Results of Selected Methods Evaluation
Výsledky hodnocení vybraných metod

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Abstract
The paper contains results of test of methods, mainly those
determined for stimulation of creative thinking, derived in different
disciplines for domain of safety and security. The systematic
research was done under the project FOCUS.

Abstrakt
Článek obsahuje výsledky testu metod, zejména metod určených
pro stimulaci kreativního myšlení, získaných v různých oborech
pro oblast bezpečnosti. Systematický výzkum byl prováděn v rámci
projektu FOCUS.

Introduction
Safety and security connected with human system and its assets
are new topics of research. They represent multi-disciplinary and
interdisciplinary fields of science. The FOCUS Project [1] should
provide a research to support the safety of Europe in order to allow
EU to cope with its future role in the response to future challenges
that are associated with the globalization of risks, threats and
vulnerabilities. In order that it may fulfill the topic it had to solve
problems. For each problem solution there are necessary methods,
tools and techniques. Therefore, the second project work package
was directed to methodology assessment.

Procedure
Because safety and security domains are new topics of
research, they have not got original methodological base yet. By
brainstorming the experts collected in the FOCUS project selected
methods derived in different research disciplines that are important
for compilation of scenarios and concepts in safety and security
domain [1]. Therefore, the attention was concentrated to methods
determined for stimulation of creative thinking. According to
rules of technology transfer it is necessary at application any
methodology in quite different domain to verify conditions of
technology transfer. The procedure of method evaluation consists
in two tests. The first one represented the theoretical verification of
both, the method assumptions and the technological transfer
conditions, and the other represented experimental verification; it
used specially collected data set from followed domains; hundred
experimental examples specially collected is in Archive of FOCUS
project [2].

Results of test of selected methods
The selected methods, tools and techniques that have been
derived in frame of problem solutions in other multi-disciplinary
and interdisciplinary fields were investigated in detail by analysis
of theoretical background and by test with use of data from safety
and security domains with aim to find out their applicability in
domains under account. The real results of methods' research are
in the following table.

Table - Outputs of research of selected methods from the viewpoint
of their application in domain of safety and security.

<table>
<thead>
<tr>
<th>Method, tool, technique</th>
<th>Way of use, principals for use, shortages at use</th>
<th>Evidence/proof</th>
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<tbody>
<tr>
<td>Case study</td>
<td>Solution of non-structure problems - critical items are knowledge of experts on problem and its context. In management and engineering the safety and security the case study was verified by real data for use in following tasks: problem structure and problem context identification; forecast of scenarios/variants/alternatives; and selection of acceptable variant from the experience viewpoint.</td>
<td>[2-4]</td>
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<td>SWOT analysis</td>
<td>Solution of non-structure problems - critical items are knowledge of experts on problem and its context. In management and engineering the safety and security the SWOT analysis was verified by real data for use in following tasks: understanding the problem; understanding the problem context; understanding the problem structure; as the source material for formation of variants of future development and for selection of optimum variant for problem solution.</td>
<td>[2-4]</td>
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<tr>
<td>DELPHI method</td>
<td>Solution of non-structure problems - critical items are knowledge of experts on problem and its context. In management and engineering the safety and security the DELPHI method was verified by real data for use in following tasks: understanding the problem; determining the problem context; determining the problem structure; determining the basis parameters of problem - e.g. occurrence probability of some phenomena; determining the process variants connected with the process manifestation; determining the occurrence probability of process variants; and determining the most probable process variant etc.</td>
<td>[2-4]</td>
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<tr>
<td>Theory of extreme values</td>
<td>Solution of structure problems. In management and engineering the safety and security the theory of extreme values was verified by real data for use in following tasks: determination of size of critical disasters that can be expected in disaster focal region; determination of return period for the given disaster size; and determining the disaster scenario either by processing the empirical scenarios corresponding to disaster with a given size or by simulation based on physical disaster characteristics.</td>
<td>[2-4]</td>
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<tr>
<td>Multi-attribute utility theory (MUT) - version TIEQ</td>
<td>Solutions of non-structure complex problems - critical items are knowledge of experts on problem and its context. In management and engineering the safety and security the multi-attribute utility theory (MUT) - version TIEQ was verified by real data for use in following tasks: identification of tasks important for problems' solving; determination of problem structure according to criteria from domain of safety, economy, environment and social (fundament for decision support systems); and selection of optimum variant of problem solved. Results can be used for prognosis of future behaviour of system under account if data on problem development are specially prepared in time series.</td>
<td>[2-4]</td>
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<tr>
<td>Methods of operation research (CPM, PERT, GERT, PETRI NETS, BAYESEON NETS)</td>
<td>Solutions of non-structure complex problems - critical items are knowledge of experts on problem and its context. The application of operation research methods has the following features: problem situation is closed system or the links to vicinity are precisely defined; problem situation is represented by mathematical model; at calculation the computation technique does not insert the human behaviour. The solution is in motion in the following stages: problem formulation; model construction; solution of problem on model; analysis of solution and corrections; and implementation. The methodological shortages are: high complexity of models; and solution that cannot be implemented. In management and engineering the safety and security the methods of operation research (CPM, PERT, GERT, PETRI NETS, BAYESEON NETS) were verified by real data for use in following tasks: identification of problems; determination of problem structure according to criteria from domain of safety, economy, environment and social; determination of problem solving variants and selection of optimum variant of problem solved; support for decision-making - i.e. retrieval of optimum results for given conditions. [2-4]</td>
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<td>Analytical hierarchy process (AHP)</td>
<td>Solution of non-structure problems - critical items are knowledge of experts on problem and its context. Decision situations to which the AHP can be applied include: - Choice - The selection of one alternative (variant) from a given set of alternatives, usually where there is multiple decision criteria involved. - Ranking - Putting a set of alternatives in order from most to least desirable. - Prioritization - Determining the relative merit of members of a set of alternatives, as opposed to selecting a single one or merely ranking them. - Resource allocation - Apportioning resources among a set of alternatives. - Benchmarking - Comparing the processes in one's own organization with those of other best-of-breed organizations. - Quality management - Dealing with the multidimensional aspects of quality and quality improvement. - Conflict resolution - Settling disputes between parties with apparently incompatible goals or positions. In management and engineering the safety and security the AHP was verified by real data for use in following tasks: determination of problem structure; results for individual levels of problem in selected hierarchy; and aggregate result for the whole. [2-4]</td>
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<td>Methods based on process models - especially methods for risk assessment, risk management, risk engineering and complex methodology for negotiation with disaster risk</td>
<td>Solution of both, the structure and the non-structure problems. In case of non-structure problems - critical items are knowledge of experts on problem and its context. Process model is used in various contexts. For example, in process modelling, in strategic planning etc., e.g. the enterprise process model is often referred to as the business process model. Process models are core concepts in the discipline of process engineering. The process models are processes of the same nature that are classified together into a model. Thus, a process model is a description of a process at the type level. The targets of a process model are to be descriptive, prescriptive and explanatory. The descriptive ones are to: track what actually happens during a process; and take the point of view of an external observer who looks at the way a process has been performed and determines the improvements that must be made to make it perform more effectively or efficiently. [2-4]</td>
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The prescriptive ones are to: define the desired processes and how they should/could/might be performed; and establish rules, guidelines, and behaviour patterns which, if followed, would lead to the desired process performance. They can range from strict enforcement to flexible guidance. The explanatory ones are to: provide explanations about the rationale of processes; explore and evaluate the several possible courses of action based on rational arguments; establish an explicit link between processes and the requirements that the model needs to fulfill; and predefines points at which data can be extracted for reporting purposes. From a theoretical point of view, the meta-process modelling explains the key concepts needed to describe what happens in the development process, on what, when it happens, and why. There are following types of coverage where the term process model has been defined differently: - **Activity-oriented**: related set of activities conducted for the specific purpose of product definition; a set of partially ordered steps intended to reach a goal. - **Product-oriented**: series of activities that cause sensitive product transformations to reach the desired product. - **Decision-oriented**: set of related decisions conducted for the specific purpose of product definition. - **Context-oriented**: sequence of contexts causing successive product transformations under the influence of a decision taken in a context. - **Strategy-oriented**: allow building models representing multi-approach processes and plan different possible ways to elaborate the product based on the notion of intention and strategy. Risk assessment, risk management and risk engineering - methods are methods that can help to solve problems and to create safety and security. For practice there are the most suitable for the first risk assessment and the fundamental monitoring the risk sizes, the following methods: check list; safety audit; what - if analysis; and relative ranking. Only for specific purposes as it is the risk determination for complex technological processes, complex objects etc. there are used more sophisticated methods as are: - Preliminary Hazard Analysis - PHA that is the procedure for searching the dangerous states (i.e. emergency situations), their causes and impacts and for their celerigation according to criteria stipulated in advance. - Process Quantitative Risk Analysis - QRA that is the systematic and complex access for prediction of occurrence frequency estimation, and of impacts of accidents on establishment or system operation. - Hazard Operation Process - HAZOP, that is the procedure based on stochastic hazard assessment and on assessment of risks followed from hazard. It is team expert complex method. The HAZOP main purpose is the identification of potential accident hazard. - Event Tree Analysis - ETA that is the procedure that pursues the course of the process from the initiating event over inventing the possible events always pursuant to two possibilities - favourable and unfavourable. - Failure Mode and Effect Analysis - FMEA, that is the procedure based on the analysis of ways of disturbances and their impacts that enables to search the impacts and causes pursuant to systematically and structured organisation of determined arrangement faults. - Fault Tree Analysis - FTA, that is the procedure based on systematic retrospective event analysis with the use of chain of causes that can lead to selected top event.
- Human Reliability Analysis - HRA, that is the procedure for the human factor influence appreciation on the disaster occurrence or some its impacts occurrence.
- Fuzzy Set Method - FL - VV that is the method of linguistic variable. It is complex multi-criterion method of decision analysis from the category of soft, fuzzy type.
- Causes and Consequences Analysis - CCA that is the mixture of fault tree analysis and event tree analysis.
- Probabilistic Safety Assessment - PSA that stipulates the contributions of individual vulnerable parts to total system vulnerability. These specific methods were derived for special practical cases, and therefore, before use it is necessary to verify if conditions of technology transfer are fulfilled.

There are also specialised methods, e.g.: CRAMM (CCTA Risk Analysis and Management Methodology – see standards CSN ISO/IEC 13335 and ISO/IEC 17799), COBRA, MELISA; methodologies - creexx (based on Monte Carlo Methods); RiskPAC: RiskWATCH.

There is also special software as: ALOHA, SAVE I, ROZEX, CEL, TEREX, EFFECTS that are broadly used for them it also holds that it is necessary to verify if conditions of technology transfer are fulfilled and it is necessary to know if they are suitable for solution of task under account because individual versions only respect special conditions. Note: on the address http://www.riskworld.com [5] - there is possible to find more than 1000 specialised methods that are supported by software - they were developed for specific cases, and therefore before their use it is necessary to verify if the conditions for technology transfer are fulfilled.

Risk management methods and risk engineering methods are complex and they are described e.g. in [4, 6].

Engineering working methods include the methods, tools and techniques used for: disaster assessment (i.e. site, maximum expected size, occurrence probability or occurrence frequency, distribution and size of impacts); hazard assessment (determination of normative disaster size - the most frequently design disaster - centennial disaster); risk assessment (in a given site according to hazard size and according to amount and vulnerability of assets). Complex methodology for negotiation with disaster risk is created by set of fasten (ted) methods for assessment of disasters and for risk management that is created by:
- method for determination of relevant disasters in a territory;
- method of determination of maximum expected disaster size (it has to modifications: root of hazard is only one source of disaster; and root of hazard is several sources of disaster);
- method for determination of attenuation of disaster impact size with distance from source of disaster;
- methods for determination anomalies in territorial distribution of disaster impacts;
- method of determination of unacceptable disaster impacts;
- method for assessment of potential damages on property caused by unacceptable disaster impacts;
- method for determination of optimum corrective measures for expected disasters in a given territory;
- method for implementation of corrective measures for ensuring the property renovation in a given territory;
- method for determination of database of corrective measures to individual disasters;
- method for determination of parametric relation between cost for renovation vs. disaster size;
- method for determination of financial reserve for renovation.

Methods, tools and techniques for risk assessment, risk management, risk engineering and complex methodology for negotiation with disaster risk are used for determination of: hazard assessment; vulnerability assessment; disaster scenarios in variant mode; risk assessment; risk mitigation and safety management; principles of prevention, preparedness, response and renewal in dependence on accessible forces, sources and means; planning and management documents in advance; personal, financial, technical reserves in advance etc. According to way of data acquisition we separate the engineering methods to:
- Empirical (based on experience). The survey of facts is made by inquiries and questionnaires. These are used at data collection on human behaviour-and human society behaviour in sociology but also at acquisition of impact distribution in the case of earthquake, wind storm or other disasters in territory. In exact sciences there are used for their rapidity and modesty. Accuracy of such data is lower than those obtained by instrumental measurement but qualified statistical processing gives good and reliable information for decision-making and management.
- Theoretical. They create findings, hypotheses, theoretical constructions on the basis of general science procedures, i.e. they are based on use of algorithms that lead to solving all tasks of a given type.

- Expert. They use professional (professionals) for activity that requires special knowledge. They are used in many situations the common feature of which is necessity of professional (expert) judgement of problem and of its further development in future. They are also used if there is necessary to eliminate local view on a given problem and to judge it independently in new, broader or more specialised frame.

According to ways of knowledge acquisition we separate the engineering methods to:
- procedures for acquisition of fundamental (usually individual) knowledge - as discovery of properties and behaviour of a given substance, behaviour of nanomaterials under different physical and chemical conditions etc.,
- procedures for solution of simple practical tasks - as allocation and application of fundamental knowledge in practice, e.g. typical earthquake impact scenario for earthquakes from one local region in a given region; way of response to chlorine release from a given building etc. In this case we must also solve at data acquisition whether we are dependent or independent on phenomena recurrence (e.g. measurement of natural events is non-reproducible) and how inaccuracies in fact acquisition may influence uncertainties and vagueness in data and by that also in knowledge,
- procedures for solution of tasks of strategic nature - as discovery of basic knowledge for support of capability to solve effectively present and future problems of a given object, e.g. connected with security and sustainable development of human system, with human society development in a given region. In this case we must solve how at data acquisition we are dependent on fact whether followed processes are or are not stable in space and time (e.g. processes of occurrence of floods, earthquakes etc. are not stable in time - extreme phenomena occur rarely and irregularly in time and space) and how inaccuracies in data acquisitions might influence uncertainties and vagueness in data and by that also in knowledge, and what follows from it for prediction and consecutively
Methods for system of systems (SoS) systems system description and management

Solution of non-structure problems - critical items are knowledge of experts on problem and its context. The methods for system of systems investigation, namely all, i.e. computational, technical and managerial must correspond to the object character. Because they have mostly several assets that are incommensurable, the more criteria must be used and all problem solution is multi-dimensional; i.e. all analysis, assessments and other procedures are multi-criteria. It means higher demand on methods, tools and techniques applied; if some problem might be decided, the managerial and computational methods, tools and techniques or managerial and technical methods, tools and techniques must be combined, i.e. heuristic approach based on good engineering practice is suitable for practice. Because we need good solution there must be applied strict rules at heuristic approach. Only in cases when the problem solved can be reduced to simple one the simple procedures can be used. For the investigation of system of systems, their behaviour and failure there are apart from analytical methods, classical methods of risk analysis, scenarios determination, deterministic and probabilistic safety analysis, security network analysis, reliability analysis, expert judgement, risk matrix, criticality matrix, Monte Carlo method etc. there are used for SoS model construction used specific methods as: Bayesian Method; Bayesian Network; Mixed Bayesian Network; Fuzzy Bayesian Network Model; Bayesian Reliability Model; Fuzzy Rule-based Bayesian Reasoning (FARBR); Petri Nets (PN); Coloured Petri Nets (CPN); Stochastic Petri Nets (SPN); Coloured Stochastic Petri Nets (CSPN); Case Study (CS); Multi-Attribute Utility Theory (MAUT); Multi-Criteria Analysis (MCA); Weighted Sum Approach (WSA); Concordance, Discordance Analysis (CDA); Technique for Order Preference by Similarity to Ideal Solution (TOPSIS); Ideal Point Analysis (IPA); Aggregation Preferences (AGREPREF); Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE); Markov Chain (MC); Multi-Objective Genetic Algorithm (MOGA); a Multiplicative Intuitionistic Linear Logic (MILL). The published results on methods for system of systems (SoS) systems system behaviour description and management are mostly in the theoretical level. We have a lot of images that were not verified on real data. The CVUT experimental investigation of electro-energy systems showed that easy application of given theoretical methods get at barriers that are formed by reality that technological, cyber, logical or territorial connections are to site specific. The results showed that the main problem consists in reality that the SoS structure is too site specific.

Combination of methods for complex territory safety management and safety engineering

If we applied these model construction methods in the form step by step (e.g. in some hierarchy of technological, cyber, logical or territorial connections) we can obtain by these methods groundwork for decision-making; retrieval of critical points and items of SoS that might be sources of interdependencies in which failure cascades can occur; determination of risks connected with critical points; and identification of priorities and aims that ensure the safe SoS and the whole community safety.

Note: territory safety management determines the aims fundamental and important for territory safety and territory safety engineering realised in general conditions and real conditions of individual sites and regions.

The combination of methods for complex territory safety management and safety engineering is combination of such methods that are suitable for solution of FOCUS project tasks. It is tailored to these tasks because human cognition and experiences show that such approach gives the best results. Its assessment is concentrated to facts that are important for solution of tasks that are in the FOCUS project, i.e. the topic is not assessment of all features and variants occurring in the practice. To obtain qualified outputs from the project we only give information that was verified on real data. Therefore, we also collected information on real solutions from domains that occur in FOCUS targets. Solution of both, the structure and the non-structure problems - critical items are knowledge of experts on problem and its context.

The complex territory safety management method consists of four main parts that are:

- Qualification of territory, identification of disasters that can affect the territory and determination territory asset vulnerabilities (TERRITORY SCREENING).
- Qualification of risks, identification of possible critical situations (RISK ASSESSMENT).
- Qualifications of available measures and activities used for trade-off (negotiation) with risks and identification of gaps in trade-off with risks (SCREENING THE MEASURES AND ACTIVITIES FOR RISK MANAGEMENT AND FOR TERRITORY SAFETY UPGRADE, AND ASSESSMENT OF LEVEL OF TRADE-OFF WITH RISKS).
- Identification of critical interfaces that must be treated in a specific way to ensure human survival and possibility for further development (IDENTIFICATION OF CRITICAL ITEMS AND PROPOSAL OF SOLUTION OF GAPS).

The details are given in publication [7]. From it follows that the real problem is too complex and that it is necessary to help experts who work with tool. If we use classical approach and we compile the representative data sets for all parts the output is relevant. Because the compilation of representative data sets is time consuming or even impossible (new problem, problem that was underestimated etc.), it is necessary in practice to use suitable heuristics, e.g. for territory screening the SWOT analysis; for risk assessment exact methods as extreme theory, PSA, FMEA etc., case study methodology or DELPHI method; for screening the tools for risk management and for territory safety upgrade, and assessment of level of trade-off with risks the specially directed methods as DELPHI, TIEQ, AHP, responsible matrix, risk matrix and other expert methods; and for the identification of critical items and proposal of solution of gaps only expert methods. For practical purposes there were, therefore, prepared for each part of tool questions that help experts to use engineering good practice rules and not to forget on fundamental data [7].
The results of first ca 84 practical tests showed that proposed combination of methods for complex territory safety management and safety engineering can be used in practice and confirmed the theoretical judgement that results are strongly dependent on knowledge and practical experiences of experts who are used for application. In management and engineering the safety and security the combination of methods for complex territory safety management and safety engineering was verified by real data for use in following tasks: problem identification; problem structure and context identification; quantitative outputs for important disasters; identification of ways for trade-off with risks; identification of responsibilities for trade-off with risks; identification of gaps in trade-off with risks and in determination of responsibilities; determination of optimum variant with regard to a given criteria set for trade-off with risks; determination of critical items that can lead to social crisis and that would be objects of research, management and engineering.

The combination of methods has potential from the viewpoint of prognosis. By help of this procedure we can obtain variants of future development of followed process but the output variants and their occurrence frequency assessment strongly depend on data quality and on human processor qualification.

Table shows that none of above described method is all-powerful, i.e. it cannot give us solution of all tasks that might be solved in the FOCUS project. Each of described method has certain principles and demands in order that its application may give qualified outputs. Each of described method is suitable for solution of one or several types of tasks. The selection of method depends on target of problem solution, on amount and quality data set, on time and techniques that we have for solution.

Conclusion

Considering the above results, even though it is possible to say that all investigated tools serve for management optimisation, so it is necessary to concentrate to reality that each method solves the problem from different view, i.e. it serves to another target. E.g.:

1. Methods for stimulation of creativity at creation of n variants (alternatives, scenarios) of solution of problems that may be decided. Among them there are belonged brainstorming, panel discussion, DELPHI method and aimed simulation techniques (NST). The DELPHI method is based on group of experts who being mutually isolated give proposals that are compared, again judged (reverse response is written) and by this way in several steps there are converged the proposed variants.

2. Methods for multi-criteria decision, e.g. process models, models based on MUT, AHP etc. The AHP is the method of multi-criteria decision for solution of non-structured problems (situations) at which the problem is separated into several levels on more simple problems and by this the hierarchical system is created. The process models in the form of arbitrary trees are mostly probabilistic arbitrary trees that serve to display and determination of optimum strategy of management of arbitrary processes with several degrees in which we can trade-off with risks.

3. Methods that serve for optimising the process courses, search of critical paths from the time viewpoint, but also sources if activities (nodes or edges) are evaluated in such way. The CPM and PERT are in principle the same. Its fundament is edge oriented graph - the edge is activity (contrary to MPM - Metra Potential Method) in which it is node oriented graph - node are activities. The CPM works with deterministic data (values), the PERT works with stochastic values (that are obtained from pessimistic, optimistic and modal judgement, it works with the $\beta$ distribution). The Petri nets are also oriented graphs that express the structure of distribute system (two types of node - places and transitions). They are used for modelling so called parallel behaviour of distribute systems. A Bayesian network (BN) is an abstract formal model allowing one to describe cause-and-effect relations between objects and systems being investigated. Causes and effects are quantities whose nature is generally random, their number is considerable, and interrelations between them are multi-various. It is established that the time complexity of algorithms of analysis of such models is exponential. This determines the necessity of computerisation of computational processes in many respects and also the expediency of development of new types of models and efficient algorithmic methods for analysing them.

For the method selection there is important the procedure:

1. To establish the aim of problem solution and to determine what partial tasks must be solved for aim achievements (to investigate problem and to find gaps in knowledge, technical measures, legal and financial measures for problem solution).

2. To assemble accessible data on problem - recent cognition and accessible data. On the base of it to determine „roads” (processes, plans) for aim achievement, namely including all sources and conditions (measures, actions) for ensuring their course.

3. To appreciate and complete existing data sets.

4. According to partial task and data quality to select suitable method. For generation of possible variants the case study methodology or the DELPHI method may be used. For selection of sufficient good variant respecting the given criteria it is possible to use e.g. the AHP. For optimising the course of a given path it is possible to use CPM, PERT, Petri nets, Bayesian nets and for decision-making during the given path again e.g. AHP.

The experience from practice shows that the best outputs are from method that is tailored to problem solving goal.

Reference


[3] D. Procházková: Final CVUT Report to WP2 FOCUS. CVUT Archives, Praha 2011, 381p. [It contains lists of publications in which appropriate methods were derived and used for problem solving and cases of events on which these methods were tested by author and experts for security and safety domain - these data are in the CVUT archives].


