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Technosphere, Risks and Their Control

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Abstract: *The paper discusses some of the most significant problems of the technosphere, the technogenetic accidents connected with it and the risk situations occurring at that. The nature of risk, the approaches and ways of risk control are considered, as well as the possibilities to decrease it to acceptable limits. Attention is paid to the necessity for creating centralized state precautions with the purpose to diminish the technogenetic risk situations.*

Keywords: *Technosphere, occurring risks, risk control.*

1. Introduction

The dependence of contemporary human society on the state of techniques, technologies and their applications, has reached considerable magnitude and is constantly increasing. The population is growing, as well as its needs for food, energy, water and normal conditions of existence. The stable development remains for the moment a desired universal purpose, though not clear when and how it will be achieved.

With the development of the technical and technologic possibilities, the risks and the probabilities of technical failures and accidents have increased. The risk is a substantial factor in everyday life and the inability to reasonably evaluate and restrict it to definite limits causes too many losses, human victims and recovery time. This makes the problem of development of methods and tools for decreasing different risks by proper control especially topical [4].

The three components – technosphere, risk and its control are inextricably bound in a triad. This requires thorough consistent evaluation of their present state and consideration of the future complex development of this triad.

2. Technosphere

Usually the term "technosphere" denotes labour tools, materials, mechanisms and program-apparatus tools, designed and used in everyday life by mankind during its long history. The term "technosphere" was introduced by Acad. A. Fersman in the 20-ies of the previous century.

An important part in technosphere is played by the technologies, created and implemented during different historical ages. Technologies (a term based on two Greek words – master and science) determine to a significant degree the level of the civilization, in which they are used.

The recent interpretation of technologies is quite broad – it includes the knowledge, aiding the production of certain products, machines and equipment, as well as the specific intellectual tools.

According to S. Lem the term "technology" must denote the evolved from the knowledge status and social efficiency ways for achieving the aims, set by society, including those not foreseen at first [9].

For the last two centuries technologies have passed intensive development that accelerated considerably in the last thirty years. Several technological stages have altered, starting from the wide spread of the steam engine at the beginning of the 19th century and coming to recent convergent technologies (info, bio, nano, cognio).

The research and co-operative structures suggest constantly new technologies for the production of real and virtual machines, equipments and products of unknown qualities, the study and estimation of which requires more energy, expenses and time. This leads to considerable new risks and threats for man and environment.

In the last decades technologies that create new technologies have gained speed. Their most distinguished representative is venture technologies. They are based on a new type of capital – the venture capital which differs from the bank capital. By averaging the risk in the different projects it enables the quick and efficient "run" through the whole route from the idea appearance up to its market realization. For the moment this is the most efficient way to introduce innovations entirely based on the market principle. It was formed and widely spread in USA.

Three technological stages have developed in world economy in the period after the World War 2. In the first one heavy industry was dominating – chemistry, metallurgy, mining, energy production. These branches require large volumes of raw materials, population and territory and they are connected with the use of technologies leading to environment contamination.

The second stage is characterized by massive usage of Information-Communication Technologies (ICT), bio technologies, high technological chemistry, micro electronics. The development of these branches requires high technological culture and education of the population, as well as creation of specific psychological predisposition in the people dealing with this activity.

Nowadays the third stage, possessing too many specific features, is being developed. It is characterized by the fact that the new ideas and technologies are associated with virtual models, structures, images, tools for influence on the conscience of the workers and their participation in various processes, including virtual production. A main resource in this activity is the creative spirit of different social elites.

The transmission from one technological stage to another is connected with the rapid increase of labour productivity, and subsequently – of the national wealth. As an example of the increasing possibilities of technologies the following facts could be noted: one ton of grain on the world market gains a benefit of 30 USD, a ton of meat – 300-400 USD, daily technique – 50 000 USD and one ton of aviation technique – above one million USD.

In the last decades the technologies are divided in three types – low, middle and high technologies. The first one usually yields the smallest relative surplus and it is met in heavy industry, agriculture, small series production.

A classical example of average (and partially high) technologies is the batch automobile production, integrating many branches of low, middle and high technologies.

The most distinguished representative of high technological production is civil aircraft building. It has annual volume of several hundred milliard USD and demonstrates the highest possible surplus value per produced unit. This class of high technological production includes also the construction of high speed railways, the production of microelectronic and photovoltaic elements, the biotechnologies, nanotechnologies, the development of virtual supercomputer models for design and realization of productions, different types of CAD/CAM computer models and systems, etc.

The use of high technologies leads quite often to the formation of stocks and services with unknown and unpredictable properties which can be evaluated only after their continuous usage. A typical example of this are the technologies for genetic modification of the agricultural products. On one hand these technologies cause considerable increase of the agricultural production, but on the other hand they bear serious risks and threats to human health. A final estimate of their influence could be given after long experimental and research activity.

The high technologies conceal new risks and dangers. The wide spread of ICT – the technologies almost in all spheres of material production and social practice, cause the formation of specialists groups, dealing with the design of "computer viruses" which negatively affect both separate corporations and state institutions, as well as the numerous users of computer networks. It is not clear when the battle "computer viruses – antivirus software" will end.

The use of the cleanest and most efficient technologies – nuclear technologies, is deeply questioned after the heavy accidents in nuclear stations "Chernobil" in 1986 and "Fukushima-1" in 2011.

As a whole, the experience gained shows that there does not exist a complex equipment or technology which will not hide any dangers for damages and catastrophes. That is why it is appropriate the mankind development to continue with the efficient overcoming of the contradiction between the increasing technological possibilities and the non-readiness for their thorough and reasonable usage [8, 9].

3. Risks and their control

The phenomenon "risk" (coming from the Italian word "riscare"– evaluate, weigh), has passed a long way before becoming one of the most important categories for evaluating the degree of danger for states that are unfavourable for man, society and nature. It is considered that the risk is evaluation of the danger in making a decision [3, 5, 6]. The notion "probability" for a certain event plays a significant role in determining the risk. Too often the notions "risk" and "probability" are mixed, which leads to terms misunderstanding.

Very often the risk is regarded as a complex function of the product of two measures – the volume of losses and damages due to the unfavourable event, and the probability for it. On the other hand, the investigations show that these two measures are evaluated by an algorithm in human brain and with their help he makes subjective evaluation of the risks [10].

At that, if the probability for an unfavourable event is high, but the losses expected are not big, the risk is not high as well. The situation is similar when the loss from a given event is significant, but the probability for its occurrence is not high. The risk has the largest value when the expected losses from the unfavourable event are big and the probability for its occurrence is also high. The fourth case, when the losses expected and the probability are small, is trivial – then the risk is also insignificant.

In modern science, technique and culture the risk is interpreted too broadly, as a generalizing category, analogous to "justice", "value" and "sense". In some scientific areas the risk interpretation has its specific features.

Quite often no difference is made between "risk" and "uncertainty", though the two notions have different nature. The risk gives possibility for digital interpretation of the expected losses or dangers, while uncertainty does not give such an exact evaluation.

The probability – and as a sequence the occurring of a risk, appears in places where the cause-sequence relations between the separate events are not clear, when these events are influenced by factors not known or vaguely known by the decision maker. A classical example of this is market functioning, as well as automobile incidents on highways.

The complexity of the products and systems studied influences considerably the risk determination. The range of possible accidents and failures in modern complex systems is quite big and it contains as a rule apriori unknown and unpredictable failure states. A good example is the story of the American astronauts from "Apollo 13". Thanks to the sequence of competent and well-timed decisions they managed to save their lives and the module after a heavy emergency situation.

Two approaches are used to describe the risk – the probability theory and nonlinear dynamics theory [7].

Probability theory has well developed mathematic apparatus and appropriate tools of models for multiple-step probabilistic decision making with one or several criteria. These probabilistic models are very suitable for optimal decision making under conditions of risk and uncertainty.

Nonlinear dynamics has developed intensively in the last half century and nowadays it is widely used in numerous applications and investigated by many researchers in different scientific areas. It follows from its results that the complexity of a system and the set of overlaying causes and sequences lead to the occurrence of random behaviour in its elements. On the other hand, the random character may be a sequence of the fact that the system is sensible to the initial conditions, i.e., its instability is "genetically" built in. The sensibility with respect to the initial data leads to instability of the complex systems, because small alterations in the input cause large changes in the output of the system.

The sensibility towards the initial data causes the occurrence of random events, which are quite often regarded as "deterministic probabilities". They serve as a basis in the interpretation of the risk and the dangerous situations when using nonlinear dynamics.

The idea to avoid this property is the basis of the widely spread principle for stable development of our planet.

The second way to evaluate the risk comes from classical probability theory. Many models can be pointed out within the framework of this theory that describe well enough the risk under dangerous conditions. In both interpretations of the risk, the horizon of prediction is limited, which influences the study of technogenetic accidents and failures. This feature is of considerable importance in the study of dynamics, risk behaviour and its efficient control.

The notion “risk” has another measuring, based on subjective evaluation.

Many well known and ranked risks of some technologies and activities are available. It follows from them that the objective risks of smoking, alcohol addiction and automobile incidents have very high values for the contemporary person. However, the inquiries made show a different picture – most of the citizens consider that the risks from nuclear energy production are much greater than the risks above mentioned, though this is not confirmed by statistic data. This happens because the individual determines their subjective risk within bi-dimensional space. One parameter in this space is the objective data for the risk, the other one – to what extent the threat is new and unknown. Using an algorithm which is unknown for the moment, the person determines their subjective risk with the help of these two parameters.

The notion “risk” is most often connected with decision making. Some decisions suppose certain risks and benefits, while other decisions – respectively greater or smaller risks and benefits. This principle lies in the first known technology for risk control, invented in 15th century and connected with the formed then marine insurance. Nowadays risk control is a rapidly developing area of considerable theoretical and practical importance.

Let us assume that after a certain decision the system (with certain probabilities) falls in one out of the several states, in which definite loss appears.

The sum of the products of the corresponding probabilities and losses when passing through all possible states is equal to the averaged estimate of the expected losses in making a decision. The decision leading to the smallest risk will be the optimal one. This is the most elementary model of expected losses at probabilistic decision making.

Such an approach supposes a possibility for apriori objective and exact determination of the separate probabilities that is extremely difficult in practice.

In real life situations the subjective approach, in which the decision maker works most frequently with his/her subjective probabilities and evaluations of expected losses, is dominating. In case the objective probabilities and losses are replaced by subjective probabilities and expected losses, an averaged subjective estimate will be obtained corresponding to a given decision. The solution leading to the smallest calculated subjective risk will be the optimal one.

Some researchers regard the models discussed as rough approximation of reality. They consider that in decision making the person takes in mind not only the mathematical expectation, but the dispersion of the respective random value as well.

Some more complex models could be proposed, based on Markov Processes for Decision Making (MPDM). It is assumed in them that at each state where the system is found, a finite number of decisions can be made, each one connected with a finite number of probabilities for falling in any of the states. When passing into a given state, losses corresponding to this transition, are obtained. An optimal decision connected with the minimal risk, can be found at every state. The set of such optimal decisions defines the general strategy of the minimal risk, determined by the corresponding universal computing procedure simultaneously for all the states.

This model enables the risk control step by step, in which the system passes from one state into another with certain probability. If optimal control is selected at every state, then as a whole optimal multi-step control with minimal risk is realized.

There is another, principally different approach for risk control, based on nonlinear dynamics models. The notion “bifurcation” is used in it.

In mathematics bifurcation is introduced by Jacobi, after that Poincare used it in cases when the number of decisions is altered or loss of stability occurs for some classes of equations. Before reaching the bifurcation point the sensibility towards small impacts rises, i.e., small changes may lead to a considerable increase with a leap of the function values. At the mere bifurcation point the function could continue along one out of several possible trajectories, after which the sensibility decreases, the stability grows until the next bifurcation point is reached. The sequence of a set of bifurcation points and sections of stability, through which the system passes, can be regarded as a bifurcation network.

The bifurcation points usually correspond to such states of the system, in which depending on the trajectory selected, significant dangers and risks are possible. In case the bifurcation points are identified with forestalling, then it is possible to choose control actions, directing the system along a trajectory with smaller risk and threats. This enables efficient risk control.

There are available some other, more complicated models of risk control, but they have built in specific characteristics of the investigated technical systems.

The risk control engages institutions at different levels – technical specialists in small and medium enterprises, corporative managements, regional and state institutions.

The state administration as a rule strives to create such technical, management and state requirements that will minimize the respective risks of technogenetic accidents and failures. Three approaches are usually used for this purpose.

In the first one the aim is to apriori program and input in the controlling computer systems the possible failures and incidents in the separate elements and in the technical systems as a whole. When emergency situation occurs, the experts or dispatchers derive the decisions proposed by the computer systems and their successive application during the failure stages leads to minimization of the losses risk.

The shortcoming of such an approach is the impossibility to program absolutely all emergency situations, some of them being too complex and unpredictable.

The second approach is connected with thorough apriori investigation and formulation of the common principles for risk decrease in separate classes of technical objects, close with respect to their functions. On the basis of these principles some rules, instructions and legislative acts are issued that have state character and are obligatory. The disadvantage of this approach is the impossibility to print the specific features of the technical objects and systems which carry significant dangers.

The third approach may be defined as a mixture between the first two. Their shortcomings above mentioned can be sometimes avoided in it, but its realization requires more expenses.

The last decades are assessed by the formation of a number of general system properties, playing important role in the occurrence of considerable technogenetic risks and dangers. The most important among them are as follows:

– The continuous cause-sequence relations in the production cycles increase the risks, since in separate sections of the cycle many harmful and dangerous substances and components are used. The risks come not only because of their current use, but their future harm also.

– The complexity of the production processes increases the risks and leads to decrease of the prediction horizon. The instability of the world markets can be indicated as an example which diminishes their reliable prognostics. The same refers to the increase of the transport units in big megapolises which increases the risks of auto incidents.

– The unfavourable global processes due to man's activity ˜ oceans contamination, alterations in the atmosphere composition, soil degradation and others, increase the risks for human population. The same effect is noticed in the uncontrollable demographic processes.

The solution of these problems requires responsible local, state and international decisions. Attempts are being made at international level, but generally the national egoism prevails. It seems that still greater challenges are needed in order to start crucial improvement of the environment and to decrease the dangers and risks of technogenetic catastrophes.

At the end of the 20th century U. B e c k [1, 2] has announced in his books the appearance of the world risk society as cosmopolitic society. Recent years have proved this tendency.

4. Conclusion

The intensive development of the technosphere and the increase of the risks and dangers related with it, is an indisputable fact.

This brings the necessity for worldwide activity connected with risks study, the design of the corresponding objective models and development of recommendations and mechanisms for their efficient control.

Modern society is being quickly transformed into "society of risk" and risk control – into an important scientific and applied direction.

The triad "technosphere – risks – control" needs continuous monitoring, control and reasonable use. If these requirements are not realized with increasing intensity and efficiency on local and global scale, a lot of new larger risks and dangers with unpredictable sequences will accumulate.

R e f e r e n c e s

1. B e c k, U. World Risc Society. Blackwell Publishers Ltd., 1999.
2. B e c k, U. Risc Society: Towards a New Modernity. London, Sage, 1992.
3. B e r n s t e i n, P. Against the Gods: Remarkable Story of Risc. Wiley N. Y. 1996.
4. Risk Control: Risk, Stable Development. (I. Makarov, ed.). Sanergetica, M., Nauka, 2000. (in Russian).
5. P o p c h e v, I. Turbolency, Solutions, Aphorisms. – Journal of BAS, No 6, 2010. (in Bulgarian).
6. Choices, Values and Frames. (D. Kahneman, A. Tversky, Eds). Cambridge University Press, N.Y., 2000.
7. A r n o l d, V. Theory of Catastrophes. M., Nauka, 1990. (in Russian).
8. K a p i t s a, S., S. K u r d j u m o v, G. M a l i n e t s k i i. Sinergetics and Prognosis of Future. M., 1997. (in Russian).
9. L e m, S. Sum of Technologies. M., Text, 1996. (in Russian).

10. N e w m a n, M. Self Organized Criticality, Evolution and the Fossil Extinction Record. – In: Proc. R. Soc., London, 1996.
11. D r u c k e r, P. Managing in Turbolent Times. Harper-Collins Publications, N.Y., 1980.

Техносфера, риски и их управление

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В работе рассматриваются некоторые наиболее актуальные проблемы техносферы, связанные с ней техногенные аварии и катастрофы и возникающие при этом опасности и рисковые ситуации. Обсуждается природа риска, способы и пути управления и возможности его снижения до допустимых величин. Обращается внимание на необходимость осуществления централизованных государственных мер по отношению техногенных рисковых ситуаций.