HUMAN FACTOR AND ITS HANDLING

LIDSKÝ FAKTOR A JEHO ŘÍZENÍ

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ABSTRAKT
Lidský faktor je významným činitelem, na němž závisí udržitelný rozvoj. Proto článek pojednává o lidské faktoru a o jeho řízení.Ukazuje na organizační havárie, jejichž příčinami jsou lidská selhání v oblasti řízení. Na základě současných znalostí a zkušeností je proto je třeba do praxe zavést kvalifikované řízení a vypořádání rizik.
Kľúčové slová: *lidský faktor,udržitelný rozvoj, oganizační havárie, řízení rizik, vypořádání rizik*

ABSTRACT
Thehuman factor is important agent on which the sustainable development depend. Therefore, the article paper deals with the human factor and its handling. It shows organising accidents the causes of which they are human failures at management. Regarding to present knowledge and experiences it is necessara to implement into practice qualified risk management and trade-off .
Key words: *human factor, sustainable development, organising accident, risk management, trade-off with risk*

1. Introduction to problems

From daily life experiences, data and knowledge in professional publications undermentioned it follows, that situations, in which each human occurs and which each human solves in each moment, represent to him / her the necessity of doing the decision. The deciding can relate to matters that are vitally important (the change of life way and that like), or to daily details (whether to go in overfull metro / not to go in overfull metro; cross a road when the light is red / do not cross a road when the light is red and that like). Sometimes the decision takes a lot of time for deciding (e.g. while solwing the working or other problems), sometimes it is necessary to decide immediately (in the situations with a direct threatening to life, real risk of a delay and that like). We adjudicate something either on our behalf (and on ourselves, what I do, what I do not do) or on behalf of our subordinate workers / persons (in harmony with their interests, but also against their interests). The decision can be only the result of arbitrament of one person, it can, however, be also the output of collective intellect. The decisions may be accurate but also false. The consequences of decisions can have different rate of weight for both, the arbitrary subject and its vicinity.
According to data in professional literature and experiences from practice dealing with the human behaviour in different situations, the human reactions to external (also internal) inputs are very various. They can have the form of unconditioned reactions, as "automatic", inherent ways of reaction to inputs (e.g. the wince at an unpleasant input), facultative reactions (e.g. in the form of habits), or purposeful action controlled by will. In psychological literature we mostly meet with difficulties of deciding connected with will and volitional processes, thonking, purpusefull behaviour, pertinetly in connection with fight of incentives (while solving the internal conflicts). In the process of the purpuseful controll of human manners not only the deciding over a selection among the different incentives and targets is used, but also over a selection between the alternatives to negotiate – not to negotiate. The person also adjudicates at selection of means and procedures in order to reach the aim, in situaction requiring the imnterruption or the stop of activity. The capability to deal with problems correctly, prudently and in time, belongs to the basic conditions of a practical activity and creative thinking, and it is simultaneously an important component of a human personality.
According to work [1] the deciding in ordinary life is mostly short and easy. It can, however, take also very long, namely in situations in which all the alternatives among them we handle, are uncomfortable, and it heads for selection of the smallest evil. At oscillation among the alternatives it often arises that this alternative to which we have inclined, has started to decrease the attractive force as a consequence of our selection, and it comes to the deviation of the other side, where the same repeats the same. Elsewhere, the tendency to some of the possible alternatives evokes the strong troubles and the human rather stays in the stage without the decision. Such state is after some time so agonizing that its termination will become a strong motive and it

leads to a concise solution, to an arbitrary decision, if only the end might be reached. Anyone, who stays in the state without decision for too long, he / she tosses again and again all for and against, he / she fails the ability to decide normally and reasonably, the chronic neurotic conflict progresses at him / her.
At ensuring the complex safety with accent to the protection of persons and properties, it is necessary to achive the right decision or at least such decision that will not lead sooner or later to destruction, namelyin case of a decision under the stress. The decision in this concept becomes the social process. In this process there is put forward the human intellect and certain inherent (natural, tacit) human knowledge and skills. In the forefront, they act the human properties as:

- responsible approach to problem and the results of its solution regarding to the public or other assets,
- moral properties as a discernment, sense for commitment and consistency,
- the ability: to analyse the problem or situation; to take an attitude for creative approach to problem solution; to know the art of foreseen of the further development, to use analogy and the like,
- and also the capability to use experiences and social skills enabling to regulate activity and his / her behaviour or the behaviour of the subordinate humans.

Just given facts form the characteristics of a human factor of well-conditioned managemental worker and it might be considered at the work with human sources. It means that the selection of managemental workers in all organisations might be performed with the aim of respecting the knowledge, capabilities, skills and experiences, and not according to the political affiliation, colour of a coat or other subsidiary features.
Regarding to all above, the human factor is the aggregation of human properties, capabilities, experiences that have in a given situation influence on safety, productivity, effectivity and reliability of system on which which they act upon and they are evaluated from psychological, physiological and physical viewpoints.
In this work we concentrate on the human factor´s influences that are important for the safe human system [2]. If we want to reach this target, we need successfully to trade-off with risks of all kinds, i.e. also those connected with the human factor. With regard to the problems connected with building the safe world we indicate that from the viewpont of ensuring the integral safety [3], it is necessary to pay special attention to deciding the situations in which there are uncertainties and a vagueness [3,4], i.e. as a rule a little data and the result is unreliable and distinct; which means that in practice we cannot use only the deterministic and probabilistic approaches, but we must apply suitable heuristics, in which there is the role of human intellect just in progress and in which there are interconnected knowledge, experiences and intuition, i.e the human personality characteristics denoted as the human factor. The human, who has capabilities just described, is very important for each organisation and this is the root of a management type called "knowledge management".

2. Human factor

The present cognition and proposition given above show that human factor cannot be considered only as negative human manifestation. It is a present reality that positive manifestations of human factor are currently seeked by the type of system management that is directed by knowledge – knowledge management; the human with his / her ideas is considered as an inestimable human capital. Given facts mean that human is the most critical and simultaneously the most capable part of each system. Therefore, the facts on positive human manifestation are also given otherwise.

2.1. Human factor mentioned as human error / human failure

Based on the results summarised in work [5] the human error is deviation of human performance from planned, demanded or given by an ideal standard. For the majority of the 20th century the view of most organisations on a human error consisted of a statement that blame for incident / accident origination was asigned to the worker whom actions were nearly tied up with a given incident / accident - e.g. the human who operated the system in the time in which the incident originated. At present it is possible to trace down quite an opposite trend. The human is considered as a thinking being who is "left to mercy" to range of designated, organizational and momentary factors that can lead to behavior, which external observer can comprehend (even though often unqualifiedly) as human error. It is not quite simple to determine, when to incline to the variant that the error was really caused by human, and when he / she was forced by conditions. It requires

many experiences in a given field so the judge should be capable to evaluate, what happened, how it happenned and mainly what was the real cause of the incident / accident.
From the management viewpoint the failure / malfunction is a result of the process composing of:

- initiator (false operation, mistakes, violation of rules, ignorance),
- contributing effects (incorrect organisation, inaccurate deciding)
- spread of defects leading to accident (organizational non-functionality).

Because the influence of style of management and deciding is important, we speak on so called organisational accident in the form of Reason model [5], Figure 1.
Safe (including the dependable) system behaviour arises from a condition that technical workers (operation, maintenance) always proceed according to the requisite procedures (the procedure is formed from correct tasks / operations performed correctly). As the Reason model shows, the so called risky operations always occur Figure 2.
Therefore, in the risk determination it is necessary in the frame of process analysis to understand the motivation of intended acts of both, the terrorists and the insiders (actual employee). Among the insider´s motives it belongs e.g.:

- inconvenient security procedures (for a safe human live they must be skiped),
- inconvenient plans (for a safe human life the modus operandi solutions must be used),
- poor perception of security risks,
- insufficient responsibility,
- stress and management attitude or finance profit.

The insider´s motivation is directily related to a safety culture.
We separate the human factor in the sense of human error (human failure) to intentional and unintentional.
The human errors origate at both:

- the performance of activities, where their sources are: routinist behaviour; not respecting the operation and security codes; default; omission; bad health state; bad conditions on the workplace etc.,
- the management process, where their sources are: ignorance; not respecting the rightfulnesses natural, technical, economic and social; arrogance and the like).
  From the analysis of big technological accidents (e.g. Bhopal 1984, Seveso 1976, Tchernobyl 1986, Mexico City 1984, Toulouse 2001, Enschede 2000, Buncefield 2005, Lvov 2007, Mexico bay 2010 etc.) [8], it follows that damages caused by human errors in management are as a rule far higher than damages caused during the performance of activities, and therefore, in connection with the human factor the emphasis is always put on the level of safety management.

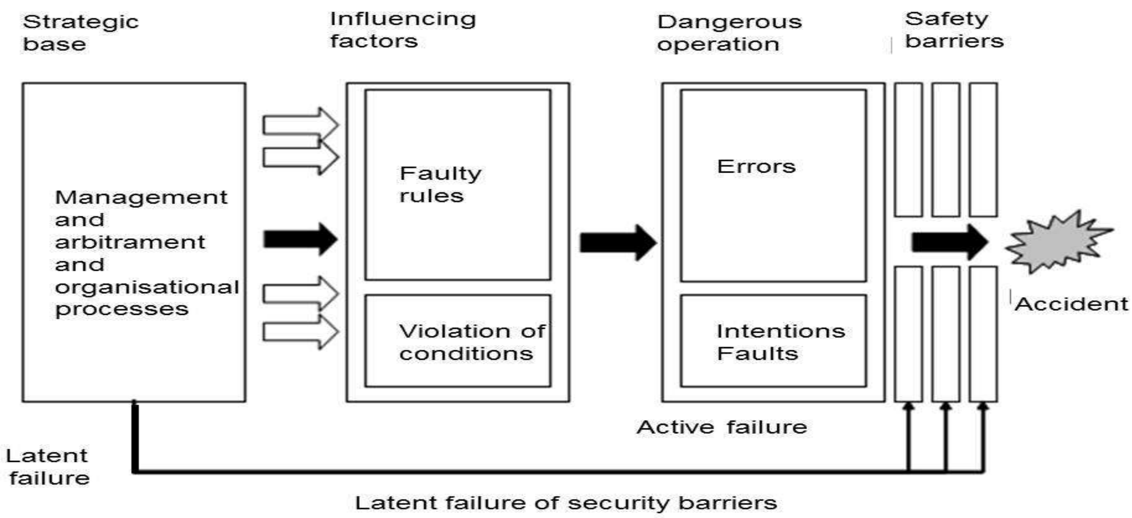

Fig. 1 - Model of organisational accident according to works [6,7]

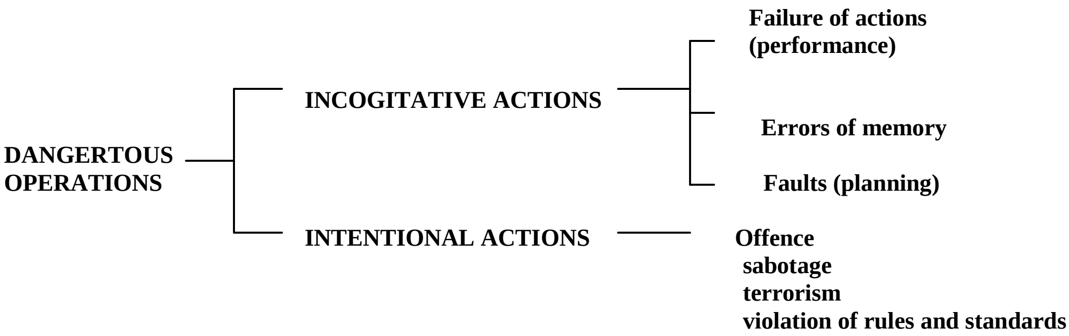

Fig. 2 - Risky operations according to work [6]

The results of the research of human factor [9-12] showed:

1. For human error analysis the procedure evaluating the human reliability and consequences of its failure "HRA - Human Reliability Assessment" is suitable. For analysis the influence of human factor is e.g. suitable the simple model SHEL (Software, Hardware, Environment¸ Liveware). Software – poor understanding the procedures; poorly writen manuals; incorrect check lists and the like. Hardware – incovenient equipment; insufficient maintenace and the like. Environment – poor working surroundings and conditions and the like. Liveware – relations on workplace, motivation, insufficient self-assertiveness and the like.
2. The analysis of a human reliability usually goes from the human error assessment. For the compilation of its models the net models are often used, i.e Bayesian, Petri and other nets. Different scenarios of human error occurrence and consequential impacts are identified, and it is determined the human error occurrence probability at real conditions. To the system of systems [3], which is human system model, it is added by this way the additional system, namely social one. Occasionally, the Fuzzy Bayesian Model is used for considering the vagueness in data.
3. At emergency situations it is important for the humans to be self-reliant and to get themselves and the others to a safe place. The self-reliance increases if humans know the content of warning instructions and if they know, how to behave. The effectivity of warning instructions is influenced by many factors – personal characteristics, form of information processing by a responsible person, social influences, indirect information and the others.
4. To the system of systems vulnerability the vulnerabilty that represent humans, i.e. the social system also contributes.

The result of the examination of incidents and accidents that runs "the error of the named real person (employee at equipment, pilot, driver and the like)", does not help at prevention of incidents and accidents, but it affects more disserviceablely, because it only shows WHERE in system the error happened, not WHY it happened there. The error caused by a human in the compex system might be:

- caused by a poor design / proposal,
- stimulated by an inaccurate training, poorly processed operating procedures, imperfect concept or eventually by the unfit processing of the operating procedures or manuals.

Such result then permits to cover the other basis causes of the incident or accident, that for such a matter must be considered at the prevention of incidents and accidents.
Reduction of risks in the framework of safety management [13] covers several spheres:

- process safety,
- protection of health and safety of an emploee (work safety),
- reduction of impacts to the environment [14].

The analysis of the impacts of management on the safety of an enterprise / plant / organisation / land (further only as "organisation") must come out, therefore, from the model of organisational accident. The

organisational accident consists from three basic elements: organisational processes; conditions that caused the origination of errors or violation of rules; and eroors and / or violation of rules [15].
Organisational processes include four processes that are part of each technical or technological organisation: projection and construction; building; operation; and maintaince. All processes are built in three interconnected activities: assignment of targets in the framework of economic and social situation of the organisation; set-up of organisation for the realisation of determined long-term strategic goals; and management of operational activities.

Each of these processes and activities forms a separate general type of failure scenario:
- determination of targets – contradictory targets,
- organisation – disproportionate arrangement (set-up),
- management – bad communication, bad planning, inappropriate inspection and monitoring,
- projection and construction - faulty projection, incorresponding barriers,
- operation – bad operational procedures, bad training and education,
- maintenance – bad maintenance plan, bad maintenance proscedures.

The conditions that caused the origination of errors are: insufficient teach-in with task; lack of time; bad separation of signal from noise; misapprehension between designer and user; inreversibility of errors; congestion by information; negative convert among tasks (bad hand over / pass of tasks); bad perception (underestimation) of risk; bad backward link from system; lack of experiences; bad instructions and procedures; insufficient check-up; unsuitable education of person for a given task; unfriendly atmosphere; and dullness and boredom.
The conditions that caused the violation of provisions and rules are: lack of safety culture in organisation; coflicts among managemental workers and emploees; bad moral; bad supervision and check-up; norms and standards permiting the violation of rules; bad perception of the sources of risk; perceptible lack of the solicitude and interest of managemental workers; low pride to own work; dab hand approach to work that stimulates to undergoing risks; belief that nothing bad can happen; low self-respect; recognised weakness; perceptible permit for the violation of rules; double-dealing, ambiguous or obviously meaningless rules; age and gender – young man execute the violation of rules.

Dangerous pursuance can be split up to errors and violation of provisions / rules:
1. The errors that become as a consequence of problems in information processes and may be comprehended in relation to the cognitional functions of an individual. They may be reduced by training, improvement of the workplaces, interfaces, better informing etc.
2. The violations of provisions / rules that are based on motivation. They are social phenomena and they can only be comprehended in connections being in a given organisation. The violation can be removed by a change of approaches, persuasion, norms, standards, moral and safety culture.

On the ground of work [10] and others in the organisation safety management system the task, how to avert the human failures is fundamentally important. In agreement with research results [9-13,16-18] it is possible to avert the human failures of activities and management if:
1. By management of professional problems only the professionals with the capability to lead the working team are authorized (they: become to be object lesson; know to explain; know to support; know to avert the bullying and the like).
2. By the qualified management of processes is ensured that projects, programs and these furthermore partial processes, the outputs of which are products, i.e. results of organisation.
3. The conditions for a qualified work are created.
4. They are provided both, the sufficient education of workers and the system of the offer of aid at the solution of complex tasks.
5. The motivation and stimulation of workes for the adherence of operationg and security provisions are ensured.
6. The in-depth supervision of processes and their interconnections to projects and furthermore also programs, that professionally and directly averts the intentional and unpremeditated errors is performed.

As it was shown above, the biggest errors originates from human errors in management. The Figure 3, processed according to work [19], shows the well-known reality that cogitative managemental workers while deciding the given matter, that is indefinite, adjudicate in the benefit of the matter, if the success probability is 0.6 (i.e. failure probability is 0.4) only in case, of:

- losses connected with decision (i.e. rights of recovery for decision in the benefit of matter, if expected result does not come) are low,
- and with the increase of losses they are more prudent.

Among managemental workers two extremes occur:

- the gamblers who adjudicate in the benefit of matter, even though possible losses are great,
- the prudential humans who adjudicate in the benefit of matter even though possible losses are low.

The gamblers occasionally reach huge profit, and therefore, they are certain ideal in human society.
The moral principles of human society conforming to the UN principles [20] give that gambling with human lives and health is inadmissible, i.e. the risk here is not permitted (tolerated). This finding might be the main principle in a selection of a personnel for activities on which the human lives depend, namely directly (drivers, pilots and the like) and indirectly (managerial workers of land, enterprises and other organisations who adjudicate the activities and measures that are directly or mediately connected with unacceptable risk for persons, property and other basic protected assets.

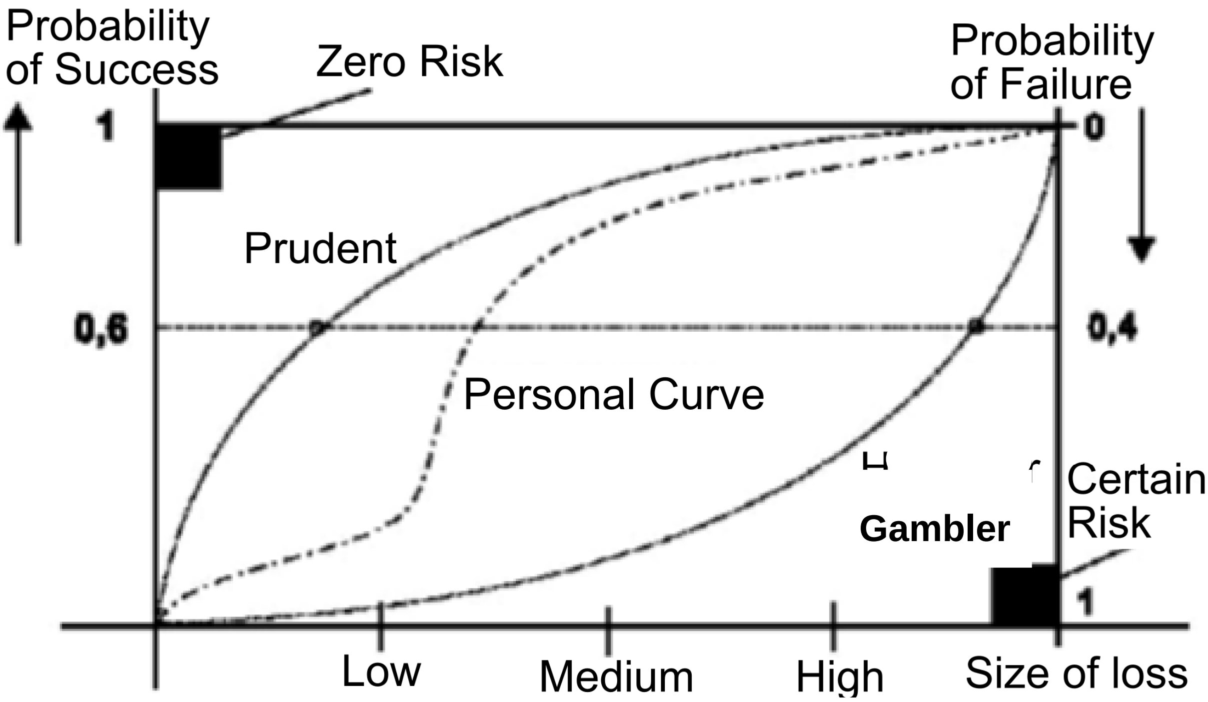

Fig. 3 - Graph delimiting the types of managemental workers at risk management

2.2. The human factor as the source of progress, development and innovation

At the analysis of complex arbitrary situations each responsible and educated person very early comprehends that human intellect is not replaceable, namely because of the lack of data, uncertainties and vagueness in data. Therefore, the discipline based on human intellect called “knowledge management” was originated. The human intellect (understanding) is the capability of a human mind to generalise the experiences, to work with abstract terms and to make conclusions from assumptions.

The basic relationship from which we go out at project and process managements is the relation among particulars, data, information and knowledge [20, 21]. Primary items are particulars in the followed object and are collected or recorded. By their evaluation and classification the data originate. By qualified data processing the information originates (the word qualified means that data mining that consists in groundless interleave of cluster of points by curves that allows PC software and in selection of curve with the smallest dispersion, is not allowed; the accent must be given on the matter-of-fact justification). By the qualified interpretation of obtained information in certain and real conditions the knowledge originates. It is necessary to perceive that affiliation with the real conditions is important. Just with the comprehension of given connections the knowledge management is inhered. The aim is not only knowledge accumulation but their rational use in practice. The examples of knowledge: method of market analysis in real situation, effective care on patients and its perfect use, design of innovation of product or service, system of effective care on clients and the like. It is evident the proximity of content of term “knowledge” with contents of terms “methods” or “algorithms”.
In security practice the tacit (inherent) knowledge is greatly appreciated. We have a lot of examples when such knowledge averts big accidents with great human losses; see work [21] and publications quoted in it.

3. Control of human factor at management and engineering

Because the human aim is to live in a safe world with the potential of development it is necessary to include the human factor into the human system safety management respecting that human system is the system of systems [3] and that it represents territory, organisation and the like. We must also include the human factor into engineering in which we realise the targets of safety management in way by which we negotiate / trade-off with risks. Because each human is an active element of a human system we must systematically build the safety culture, namely in workplaces and in territory / land [20]. All given ways are important and will be followed in next paragraphs.

3.1. Safety culture

The safety culture must be systematically built taking into account the actual piece of knowledge and experience. The appurtenant tool for its establishment is called “safety management“. In each system it represents the strategic, pro-active and process management based on the risk management and on results of science and advanced technologies. The present work deals with what is related to the human system and what ensures:

- a prevention against the disasters of all kinds, i.e. natural, technological, environmental, social and caused by interdependencies in critical infrastructure, including the terrorist attacks and the existing interactions between the human system assets and its vicinity,
- a preparedness to put all emergency and critical situations under the control with the capability to renovate the affected part of the human system,
- a response if emergency or critical situation affects the human system,
- a renewal after each emergency or critical situation.

The safety management establishing the safety culture has three basic phases:

- standard (current) management,
- emergency management,
- crisis management.

All these phases must be reasonably interconnected and must respect characteristic features and targets. The standard management is directed to build the safe community, safe territory, safe state etc. Its attention is mainly focused on the territory development, prevention and preparedness. Its main tool is a strategic planning based on knowledge, experiences and good engineering practice. The emergency management is focused on copying the emergency situations with the help of standard sources, forces and means. The crisis management is focused on copying the critical situations, human survival and stabilisation of situation so that the renewal and follow up development might be started, namely with the help of standard and beyond standard sources, forces and means, details are in [20].

To reach the security and sustainable development, the territory (including the human society of this territory) safety of must be sophistically built. In agreement with principles in [3] it means to constitute the human system safety. According to present knowledge the human system has the following assets: human lives and health; property and public welfare; environment; infra-structures and technologies; mainly the critical ones. The appropriate tool "human system safety management" is dynamic integral territory safety management", that pro-actively respects a dynamic behaviour of world [20, 21], for practical purposes in work [21] the golden rules for workplaces and territory / land are given; they facilitate daily safety management in each entity.

3.2. Negotiation / trade-off with risks

The aim of negotiation / trade-off with risk from human factor viewpoint is to give precise procedures in which there are included knowledge and experiences from practice that avert human factor failure at management and engineering.

The term "risk" has the origin in the middle Ages. There are different definitions of risk for each of several applications. The widely inconsistent and ambiguous use of the word is one of several current criticisms of the managing risk methods. Risk is the potential that a chosen action or activity (including the choice of inaction) will lead to a loss (an undesirable outcome). The notion implies that a choice of having an influence on the outcome exists (or existed). Potential losses themselves may also be called "risks". Almost any human behaviour and endeavour carries some risk, but some are much more risky than others [22, 23]. The present concept has been developed since 50s of the last century. In present practice we use three important terms: disaster, hazard and risk [24]. The hazard expresses the disaster potential to cause losses, detriments and harms on assets in a given site [3, 20]. The risk expresses the probable size of undesirable and unacceptable impacts (losses, harms and detriment) of disasters with the size of normative hazards on system assets or subsystems in a given time interval (e.g. 1 year) and a given site, i.e. it is always site specific).

Risk is a measure of the violation of monitored system security, which is a subject of possible disaster occurrence monitoring. It goes on the measure of disaster potential to disrupt security and sustainable development of monitored system. The most concise definition of risk is to use the expected loss, damage and harm on assets in a certain standardized way in order to ensure comparability (e.g., converted to area unit and time unit [3], which is used in materials for strategic management). In dependence on the specific needs [3] we determine either the risk of one disaster or of the set of all disasters, which can affect the real object reference. In determining the risk either one asset is considered and partial risk is determined, or complex assets are considered and integrated or integral risk is determined. Integrated risk only represents a certain aggregation of partial risks, which is usually determined by norms or standards. The integral risk includes both, the risks associated with individual assets and the cross-cutting risks that are associated with links among the assets and with the couplings among the assets realized by flows (energy, information, instructions, commands, responses to them from top to bottom and vice versa), i.e. it represents a complex risk for the qualified management of which provides the integral safety.

In the safety management system (shortly SMS) concepts we consider two cases, namely either the risk realisation is still substantially the same or it is significantly different. In the first case, we consider from safety reasons either the worst case (such approach is found in standards based on a deterministic approach to safety provision) or we admit random uncertainties resulting from the momentary local and temporal conditions of assets and as a representative variable for risk management we use the mean value obtained by evaluating the possible alternatives (arithmetic mean, median, median + σ, where σ is the standard deviation, the probable mean value). The other procedure is now commonly considered in the preparation of documents for strategic management (the alternative scenarios for the risk realisation and their occurrence probabilities are determined; and the mean and its dispersion are derived from them by a clear mathematical approach); we can find it in the norms and standards based on a probabilistic approach. In cases when we take into account the existence of vagueness in data we must use the combination of analytical and heuristic approaches that offers different theories, e.g. extreme values theory, fuzzy set theory, fractal theory, dynamic chaos theory, selected expert methods, suitable heuristics [3,4] and the recent theory of evidence [25, 26].

The risk partly depends on the hazard and partly on the vulnerability of assets in a given site (i.e. on the sensitivity of each individual asset in a given place against to the physical manifestation of a disaster in a given site). It expresses a possibility what it might be happen. From this fact it follows that for each management it is important to know the risk, namely in comprehensible expression. In practice of public administration management it is certified that the risk expression in a form that by risk analysis and assessment it was find that on specific section:

- 5 million EURs a year is necessary for the remedy of harms caused by existing risk,
- each ten years ten persons die as a consequence of a given disaster,
- each five years the property damages caused by disaster exceed 5 billion EURs etc.

Methods of the determination of a risk size respect both, the nature of phenomena, which are their sources (i.e. characteristics and physical nature of disasters) and the parameters of medium in which phenomena impacts affect. There are used methods based on the mathematical statistics, fuzzy sets, approaches of operational analysis etc., that inherently assume the certain model of phenomena occurrence, i.e. they do not permit that these phenomena are extraordinary, and methods based on scenarios that are simulated or empirically obtained, see data in work [4]. In principle we can split up two basis approaches, namely:

1. Determination of hazard from disaster *H* and return period t (in years) is performed by methods based on the theory of large numbers, theory of extremes, theory of fuzzy sets, theory of chaos, theory of fractals etc. [3]. According to site vulnerability in an investigated land (e.g. around a given site: square 10 x 10 km; circle with radius of 5 km) the whole damage on all assets is determined for the *H* denoted by *S*, usually expressed in money. Risk *R* connected with the given disaster in a given site is determined by the relation

   $$R = S / \tau$$

   The result is very clear: e.g. “the risk from a given disaster in a given site is X EURs and for town it is MX EURs”.
2. Determination of disaster scenario for the disaster with size corresponding to maximum expected disaster (it is possible with regard to demands of norms to use the probable size of expected disaster, or the value of standard size of determined disaster or at least unfavourable disaster) is performed; the exact scenario compilation methods [4 are used]. According to data for a given land it is determined:

- the value of whole damage on all assets in affected area SS (the method for SS determination is described in [24] usually expressed in money according to amount of assets and their vulnerability to impacts of a followed disaster in the affected area, usually normalised to a certain land unit S,
- the occurrence frequency of maximum expected disaster normalised to 1 year f according to the professional data from databases or expert opinions. Risk R is given by relation

$$R = S * f$$

The result is in the same form as in the foregoing case. This case is often used for technological and other disasters for which we have not good long-term catalogue (this shortage the EU want to remove by paying the special attention to the compilation of the MARS database [3].

From the facts given above, it is evident that risk value determined is related to a certain land unit and time unit. We say that the risk is a site specific quantity. If we can negotiate / trade-off with risk we must know the risk size and at its determination we must respect all assets and their interfaces as they are shown in Figure 4. Because the human system is the SoS (system of systems / systems system), we must respect this character and we must consider also cross-section risks, i.e. we must determine the integral risk. For such risk form we do not have a simple formula respecting all human system public assets because interdependences causing cross-section risks are site specific [3]. They cause that the problem is non-linear, non-regular and is very complex.

The risk is for engineering practice expressed as the probable size of losses, damages and harms on followed assets that are caused by a given disaster with specified size and that are rescheduled for a certain time unit (usually 1 year) and a certain territory unit that is in agreement with the EU standard under preparation [23, 27]. At advisement in practice we distinguish whether the risk realisation goes on steadily by the same way or variously in dependence on the immediate site and time conditions of assets. In the first case we determine a sort of a mean value, and its validity for use in practice which is connected with the condition of its determination for much worst case (we can find this case in the norms and standards based on deterministic approach). The second case corresponds to a variable reality - there are determined the variant scenarios of risk realisation and their occurrence probabilities; from these data by a clear mathematical approach the mean value and its dispersion are determined (we can find it in the norms and standards based on probabilistic approach). At present practice for complex cases the precisely defined heuristic procedures [3] are used and are considered at the preparation of groundwork for strategic management.

The principal attributes of each risk are ***uncertainty and vagueness***. We divide their sources into three groups, namely to variations originating at: usual system process life cycle at normal conditions in the vicinity (uncertainties); real changes of system process life cycle in the time and space that affects occasional extreme values occurrences – we consider normal and abnormal conditions - (uncertainties and vagueness); variable system process life cycle that is caused by process changes in the time and space induced by outside causes or by critical conditions (vagueness).

The data uncertainty relates to the dispersion of observations and measurement. It may be included into assessment and prediction by mathematic statistics apparatus. The vagueness relates to both, the lack of knowledge and information and the natural variability of processes and actions that caused disasters. For processing the vagueness the mathematic statistics apparatus in insufficient and , therefore, it is necessary to use recent mathematical apparatus that offers e.g. extreme values theory, fuzzy set theory, fractal theory, dynamic chaos theory, selected expert methods and suitable heuristics [4].

The data vagueness follows from the reality that data are incomplete, inhomogeneous (i.e. their accuracy depends on their size or on the time of their occurrence) and non-stationary, i.e. data have massive dispersion and are encumbered by random and sometimes also by systematic errors, the distribution functions of which cannot be usually determined. Because, nothing is absolutely precise, we must generally considered data uncertainties and vagueness at each quantity that we investigate. Therefore, both the safety engineering and the risk engineering require in order that the quality of data set ought to be verified from the viewpoint of their credibility with regard to a given task.

3.2.1. Risk management and safety management

Strategy of management for ensuring the security and sustainable development of managed subject consists in negotiation with risks [24, 28]. In its frame according to present possibilities of human society we apply several ways of dealing with risk:

- part of the risk is reduced, i.e. by preventive measures the risk realisation is averted,
- part of the risk is mitigated, i.e. by preventive measures, activities and by preparedness (warning systems and another measures of emergency and crisis management) non-acceptable impacts are reduced or averted,
- part of the risk is re-insured,
- part of the risk for which there are prepared resources for response and renovation,
- part of the risk for which there is prepared contingency plan, i.e. it is used for a part of the risk that is non-ontrollable or too expensive or low frequent.

To this it is joined the distribution of risk defeating among all stakeholders [26]. The distribution in good governance is performed according to rule that all stakeholders have responsibility for the risk defeat and that the defeat of a real risk is assigned to a subject the preparedness of whom is the best.

In practice two risk management models are usually used:

- classical risk management [3],
- safety management, i.e. risk governance for security and sustainable development [3].

3.2.2. Risk engineering, security engineering and safety engineering

The risk engineering was the 20th century phenomenon and on its base there was set up the groundwork for human development in developed countries that is quite resistant against the traditional disasters, namely natural ones; human, animal and plant diseases; technology failures; and social disasters. According to definitions used by the UN, Swiss Re, World Bank etc. the risk engineering:

- is the systematic use of engineering knowledge and experiences for the optimization of protection of human lives, environment, property and economic assets, i.e. for the optimum reach of security and sustainable development of human system,
- has a main purpose to reduce all types of harms and losses by the means of aimed and qualified risk management.

It is necessary to note that at present practice the risk engineering has not been interpreted yet by explicit way.

The original risk engineering is lean on risk management and it seeks the problem solving by way that it step by step considers individual disasters and it requires to cope with all the risks the occurrence probability of which is greater or equal to 0.05. It usually includes only disasters the sources of which are within the investigated system, it often solves only the technical aspects of a problem; and the human factor problems are only included in the later version from 80s of the last century, Figure 4.

The aim of the original risk engineering has been to reduce the risks of technical systems connected with the internal sources of risks. As it was given above for practical purposes the risk has been expressed as a probable size of losses, harms and detriments of followed assets that caused a given disaster with the specified size that is calculated for a certain time unit (usually 1 year) and a certain territory unit. At risk calculation we distinguish whether the risk realisation develops forever identically or differently in dependence on the momentary local and time asset conditions. In the first case we determine a kind of a mean risk value and its validity for the use in practice we connect with condition that the less unfavourable case is considered (the given approach is in norms and standards based on deterministic approach). The other case corresponds better to reality, and therefore it is considered at the groundwork preparation for strategic management directed to safety. There are determined variant scenarios of risk realisation and their occurrence probabilities; from these the mean value and its dispersion are determined by clear mathematical procedure (the given approach is in norms and standards based on stochastic approach). The actual reality, however, is more complicated because as it was given above the data have uncertainties and vagueness that connect with the variability of conditions in the time and space. At present exactly defined heuristic procedures [3] are used.

The advanced risk engineering disciplines, i.e. original engineering disciplines directed to safety, considered the consequences of human errors but they did not investigate their causes. The systematic elimination of human errors was included into engineering disciplines in the middle of 80s as the reaction to the Chernobyl accident [20].

During the last 30 years there were produced two engineering disciplines based on risk management and directed to ensure the security for system and later on the security of system and its vicinity:

1. The discipline “security engineering” has the aim in order that each individual system (technical or another nature) may be in security with regard to the internal and external risk sources [29]. The vicinity security is out of its interest. It is applied at e.g. the provision of bank information systems, boundaries, cyber networks against attacks, specific facilities etc. Because it does not solve the system vicinity the conflicts with other systems being in neighbourhood originate and they are heavily solved.
2. The discipline “safety engineering” has the aim in order that each technical system produced by human and implemented into human system might be the source of non-acceptable risks neither in technical system nor in human system [30]. Therefore, it deals with a technical system and its vicinity, namely during its whole life cycle, i.e. it does not only solve system technical problems but it also respects pubic assets (human lives and health, welfare, property, environment and neighbourhood facilities and infrastructures). It inherently includes coexistence of varied systems [31]. It is used in connection with nuclear, chemical and similar facilities, aerospace transport, hazardous substances transport etc. It is necessary to note that it inherently also includes the environment protection [20] and its conflicts with orthodox ecologists as a rule comes from knowledge deficiency and from the insufficient capability of a certain ecologist group to comprehend priorities that the human must applies for his / her survival at strategic territory management.

It is evident that the aims of the second discipline are broader and more ambitious, and therefore, their achievement is substantially challenging that in the first discipline. Both disciplines in recent form include the risks connected with the human factor.

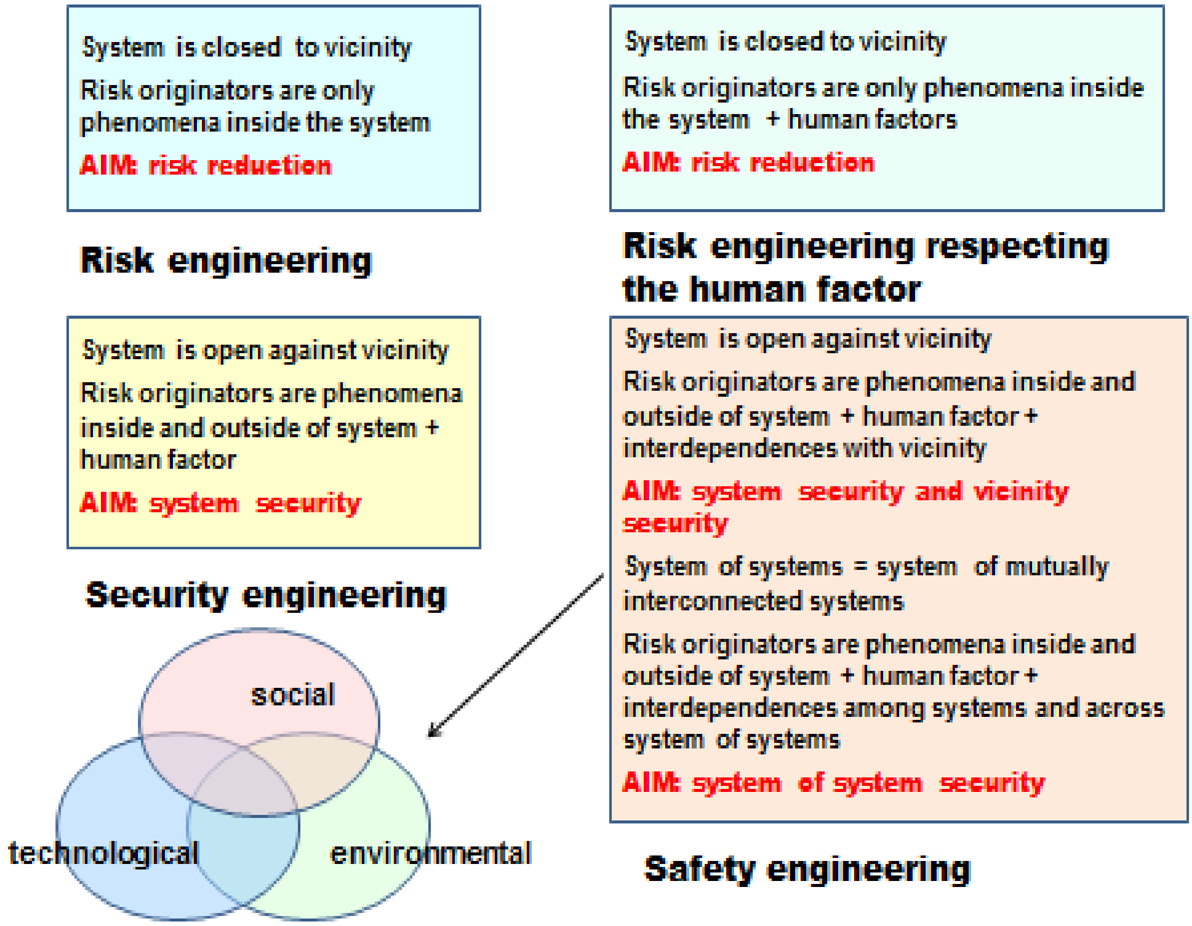

Fig. 4 - Engineering types considering the risk

The key concepts of present engineering directed to safety are:
1. The approaches are based on risk – the work intensity and documentation is adequate to risk level.
2. The professional approach is based on reality that only the critical attributes of quality and the critical parameters of process are considered.
3. The problem solution is oriented to critical items – the critical aspects of technical systems ensuring the consistence of system operations are followed and managed.
4. Verified quality parameters are included in the project proposal.
5. The accent on quality engineering procedures – it must be proved the accuracy of selected procedures under given conditions.
6. The aim of a safety upgrade – permanent improving the processes with a use of analysis of the root causes of malfunctions and failures.

From given facts it follows that considered engineering types are multidisciplinary and interdisciplinary disciplines, and therefore, they use very various methods, tools and techniques because the safety management targets cannot be reached only technically and or by mastery, but the methods, tools and techniques respecting the data logic, technological, financial, managerial and decision-making must be used, because their integral part is the decision-making over technical problems, human factor, costs and time planning.
In practice the system security (the security of system) is reached by tool security engineering [29]. High-powered tool represented by the engineering of the safety called "safety engineering" does not deal only with technical problems but it respects public assets in the system vicinity. It is a branch applying the methods, tools and techniques and it is based on engineering and managing approaches by way in order that the system might

be safe for all public assets during their whole life cycles [30]. The both engineering type predecessor was the risk engineering the standards and norms of which started to be developed in the middle of the last century [3, 15, 29, 30].
In the original risk engineering there were, for risk determination used further given principles: risk was determined after the design of the system; risk determination was directed to a level of system and its components, i.e. there was not considered outer vicinity and the protection of public assets; there were only required the knowledge of system and processes, i.e. there were not required the knowledge of outer vicinity and protection of public assets; and if the risk existed then it was determined and solved but with the lack of the possibility to remove the risks connected with an inappropriate solution for a given site and system.
The risk engineering leans on risk management and it searches the problem solution by way that it individually considers disaster after disaster and requires coping all the risks the occurrence probability of which is equal or higher than 0.05. Usually it only includes disasters the sources of which are within the system and hence it very often only solves technical aspects of the problem [20].
The comprehended safety management is particularly marked from the risk management viewpoint by these characters: sitting – designing – construction – project with risk reduction; operation with the integration of early warning systems and of procedures for the management of acceptable level of risks; and defeating the abnormal, emergency and critical conditions at the operation and at putting out of the operation [29, 30].

The advanced safety engineering uses at risk determination the following principles:
- risk is determined during the given system whole life cycle, i.e. at sitting, designing, building, operation and putting out of operation, and eventually at territory bringing in original condition,
- the risk determination is directed to user's demands and to the level of provided services,
- risk is determined according to the criticality of impacts on processes, provided services and on assets that are determined by public interest,
- unacceptable risks are mitigated by tool for risk management, i.e. according to technical and organisational proposals, by standardisation of operating procedures or by automatable check-up.

The safety engineering leans on risk management from all possible disasters at a stroke and it searches an optimum problem solution applying the All Hazard Approach [32] (i.e. it considers all possible disasters without respecting whether their sources are within or outside a given system and it uses the precaution principle). It uses tool "safety management", i.e. risk management supporting the human system security in which it is also included sustainable system development. In technical slang we tell that safety management forms inherent safety of human system against the design disasters and by implementation of precaution principle we upgrade resistance against the unacceptable impacts of beyond design disasters the occurrence of which is so low probable that it is unforeseeable [20]. In practice there are introduced principles as fail safe; carry out only determined functions, i.e. if you cannot fulfil the aim, do not do anything etc.

The key concepts of safety engineering are:
1. The approach to a problem is based on the risk with a rule that the intensity of work and documentation are adequate to the risk level.
2. In the professional procedure respecting the solved problem logic there must be considered the critical attributes of quality and critical parameters of process.
3. The problem solution is directed to critical items, i.e. the topics are monitored and it is performed the management of critical aspects of technical systems ensuring the operation consistence of systems.
4. Certified parameters of quality must be included in the project proposal for the problem solving.
5. It puts emphasis on quality engineering procedures which means that the correctness of selected procedures in given conditions must be demonstrated.
6. During the whole life cycle there is the aim of a safety upgrade (by the help of safety management systems), i.e. it goes on continually improving the processes with a use of analysis of the root causes of defects and failures.

For respecting of the principles given above, there must be used relevant data sets and only verified methods that provide outputs with a designated testified competence. Because in the group of cases there is not well coped with vagueness in data, in practice there are used the procedures designated as good practice

procedures / good engineering practice procedures. Modus operandi procedures in individual domains go on that on the basis of experience lead to a good result. The given procedure is used in cases in which there was not approved any unified procedure. It is often used at measurements in laboratories, negotiation with humans etc.
Owing to a lot of factors, including the human factor, influencing the problem solving at real conditions exist; and these factors are not only random but also epistemistic, the measures, activities and procedures denoted as good engineering practice are typical for engineering disciplines.
Good engineering practice (good engineering procedure) is then defined as a set of engineering methods and standards that are used during the life cycle of technical system with the aim of reaching the appropriate and cost- efficient solution. It is supported by fit documentation (conceptual documentation, diagrams, charts, manuals, testing reports etc.).

In a given context the engineering expertise is the expression of the capability to:
- apply the knowledge of mathematics, science and engineering,
- propose and realize experiments,
- analyse and interpret data,
- propose components or the whole system according to requirements and under the frame of realistic limitations identify, formulate and solve engineering problems,
- ensure the effective communication,
- comprehend the impacts of engineering solutions in a broader context,
- use the advanced tools and methods in engineering practice,
- adhere professional and operational responsibilities and ethics,
- lead the interdisciplinary team.

Most of the demands give above is directed to correct the human factor negative manifestation.

Based on the knowledge of the past decade, it is necessary to admit when considering the risk realisation, that in addition to random uncertainties, there exists also knowledge (epistemic) uncertainties, i.e. vagueness in the data. By admitting the other uncertainty type existence we de facto admit the existence of significant changes in the process of risk realisation, which go significantly beyond the simple effects of random changes. Thus in recent years, the approaches of theory of possibilities, i.e. Dempster - Shafer theory [25, 26] have been introduced into practice for modelling the safety and reliability. It assumes that the available data and our knowledge have vagueness, i.e. they contain knowledge (epistemic) uncertainties in addition to random uncertainties. Using this theory, the variants corresponding to different processes are modelled, what is possible due to knowledge shortcomings. Of these, optimum variant is selected. For selecting the options service of experts is used and calculations are combined with the best practices. The practice has shown that one expert is not enough, but that it is necessary to combine the knowledge of several experts. Such a combination can be ensured by analytical methods or heuristics, such as DELPHI, panel discussion [4].

4. Conclusion

For human safety and for human system safety (i.e. territory, organisation, plant) we must manage the integral risk including the human factor, i.e. to find the way of cross-section risks management and to concentrate the investigation on interdependences and critical spots with a potential to start the system cascade failures, and on the basis of such site knowledge to prepare measures and activities ensuring the continuity of limited infrastructure operation and the human survival.

Considering the critical present knowledge evaluation, we recognised that one from causes of interdependences inducing the failure cascades in human system or in its parts is the human error (intentional or unintentional) in management. Therefore, in both, the managemental activities and the engineering activities we must do all procurations with aim to avert human failure, especially at the decision-making. Because consequences caused at decision making are often huge, the human failure causes at managemental level are in detail given above.

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