and overall system performance [7]. Ergonomic terminology is considerably complicated by interpretation and uncertainties in the name of the discipline itself. The problem consists especially in the synonymic use of terms "ergonomics" and "human actor" or "human factor". Both these terms are worldwide adopted terms for the theory and practice of learning of human characteristics and abilities, and then using of acquired knowledge for improving interactions among people and things used by them and environments in which they do so [1].

In ergonomics, the design process, management system, methods, equipment and environment are always evaluated in relation to human abilities, capacity and human limit values. It is typical of a modern world that disciplines of present-day relevance and value are generally multi-, inter- and trans-disciplinary, and thus they cannot be defined simply [2].

A considerable number of methods so far published, i.e. more than three hundred methods, including obligatory and recommended methods, are greatly indebted to special methodological division, and do not give technicians – engineers, who carry out the optimization of work systems, a sufficient overview of possibilities of applications of ergonomic evaluation methods. With reference to the great number of methods and variety in possibilities of their application, the need appears to summarise and classify systematically the methods, above all with regard to transparency, effectiveness and significance of required applications. Under the current conditions of engineering practice, the points of view of obligation and also economical, professional and time demands play a great role.

The significance of ergonomics increases with the efficiency of applications and on the basis of correctly used methods of design and evaluation of effectiveness of ergonomic solutions. The ergonomic methodology deals with principles, procedures, methods and techniques that are at present used or can be used in analyses, designs and evaluations of machinery in relation to machinery-human interaction, analyses, designs and evaluations of work positions, work tasks, working conditions, work environment and work organisation. Requirements of modern developing companies for increasing work performance, quality and productivity and a related increase in competitiveness and better market positions are reasons for increasing the significance of correct ergonomic design and functionality of work systems.

2 Methodological Principles of Ergonomic Activities in Work Systems

For managing successfully the process of a comprehensive ergonomic evaluation and for achieving the improvement or optimization of a work system, a system approach to solving is expected. The system approach shall be applied in cases of making ergonomic analyses for current as well as new situations. In evaluations and designs basic ergonomic principles shall be always utilized for the design of optimal working conditions with regard to well-being, safety and health of workers, including the development of existing skills and the acquirement of new skills, with taking technological and economic effectiveness and efficiency into account [4].

Accepted and valid international standards are orientated towards the evaluation and design of work systems and can be

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used for other areas of human activity as well. In the process of ergonomic evaluation and design, the major interactions between or more people and the components of the work system, such as tasks, equipment, workspace and environment shall be dealt with. The process of ergonomic design of a work system can be divided into the following phases:

1. **formulation of goals (analysis of requirements),**
2. **analysis and allocation of functions,**
3. **design concept,**
4. **detailed design,**
5. **realization, implementation and validation,**
6. **evaluation.**

All the phases contain a fixed methodological framework, e.g. in the form of the detailed design it is necessary to evaluate and design individual elements of the parts of which the work system is composed. In accordance with the relevant international standard, the detailed design should be carried out so that all related ergonomic knowledge and requirements may be respected. The work system design shall include the design of the following components:

1. work organisation
2. work tasks
3. work
4. work environment
5. work equipment, hardware and software
6. workspace and workstations.

For the evaluation of quality of the design of technical components of a work system, the concept of usability provides a suitable framework, because usability covers all three categories of evaluative criteria.

Methods of evaluation in relation to evaluative criteria [3] Table 1

Category (aspect)	Evaluation methods
Health and well-being	medical, physiological, objective, subjective, psychological
Safety	reliability, errors, hazardous behaviour, near misses, accidents
Performance	quality, quantity

The ergonomic approach to the design scheme for work system optimization can be characterized by the following parameters:

a) active participation of users and clear understanding of user requirements and the given task;
b) suitable allocation of functions to users and technical resources;
c) iterative design schemes;
d) multidisciplinary design.

Ergonomic design activities are interrelated.

Ergonomically designed work systems increase safety, effectiveness and performance, improve human working and living conditions and compensate unfavourable effects on human health and performance. A good ergonomic design has thus favourable effects on a work system and human reliability in the system. The work system is based on a conception connecting operators, work equipment (including machines), workspace, work environment, work

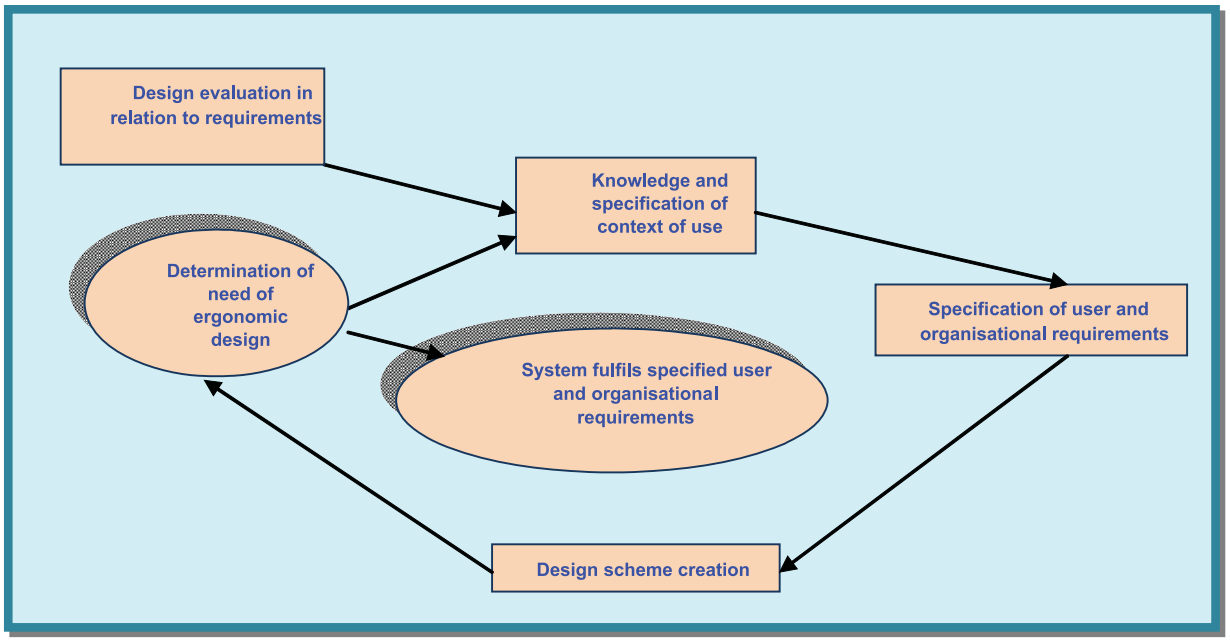

Fig. 1 Interrelations between ergonomic design activities [3]

process, work task, management and organisation and also their interrelations into one unit.

The design shall take into account the following:
1. anthropometry and biomechanics
2. mental abilities
3. displays, indicators and control actuators
4. interaction with the physical work environment
5. interaction in the work process.

Interactions among the design of machinery, design of work task and job position are of key importance to the accomplishment of goals of ergonomic activities. Work systems require high productivity and high quality and also health and safety provision [6]. The best work systems are based on the utilization of experienced employees in such job positions that are designed well and that consist of suitably designed work tasks.

3 Methods Used in Ergonomic Activities in Work Systems

Requirements for the comprehensiveness of outputs of ergonomic activities are high, and thus there is a need to systematise and structure input data on methods for these purposes so that results of ergonomic designs may be effective and may lead to work system optimization. Primarily for all ergonomic disciplines it is true that the results of evaluation are intended for the generalisation and prediction of human factor position above all from the point of view of performance, quality, safety, reliability, and for the reduction of undesirable health effects of work on humans. Subsequently, the methods also play a really critical role in the validation of obtained generalisations and predictions. Of the determination of criteria for ergonomic evaluation and the correct selection of methods, intentions and goals of applications especially in the course of the following items are decisive:

- collection of data on work systems, technologies and humans,
- system development and improvement,
- evaluation of system layouts,
- evaluation of impacts and effects of work on humans,
- cognition of why systems fail,
- development of management programmes based on the ergonomic approach.

A considerable number of modern methods of ergonomic evaluation and design are usually divided by authors according to various methodological and ergonomically logical criteria. In spite of the fact that to the processes of ergonomic evaluation, improvisational characteristics of procedures are significant, namely according to the quantity of aspects, factors, influences and interfaces in systems, to each ergonomic investigation its framework structure is of importance.

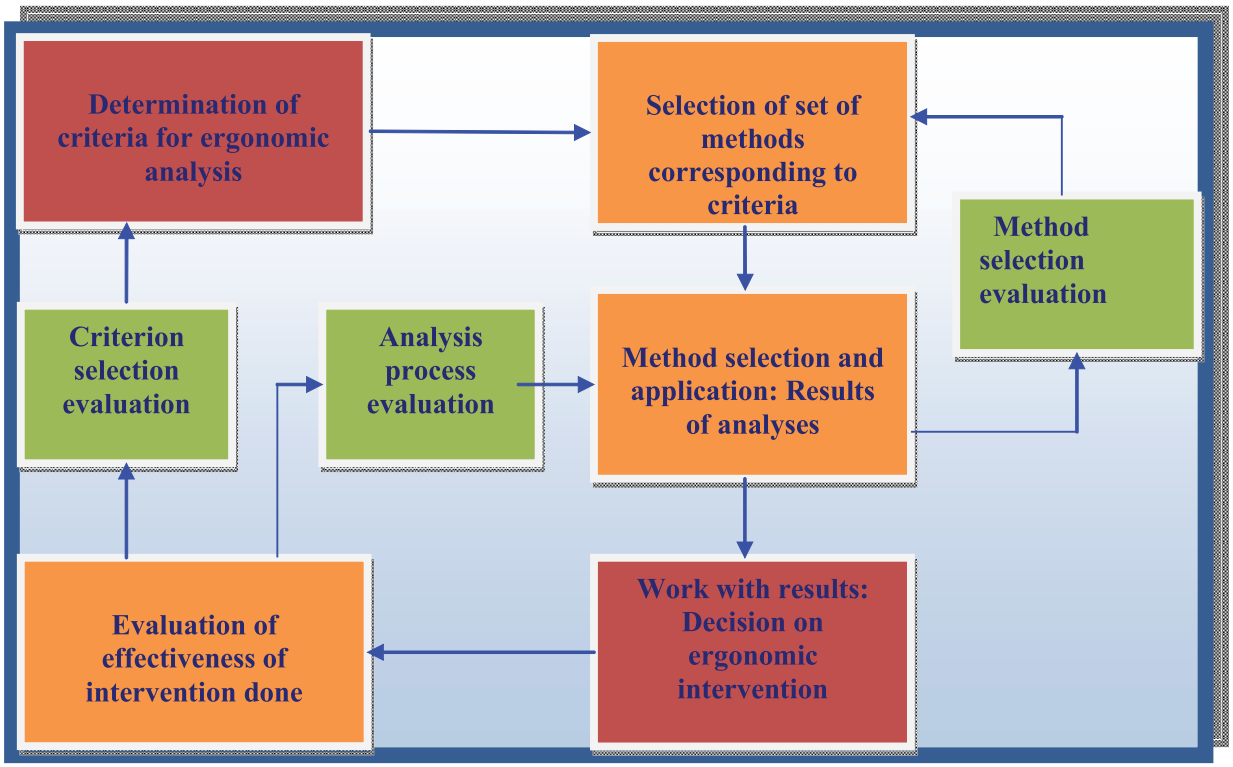

Fig. 2 Process of evaluation, method selection and ergonomic intervention [5]

The basis of the framework structure of each evaluation is the formulation of goals of investigation, study, research. What is of importance to making decisions about methods, techniques and recognition procedures is the cognition of situation under concrete conditions.

Steps leading to a successful ergonomic activity shall be, with regard to a broad basis and multidisciplinary character, systematised in accordance with the principles of ergonomic designs.

4 Classification of Ergonomic Methods according to the Hierarchy of Obligation

The great number of current methods of the ergonomic evaluation and design of work systems determines the need to systematise them so that they may be lucid and usable under the present-day modern conditions of engineering practice with high requirements for effectiveness and economic return of activities carried out.

After application of rules and principles of ergonomic evaluation and design and correct determination of priorities of ergonomic applications in work systems, subsequent dealing with the ergonomic approach is to be subject, also with reference to the availability of methods used in ergonomic activities for engineering practice, to a uniform hierarchy.

A proposal for the division of methods used in ergonomic activities for their application in engineering practice assumes and respects the hierarchy of obligation.

1. **Methods obligatory and methods necessary for the application of obligatory requirements (i.e. minimum requirements for occupational safety and health)**
2. **Methods recommended, developing obligatory requirements and contained in international standards related to the ergonomics of work systems**
3. **Methods supplementary, identifying and analysing specific areas of human activities in work systems**

4.1 Methods obligatory *and methods necessary for the application of obligatory requirements (i.e. minimum requirements for occupational safety and health)*

Methods used for health risk assessment are to be taken as the basis of all ergonomic activities in work systems. Applications of these methods that are obligatory in the range of valid legal regulations are intended especially for use in a real environment. The use of them is connected with a concrete work process with concrete work activities and tasks carried out in the framework of a characteristic working shift. Exposure assessment has become more or less an independent specialisation with its own international professional society ISEA (International Society of Exposure Assessment). The analysis of health risk factors at work is based on the systematic monitoring of all factors of work environment and working conditions from the point of view of human health load due to these factors and their possible harmful effects on occupational health and safety. It predicts a possibility of occurrence of occupational injuries, occupational diseases or other injuries to health associated with work and working conditions (e.g. diseases connected with work). Part of this activity is the evaluation of proposals for measures to limit or eliminate risks, including the check and evaluation of accepted measures. The assessment of all health risks, with some exceptions, rests on requirements for objectivity, which brings with it the fact that for the reproducibility and subsequent classification of results of evaluation it is necessary to accept the response of the "average healthy human" organism.

4.2 Methods recommended, *developing obligatory requirements and contained in international standards related to the ergonomics of work systems*

The detailed evaluation of working conditions with a view to their optimization can be made according to valid international standards so that ergonomic activities may be in accordance with generally valid rules and principles of ergonomic design. Methods contained in international standards are recommended and take into account also criteria not dealt with by obligatory regulations. It is a case of analysis procedures with respecting differences e.g. anthropometric and biomechanical, in age, etc. Work systems designed to respect also requirements and recommendations of international standards increase safety, effectiveness and efficiency, improve human working and living conditions and diminish unfavourable effects on human health and work performed. For this reason, a good ergonomic design has a favourable influence on a work system and human reliability in this system.

The recommended methods that develop obligatory requirements and are contained in international standards are in the draft classification for applications in engineering practice divided into methods intended for the assessment of:

- Machinery risks
- Human physical performance
- Human mental performance
- Human performance with regard to physical, chemical and physiological working conditions
- Human sensory performance
- Ergonomic design of control centres
- Display units and clerical work

4.3 Methods supplementary, *identifying and analysing specific areas of human activities in work systems*

The set goal in the area of optimization of work with regard to health protection, safety and reliability and also optimization of work efficiency, work quality and productivity can be achieved by applications of other suitable and selected methods that are contained neither in any regulations nor international/national stan-

dards. Their application follows from the requirements given by abilities, limits and requirements of all elements of a system [6]. Supplementary methods can be applied in any phase of ergonomic design; they do not replace either obligatory or recommended methods and can be divided into the following eleven categories:

1. **Data Collection Methods**
   Data collection methods are used for the collection of specific data related to the system and scenarios. They are basic methods for designing and planning new systems and for evaluating currently operated systems.
2. **Task Analysis Methods**
   These methods are used for analyses of human position and human role in executing tasks and scenarios in systems. Analytical methods specify tasks and scenarios (e.g. working procedures, task contents) to individual steps, for human-machine, human-human (other persons) interactions.
3. **Cognitive Task Analysis (CTA) Methods**
   CTA methods are used for the description of yet not known sets of arrangement of activities and operations. They are used in the description of mental processes of system operators in the course of completing and making up operations to be performed and their sets.
4. **Process Charting Methods**
   They are used for the graphic representation of tasks and processes by means of standardized symbols. The output of process charting methods and techniques can be a basis for the cognition and understanding of different sequences of tasks that are contained as part in the overall scenario – a detailed overview of work activities. Furthermore, they are used for the clarification of time schedules of operations that may occur and for the clarification of which technological aspects of the system and its relations are required.
5. **Human Errors Identification (HEI) Methods**
   Human error identification methods are designed for the prediction, identification of possible human errors in a work system, especially those that may occur in interaction with machinery. By the application of Human Reliability Analysis (HRA) methods is then carried out the quantification of cases of human failure in the system.
6. **Mental Workload Assessment Methods**
   A mental workload represents a level of abilities of a human to satisfy requirements imposed on the human. Quite a lot of such methods exist and they can be used widely in the assessment of processes and also in the design of them.
7. **Situation Awareness Assessment Methods**
   Situation awareness assessment methods are used for the analysis of human preparedness for situations that may occur in a system. They are used for the determination of requirements for knowledge and abilities of operators and machinery operators and are also a confrontation with the determination of target requirements for system functionality and quality of management preparedness in relation to the corresponding comprehension of formulation of individual operations and their interrelations. They are also used for planning the overall layout of the system. These techniques are used for partial as well as comprehensive evaluations of mainly dynamic systems.
8. **Interface Analysis Methods**
   Methods and techniques used for the analyses of interfaces in a system serve the evaluation and design and planning of requirements and functions of interconnections between specific elements of a system with a view to optimization, including the evaluation of e.g. employee satisfaction and consideration of employee opinion.
9. **Design Methods**
   They are the methods that are typically used in designing and planning new systems, activities and human factor relations in processes – of individuals, groups and sequences in the framework of large working teams.
10. **Performance Time Prediction Methods**
    They are used for the determination of corresponding time requirements for work operations, tasks and activities, including the creation of designs of overall detailed overviews of work activities and scenarios.
11. **Team Assessment Methods**
    They are used for the assessment of performance of groups and teams for individual activities and also overall scenarios and work images. For such assessments, a whole series of aspects is usually specified and those are later evaluated and compared. Requirements and the level of intercommunication, awareness, co-decision-making, load and co-operation are assessed.

5 Conclusion

In the framework of ergonomic evaluations of work systems, equal attention shall be paid to three basic aspects from the point of view of human position in a work system. They are the propositional aspect, task aspect and social aspect, and their interfaces. For these purposes, assuming the hierarchical process, the applications of methods intended for data collection, analytical methods and presentation methods are necessary. New technologies together with development lead on the one hand to the facilitation of some working procedures; on the other hand they bring growing requirements for the professional and also psychical abilities of employees to give expected and high-quality work performance. [8] Engineering practice usually inclines towards extensive and detailed investigations of working conditions and subsequent ergonomic interventions provided that sufficient arguments on benefits and improvements are available. Respecting the modern ergonomic principles, including the systematic classification and hierarchical analysis of selected methods can contribute to the wide use of specific ergonomic designs, which have been implemented so far only in a limited degree, in practice. Only a correctly and reliably made ergonomic evaluation, utilizing the combination of methods that are suitable and verified tools, can lead to an effective and long-term ergonomic solution in the framework of work systems.

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