

CAUSAL DEPENDENCE OF EVENTS UNDER MANAGEMENT SYSTEM CONDITIONS

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Tools for quantitative risk assessment used in praxis are predominantly based on linear transformations. A parallel problem of current risk assessment methods is constant time and imperceptions of variability of threat over the course of time. Two specific cases of causal dependence are domino effect and synergic effect. Risk as an attribute of causal dependence is common for all present management systems. The paper deals with details of synergic effect mechanism, its identification and possible utilization in the field of safety. Risk assessment is a basic tool of every management system (at this time very important for quality management system). It enables appropriate decision making. Being prepared to manage risks involves the ability to identify them, assess them and take appropriate measures. Today's construction does not only involve the manufacture of products but also designing procedures for other areas of human activity. There are numerous interdisciplinary methods that enable us to create new products. New products = new threats.

KEYWORDS

causal dependence, quality, management system,
risk assessment, synergic effect

1. INTRODUCTION

Safety of technical and technological systems (chemical, petrochemical and gas) began to be taken more seriously in the 1960's, because of technological accidents with consequences lasting over decades. As a result, directive SEVESO II and related activities concerning technological systems have been implemented.

Safety of linear systems (transport and distribution of gas, oil, electricity and materials via road and railroad transport) is just a logical outcome of perceiving safety more comprehensively. The safety issues of critical infrastructure reflect current threats, which are not only of technological nature.

2. TOOLS FOR SUPPORTING DECISION MAKING IN MANAGEMENT SYSTEMS

The level of comprehensive safety certainly depends on the degree of integration of its partial components. The issues of integration are related to the subject of enterprise, policy, and personalities of managers, able to use their knowledge to manage the subsystems in an integrated way.

Ludwig von Bertalanffy [Drack 2008], the founder of the general systems theory applicable to biology and other fields, proposed the equifinality principle (the same end state may be achieved via many different paths or trajectories within a system). Wiener's work [Wiener

1960, 1963] contributed to the systematic perception of technical systems. In the late 1960's, he suggested interdisciplinary approach within the theory of systems. The theoretical issues of nonlinearities near equilibrium state were elaborated by Ilya Prigogin [Prigogine 1980].

Current technical and management systems are presented as dynamic management systems that are constantly being improved. This approach is formal and commercialized. However, a standard or a regulation is just a summary of the existing knowledge. The interdisciplinary of approaches requires deeper and more systematic understanding of the problem.

3. CURRENT STATUSES IN THEORY OF RISKS

The term risk as an attribute of causal dependence is common for all management systems. In relation to the development of technological sciences and emerging problems, accidents and disasters, this term has become to be used in quantification of causal dependence, not only in quantification of the result. Current management approaches require integration of systems into one unit. Today, this process is understood as integration of structures not of entire subsystems. However, much more important task rests in the integration of systems, i.e. not ordinary system components but also their relations that give rise to characteristic threats.

The concept of the causal dependence is as old as humanity itself. In 1950's and 1960's, there was a significant development of numerous important scientific disciplines related to systematic approach. Synergetic as a scientific discipline deals with concurrence of respective systems within a complex system. This gives rise to complex structures, new behaviours and new qualities that are not ordinary sums of subsystems. Domino effect and synergic effect are specific cases of causal dependence. A qualitative change from one stage to another caused by a change in external conditions is called a sudden phase change. All phase changes are its typical examples – industrial accidents, natural disasters, as well as ordinary operation accidents such as boiling liquid expanding vapour explosion (BLEVE). It is an explosion caused by the rupture of a vessel containing a pressurized liquid above its boiling point. In spite of the fact that we usually take notice only of the consequences of such events, their mechanisms contain a sequence of events – causal dependence. In case of synergic effect there occurs a permanent structural change.

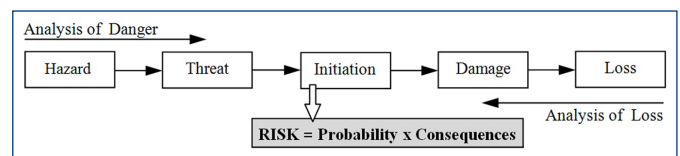


Figure 1. Causal dependence [Sinay 2014]

All risk assessment procedures, both deductive and inductive, use causal dependence, shown in Fig. 1. Quantification of risk is necessary for the economic aspect of prevention.

The processes have often been simplified in search of relevant physical and chemical basis. Some details had been neglected in the simplification process, which later caused catastrophes. In the description of causal dependence it is advisable to take into consideration also consequences that are possible in particular time and space.

In prevention it is important to take measures before the threat is activated. Prevention within the causal dependence is shown in Fig. 2.

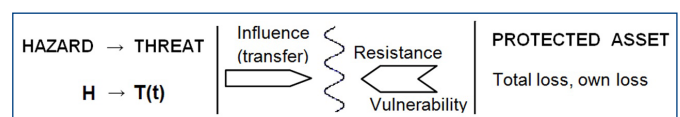


Figure 2. Prevention solutions in causal dependence [Svoboda 2010]

Resistance is characteristic for a particular system, which is financially expressed in the form of an asset. The resistance can be either natural or supplementary (increased on purpose) [Svoboda 2010].

4. NEW RISK ASSESSMENT TOOLS

Tools for quantitative risk assessment in praxis are generally based on linear transformations. Another problem is the constant time, i.e. not taking into consideration the changing nature of threat over the course of time. Human activity remains the most serious problem. A human represents various nonlinearities simultaneously.

Mathematical models as well as currently used methods are simplifications that are frequently usable only when remaining system parameters are fixed. It will be necessary to deal with specific phenomena such as synergic effect and domino effect as parts of causal dependence in the field of economics, strategic management but also in general chemistry. New procedures able to identify serious unbalanced states of systems with the potential of unexpected changes are being offered for the fields of assessment of industrial accidents and nuclear disasters but also for economics and sociology. These procedures are shown in Fig. 3.

In the USA, procedures arising from the economic premise of public welfare WTP (Willingness to Pay) or inability to perform a job VLYL (Value of Life Year Lost) are used for nonlinearities cumulated in the concept of human factor. The value of statistical life (VSL) is then the ratio of average value of WTP and the change in the extent of risk after the risk minimization measures. In some non-members countries of EU is the American system used too. In Europe, such procedures are used in the insurance business, but The European standards are also connected with law requirements like is Machine directive, 2006/42/EC.

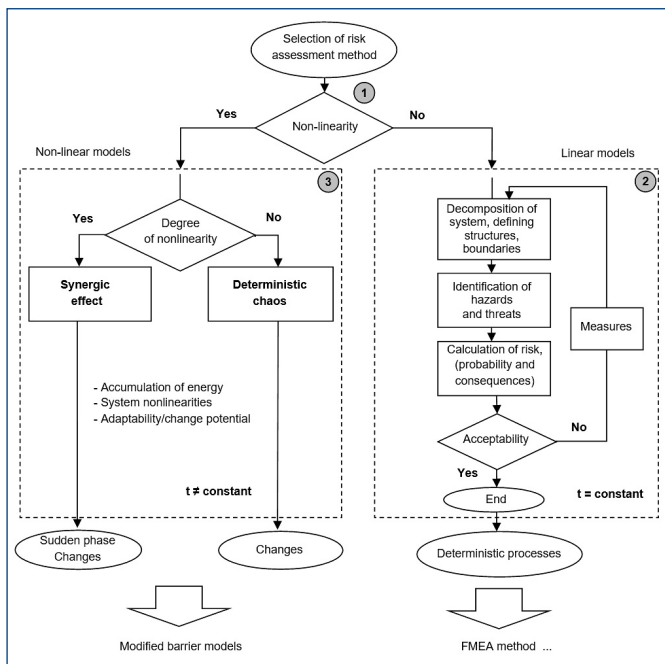


Figure 3. Relation of linear and nonlinear risk assessment procedures [Oravec 2011]

- Point 1:** Nonlinearity and system stability is determined by the relations within the system.
- Point 2:** Traditional risk assessment procedures, constant time and deterministic linear relations within the system.
- Point 3:** New causal dependence identification tools, especially hazard/risk interface. Forms of identification of nonlinear relations and the degree of nonlinearity.

Future efforts should be aimed at understanding mechanisms of nonlinearities, i.e. the left part of Fig. 3. Many findings have been sufficiently described, although not yet applied. Identification of the control parameters of change is frequently related to the system's sensitivity.

The formation of new qualities (sudden phase change) is possible only if:

1. there exists energy potential able to induce a change (open system in terms of the second main clause of thermodynamics),
2. the system contains nonlinearities (at least square power or higher) or higher derivatives, according to time or position coordinates,
3. several equations are necessary to describe the system (not one), multiparametric systems.

The usage of the nonlinear dynamic models is meaningful only if it is possible to prevent major losses; e.g. current procedures in the field of industrial accidents, critical infrastructure, continuity planning [Oravec 2011, Krempasky 1994].

Typical steps of mechanism of identification of synergic effect are:

1. analysis of the system parameters (system structure and relations),
2. identification of unstable components of the system and their energy potential,
3. identification of nonlinearities in the relations within the system,
4. change potential,
5. control parameter/s of change and its stability/change potential, position of the critical point of the system (parameters of sudden phase change),
6. character of a new quality,
7. external response – there always occurs a change, modification of the environment.

It is necessary to realize the particularities of the sudden phase change. Feigenbaum constant expresses the periodicity of sequenced changes and also possibility of taking measures. Upon completion of the transformation (nonlinear operator) it is impossible to return the system to its original condition, as its structure has changed. It may be better or worse than original. Causal dependence is represented by the black line and it illustrates the transformation of the system over the course of time.

Table 1. Differential equations for selected phenomena

Domain	Scope
Technical sciences	
Fourier's equation	non-stationary heat transfer, coefficient of thermal conductivity
Gas dynamics of a spherical flow field	description of explosions
Natural sciences	
Magnetism	health care, military establishments
Korteweg-de Varies equation	tsunami

An example of the abovementioned sequence of steps is the protection of important objects with the potential of undesirable attacks. Current critical infrastructure of Europe and the Slovak Republic has to be protected against such attacks.

Conducting respective steps to utilize the synergic effect assumes deep knowledge of technical sciences as well as knowing the particular objects. The descriptions of simple physical laws, including nonlinearities (Tab. 1) are used for the quantification of consequences.

5. CONCLUSION

Development of procedures in the field of risk assessment aims towards integral procedures, not partial ones. The direction of the theory, but also of its practical outcomes, leads towards the creation of tools usable in the near future. The currently used tools that describe causal dependence are predominantly technical, not economic. All future risk assessment methods will have to possess variability depending on the process changes and will use general system rules [Oravec 2008]. The methods will have to use mathematical formalism applicable for the needs of economy and safety. The integration, the shift from partial to integral risks within the comprehensive safety, requires

creation of procedures applicable across management systems. The process approach and the risk theory are unifying components in the management systems.

Safety and risks are like communicating vessels, be it in the field of safety of people, property or environment, objects situated under, on or above the ground. That is why it is necessary to set a unified terminological frame.

Newly designed procedures should focus on solving the hazard/threat interface, particular uses, which will speed up the risk assessment process. The classification of barriers in structured systems is especially important. Sensitivity analysis of complex systems is a faster indicator of potential threat than currently used identification tools.

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REFERENCES

- [Andrassyova 2012] Andrassyova, Z. et al. Improving quality of statistical process by dealing with non-normal data in automotive industry. In Management systems in production engineering. No. 3 (2012), ISSN 2299-0461.
- [Drack 2008] Drack, M. Ludwig von Bertalanffy's early system approach, Theoretische Biologie und Problems of Life. <http://journals.issn.org/index.php/proceedings52nd/article/viewFile/1032/322>
- [Gniadek 2015] Gniadek, M., Brock, S. Basic algorithms of input shaping autotuning, MM (Modern Machinery) Science Journal, October 2015, ISSN 1805-0476, DOI:10.17973/MMSJ.2015_10_201509
- [Mukhametzianova 2015] Mukhametzianova, L., Kotek, L., Dohnal, M. Qualitative model of performance shaping factors in HRA,

MM (Modern Machinery) Science Journal, December 2015, ISSN 1805-0476. DOI: 10.17973/MMSJ.2015_12_201551

[Krempasky 1994] Krempasky, J. Synergetics. The basics of dynamics of nonlinear systems, Bratislava: STU, 1994. ISBN: 8022707074. (in Slovak)

[Oravec 2008] Oravec, M. Risk assessment, SPBI Ostrava 2008, ISBN 978-80-7385-043-2. (in Slovak)

[Oravec 2011] Oravec, M. Synergetic effect-commercial abuse of the tool, CNP 2011, IOO Bohdanec 2011. (in Slovak)

[Prigogine 1980] Prigogine, I. From Being To Becoming, 1980, Freeman, ISBN 0-7167-1107-9.

[Sinay 2014] Sinay, J. Safety management in a competitive business environment, 1st edition - Danvers: Taylor & Francis Group, 2014, - ISBN 978-1-4822-0385-1.

[Svoboda 2010] Svoboda, O., Roudny, R. Modelling links between threats. Scientific Papers of the University of Pardubice, Series D, Faculty of Economics and Administration, 2010, vol. 15, no. 18, s. 153-163. ISSN: 1211-555X. (in Czech)

[Vykydal 2013] Vykydal, D., Plura, J., Halfarova, P., Fabik, R., Klaput, P. Use of Quality Planning Methods in Optimizing Welding Wire Quality Characteristics. Metalurgija = Metallurgy. 2013, Vol. 52, No. 4, p. 529-532. ISSN 0543-5846.

[Wiener 1960] Wiener, N. Cybernetics: Or Control and Communication in the Animal and the Machine SNTL, Praha 1960, Academia, The Publishing House of the Academy of Sciences of the Czech Republic (Czech translation)

[Wiener 1963] Wiener, N. The Human Use of Human Beings. Cybernetics and Society, (Czech translation, Academia, The Publishing House of the Academy of Sciences of the Czech Republic, 1963).

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