MODELING ECOLOGIC PROCESSES OF PRODUCTION

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Abstract The process of production formed ecologically should be directed on an economical use of resources and optimal steering of the process in view to the elimination of causes of disturbances. Strategic decisions concerning composite technical and social systems take under consideration the knowledge on relations of production processes with the environment and their results caused in the ecosystem. The source of desired information is historical data related to occurrences, accidents and failures. This base of knowledge becomes the funding for created system reparation activities, like mechanisms that compensate shortages. Connecting and coordinating all assets of the enterprise in view to achieve ecological production processes is the basis of the management process, which simultaneously forms mechanisms of mutual stimulation and development. Described standards, models of reliability structures, characteristics of dynamic phenomena, determined limits of tolerance for acceptable values of variables of the process and modeling critical resources support the process.

Paper type: Research Paper

Published online: 16 July 2016
Vol. 6, No. 3, pp. 217-229
DOI: 10.21008/j.2083-4950.2016.6.3.3

ISSN 2083-4942 (Print)
ISSN 2083-4950 (Online)

Keywords: *modeling exploitation processes, uncertain knowledge, system resources, fuzzy logics*

1. INTRODUCTION

Strategic decisions concerning composite technical and social systems take under consideration the knowledge on relations of production processes with the environment and their results caused in the ecosystem. It requires describing dynamic phenomena, which are important for the planned targets. Prepared descriptions of elements and relations within the system, with use of various tools, shape certain parts of reality from the point of view of the purpose of the analysis. Difficulties in describing natural processes lay in a complex image of phenomena that can be observed in the environment of production processes and relations between causes and effects in the same time. The application of the system analysis is a sort of solution. It allows obtaining a detailed model of a decisive situation. In addition, if a description of production processes will be deepened with a tacit knowledge, along with the use of fuzzy rules of concluding, the fusion of formal data and detailed information on the situation will result from and ecological model of a production process. A base of knowledge constructed this way can reason the reduction of the risk level in resource management of an economic organization, in which ecology becomes a domain. In the research of designing methods appropriate in a determined production process, it is crucial to establish categories of assessments of trends of the development into ecology.

2. ECOLOGICAL PROCESSES OF PRODUCTION

An ecological process of production is a process that keeps the defined relations between determined elements of a specific system and with regard to the accompanying phenomena in the nearest environment of the organization and in its wider surrounding of the system, determined in view to the technology of production and legal requirements of this activity.

However, reality shows that the problem of documented important for the balance, different environment of the economic activity, is open. The process of production formed ecologically should be directed on an economical use of resources and optimal steering of the process in view to the elimination of causes of disturbances. However, numerous accidents and failures suggest that there is a lack of observed positive effects of management in industrial companies. Figure 1 illustrates it with statistical data (ZDR (CHR) – companies with high risk of major industrial accident, ZZD (CIR) – companies with an increased risk of major industrial accident, other companies, where the economic activity can cause severe industrial accidents).

The system approach of problems requires a composite approach for production processes, which are various from the point of view of quality and composition, as well as for different phenomena occurring in the environment. This refers both to the nearer environment, for example: the structure of the warehouse area, competences of the staff, clearance of the technological documentation, means of transport, etc., and the further environment, for example: regulations on environmental protection, market competitiveness, climate phenomena, etc. One of definitions of ecology: "Ecology is a study of ecosystems that is opened on a wide scope of areas, from physiology to bio-geography" (Zięba, 2004, p. 13) shows the wide spectrum of study that require registration and analysis of primal causes of inaccuracies in the wide context of coexistence of diversified environments. The source of desired information is historical data related to occurrences, accidents and failures. This base of knowledge becomes the funding for created system reparation activities, like mechanisms that compensate shortages. The second method for preventing inaccuracies is to design systems, in which the reliability of elements and relations results from natural abilities formed for planned production processes and from features of designed resources of the system.

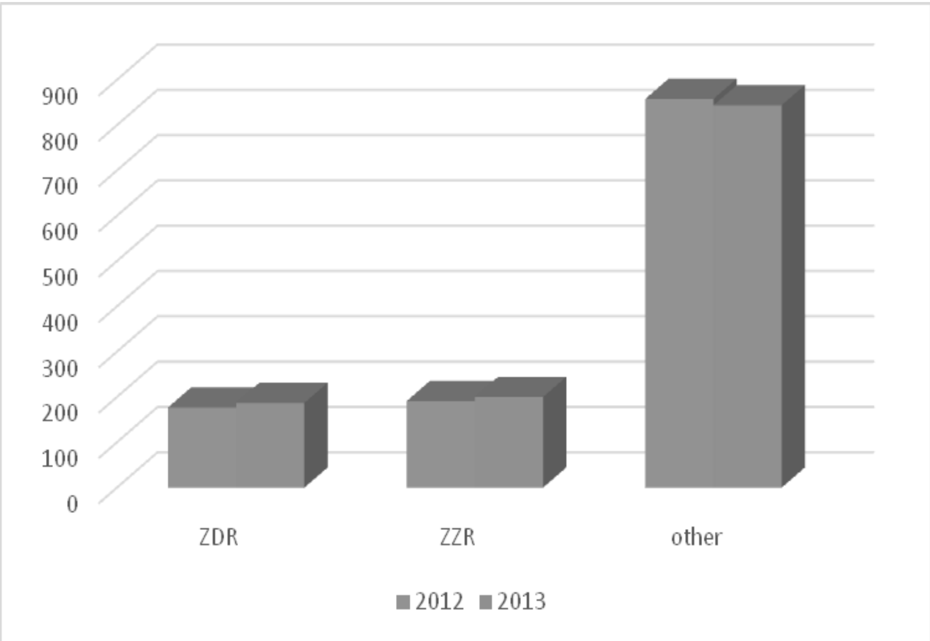

Fig. 1 Occurrences with symptoms of major industrial accidents; Source: Report on occurrences with symptoms of major industrial accidents in 2013, 2014, p. 5

The suggested idea of modeling ecological processes of production results from the need for improving the reliability of mechanisms that compensate insufficiencies or lack of system resources. In this case it is important to have knowledge of relations that decide on the balance in the system. In the same time, it is being accepted that an unreliable unit is a unit that hampers or makes difficult the functioning of other units because of own error. However, an unreliable unit is also a unit that block achieving new aims, which occurred from a wider context of the situation, in relation with changing characteristics and states of individual elements of the system and new relations, even though it functions correctly.

The ecological process of production is an assembly of elements and relations of the system, which allow the analyzed chain of actions of the elementary unit of the production process to obtain a high assessment in the category of quality of the exploitation of devices (exploratory range) and a high assessment of the ability to work in time (reliability). Connecting and coordinating all assets of the enterprise in view to achieve ecological production processes is the basis of the management process, which simultaneously forms mechanisms of mutual stimulation and development. Described standards, models of reliability structures, characteristics of dynamic phenomena, determined limits of tolerance for acceptable values of variables of the process and modeling critical resources support the process.

The organization of the work system resources consists in creating relations and mechanisms of an automatic steering the relative level of the sustenance between the positive, negative and protective potential. The system analysis constitutes the fundament for determining the specific character of the system and its environment. It provides data for characterizing the moment t of the vector of potentials.

$$V(t) = \{ VN(t), Vp(t), VO(t) \},$$

where:

Vp – positive potential, ability to affect in a supportive way other systems (objects) – potential of cooperation;

VN – negative potential, i.e. ability to affect in a destructive way other systems (objects) – potential of risk;

VO – protective potential, which is an ability of the system to prevent destructive influences of other systems (adaptive abilities, resistance, ability to fight).

Potentials Vp, VN, VO depend on general potentials of systems (objects) that threat or are threaten, potentials and states of the environment of systems (Łozownicka, Stupnicka, 2000, pp. 75-76).

The level of safety in the work systems is also dependent on its relative dynamics, it means that it depends on characteristics of streams of risks in reference to characteristics of time streams of preventive actions of the system (adaptive abilities). As it is man, who makes decisions, shows his creativity and is the final element that ceases to function, adaptive mechanisms that take under consideration the tacit knowledge of the employee are beneficent for the preventive stream of the system of work and they contribute to a progressive development of ecology in economic organizations.

3. THE ISSUE OF PROCESS MODELING

3.1. Categories of assets in produktion systems

Assets used by all sorts of organizations can be categorized into four basic groups:

1. Human resources – skills, knowledge, abilities of all people involved in production and administrative processes.
2. Financial resources – the capital used by the organization in financial processes for short and long term operations.
3. Material resources – assets enclosing raw materials, half-products, offices and production facilities, as well as all kind of equipment used in work processes of the organization of the enterprise.
4. Information assets – various types of information and data in the database used in decisive processes.

The system theory assumes that the relation between individual subsystems constitutes a qualitatively new characteristic of the system. It means that it assumes that every element of the system has not only its specific features, it also has systemic characteristics, which do not result directly from determined elements of the system but from the integrative features of the system itself. And so, integrative features of the entire system include characteristics of its elements, which construct the total work system: people (their personalities, health condition, level of competences, stress resistance, motivation, etc.), devices (work conditions, resistance, standards for exploitation and how they are followed, reliability, readiness, etc.) and management (standardization of loads, preparation and training of the staff, accidents' analysis system, etc.).

The presented characteristics of the work system shows that the issue of the research related to the security of work is analyzing groups of numerous elements of the system (sectional view of the system) and relations within the system. In view to the target of the research, i.e. optimization of factors determining the safe utilization of the technique, it is important to gain knowledge that will supplement information on the exploitation, necessary for the management of the information, financial and material resources. The mutual participation of these assets is constantly changing because of different aims and needs resulting from them. The dynamics of these changes is manifested by the potential of the system, which is a value illustrating possibilities of the system in achieving aims and realizing tasks, as well as appropriate functioning. It is the potential of the system in every moment

moment $t \in [t0, t]$ this means, that these are conditions forming the possibility for the possibility for the realization aimed tasks by a chain of operations accordant to its nature.

In view of safety of work requirements, the system's potential can be shaped by following components, which represent different types of resources:

1. Structure integration potential VS(t), depending from the quality and intecity of relations between elements of the system VEL(t),

2. Human resources VL(t),
3. Biotic ecosystems' potential VB(t),
4. Information potential VJ(t),
5. Technical potential VTE(t),
6. Potential of energy VEN(t),
7. Substantial potential VM(t),
8. Regulative, steering potential VR(t),
9. Economic potential VE(t),
10. Resources of time VT(t), and other.

Diagnosing and monitoring them is described in works of T. Łozowicka, Stupnicka (2000, p. 15), taking under consideration the context of risk assessment, hazard and security in the optimization of composite technical systems.

Individual systems are characterized with a suitable ranks of its partial potentials, resulting from their structures. If they do not have some types of potentials, the fact is considered by assigning an appropriate vector of assignment:

$$\alpha (t)=\{ \alpha EL, \alpha S, \alpha L, \alpha B, \alpha J, \alpha TE, \alpha EN, \alpha M, \alpha R, \alpha E, \alpha T , \ldots t \}$$

However, individual partial potentials can have a validity coefficient range assigned in view to the current goals of the functioning of the system:

$$_{\beta} (t)=\{ _{\beta}EL, _{\beta}S, _{\beta}L, _{\beta}B, _{\beta}J, _{\beta}TE, _{\beta}EN, _{\beta}M, _{\beta}R, _{\beta}E, _{\beta}T , \ldots t \}$$

Therefore, further it is:

$$VSEL=\alpha EL\ _{\beta}EL\ VEL$$

$$VSS=\alpha S\ _{\beta}SV$$

$$\ldots$$

$$VST=\alpha T\ _{\beta}T\ VT$$

The overall potential of the system is a function:

$$VS(t) = L (VSEL, VSS, VSL, VSB, VSJ, VSTE, VSEN, VSM, VSR, VSE, VST, \ldots t)$$

Maximum abilities of the system (*VSmax* – maximum limit of the potential), might be achieved when every component of the potential reaches its maximum value (extreme).

Minimum (*VSmin*), limit of the potential of the system that allows its functioning, depends on the minimum level of potentials of its components *VSi*:

Recognizing components of the potential *VSi*, which value is smaller than the minimum limit *VSmin* is a confirmation of loss of functional abilities. Therefore, the deficit of assets (resources), if is not compensated (supplemented), can cause in consequences a state of unreliability of system requirements.

“The extreme of the partial potential in the system, the minimum potential *VSi=VSi min*, or the maximum potential *VSi=VSi* max, can be accepted as a potential; a critical resource, because of the security of the system” (Łozowicka & Stupnicka, 2000, p. 75).

If at least one of components of the potential *VSi* has a value that is smaller than the minimum – *VSi min*, the system loses the ability for functioning (resource deficit). Also, crossing over the maximum limit of value for partial potentials can cause a loss of functionality of the system.

Different interpretations of „critical resources” in the literature of the subject can be a result of quantitative limitations and simultaneous use of the same resource in all operation chains of the determined system. These assets affect the current functioning of the company and they might cause disadvantageous conditions for the functioning and result with a change of the state of the system.

3.2. Aspects of the process designing

Works on the model of production processes are currently realized by many researchers; they enclose models:

- abstractive – drawings like the model of a process of machine maintenance (Jurga and others, 2010, p. 121), verbal description, like diagnostic tables for the production process in the steam station of a refinery (Kościelny, 2010, p. 127), mathematical equations, like the presentation of a model of a production system (Pawlewski, 2011, pp. 101-110)
- substantial – e.g. modeling the position of the car driver in the ergonomic risk assessment (Górny & Dahlke, 2013, p. 97). Presented examples illustrate different accuracy of modeling real systems, mostly in view to the target, which is important in the determined analysis and where the chosen functional module of the system was selected for specific purpose.

However, in the initial part of presented elaboration the author shows that the safety of work remains the superior problem of production processes. As “safety in technology is a result of certain environment and objects – products in it (Butlewski & Tytyk, 2011, p. 5)”; therefore designing system relations is important in descriptions of resources of organizations. The basis for this is the description of processes, especially of the sequence of actions and its consequences, which form the damage of the object and the transition of the object from its state of usability to unfitness.

The general damage of the object is a state, in which at least one measurable or unmeasurable features of the object stops to fulfill established requirements.

In result of the influence of the environment and working mediums, features of objects are changing. By following diagnostic signals it is possible to recognize and identify disturbances, for example in a production process (Niziński, 2000, pp. 72-75). Because of disturbances, the work subsystem manifested by a model in form of chain of actions (employee, device and technological process) changes the state from reliance to failure, passing many intermediate states. Modeling relations in the chain of actions, with use of the tacit knowledge, it is possible to specify significantly the assessment of deficits in potentials of production processes.

The category of interaction between man and technology in the chain of actions is a system characteristic. A system characteristic is a feature of the element that does not result from this element in a natural way, but it comes out because of iterative characteristics of the entire system (Jaźwiński, 1993, p. 24). The system of the chain of actions takes over feature of other elements of the system; this allows it to constitute an important source of information on exploitation, in view to keeping requirements of the safety at work.

4. MODELING THE PRODUCTION PROCESS

The structure of the model of exploitation processes (Fig. 2) gives important information on conditions for the cooperation of man and technology in sensitive situations of transition between states of the system. The model of the process of exploitation in form of a sequence of states is directed in the same time on the passage of time and on features of the object changing in time, which is described in it (Kaźmierczak, 2000, pp. 165-168). The model of exploitation processes uses temporary states of the exploitation system – *St(i)*. such states are observed in points determined in the beginning on the axe of life cycle of the system. In case of many features of the objects, intervals of acceptable values are determined, trespassing these limits is interpreted as a damage, for example established value of maximum clearance in the shaft-pan system. The time until the moment, when the feature exceeds the acceptable value is the time of the correct work of the technical element of the system. In the process of modeling production processes values Δt have an assigned critical value of time for fulfilling the deficit of system potentials.

Potentials must be assessed in a practical way, in view to their characteristics, which have been clearly determined for specified resources in the initial stage, in accordance to determined categories of resources presented in the subsection 2.1.:

ad.1. The force of systemic relations in form of a feedback that gives the effect of synergy (sufficient/insufficient).

ad.2. Adequacy of applied technical means, i.e. adjustment of features of elements in view to their destination (adequate/inadequate).

ad.3. Range of competences of the staff, which enables improvement of the efficiency of their operations (accurate/inaccurate).

ad.4. Level of the implemented knowledge on the nature of coexisting environments that form a system (high/low).

ad.5. Reliability of information systems, i.e. ability to transmit a correct information on the state of the system. The reliability of an information system is measured by the probability of a correct transmission of an information on the state of the system (reliable/unreliable).

ad.6. High level of explore, its quality for devices used in the production process (appropriate/inappropriate).

ad.7. Stability of power in used sources of energy (good/bad).

ad.8. Efficiency of regulative mechanisms responsible for the balance in the system (good/bad).

ad.9. Level of financial limitations (appropriate/inappropriate).

ad.10. Lack of critical paths in production processes, deficit of time (occurs/does not occur).

The obligation of carrying out measurements of elements of the material work environment resulting from legal regulations and principal requirements related to this obligation, enclosed in the Labor Code, is described in the work entitled "Methods of measurement in safety of work and ergonomics" (Górny & Dahlke, 2013, pp. 19-99).

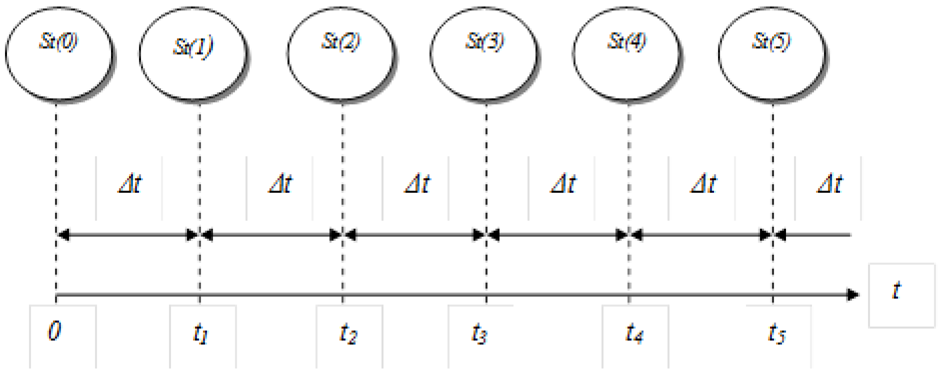

Fig. 2 Graph of the model of the exploitation process in form of a sequence of states (personal elaboration)

There is an efficient method of concluding in case of uncertain and imprecise data – it is the fuzzy logics, obtained both from workers and on basis of observations of processes during the stage of preparing the prototype. In result of the application of the fuzzy logics for the assessment of process variables, fuzzy diagnostic signals appear […]. The diagnosis points at defects and suitable level of activation of rules, which are interpreted as indicators of the appearance of particular defects. […]. In practice, one can never be certain that the assumed set of defects includes all potential failures. Rules omitted in the base correspond with states of the object with omitted defects (Kościelny, 2010, pp. 127-128). Applying the analogic operation method for realization processes for tasks of the worker, one can obtain important information on factors of his reliability.

In the stage of preparing the prototype, employees record their observations, on basis of own experience and knowledge. Collecting these pieces of information for the operation database can be used in descriptions of dependencies that employees observed in view to the functioning of the chain of actions. This knowledge has a systemic character in it qualifies for creating fuzzy models, based on a so-called tacit knowledge (Fig. 3). It is important to notice that the use of these rules for concluding in managerial decisions is a method of implementation of the tacit knowledge on phenomena that accompany production processes. Basing on data obtained from observations of the behavior of the worker, it is possible to determine functions of dependencies, which have the acceptable probability of occurrence can be implemented as a critical value during the fulfilment of deficits of resources. For functions of membership presented in the figure 3, the process of dispersing can be proceeded as follows:

μ (B) loss of attention (t=100 minutes) = 0.75,

μ (B) maintenance of attention (t=100 minutes) = 0.25

μ (C) strong fatigue (t=190 minutes) = 0.45

μ (C) average fatigue (t=190 minutes) = 0.1

where:

μ (B) – difficulty in keeping the attention, depending on the length of usage of the technical object, measure in minutes,

μ (C) – fatigue, depending on the length of exploitation of the technical object, measured in minutes.

The system approach in the design of technology assumes only a very detailed knowledge on particular subsystems (e.g. technical subsystem, biological subsystem, psychological subsystem, ecological subsystem, etc.), but most of all, it assumes knowledge on relations that take place between individual subsystems and on the general structure of the entire system (for example of the organization unit).

Thus, the composite character of the task context of the worker decides on modeling the approach of the work system that would create conditions for the verification of recognized phenomena during the specific course of the production process, like a failure. It requires proceeding a decomposition of the system of work to diagnostic levels and preparing a cross-section of a decomposed technical object (system). It is possible to accept following criteria of selection of subsystems that should be diagnosed:

- Criterion of safety,
- Criterion of probability of damage of elements,
- Criterion of costs of damages,

- Criterion of reliability and economics (Woropay, 1981, [following:] Niziński, 2000, p. 87).

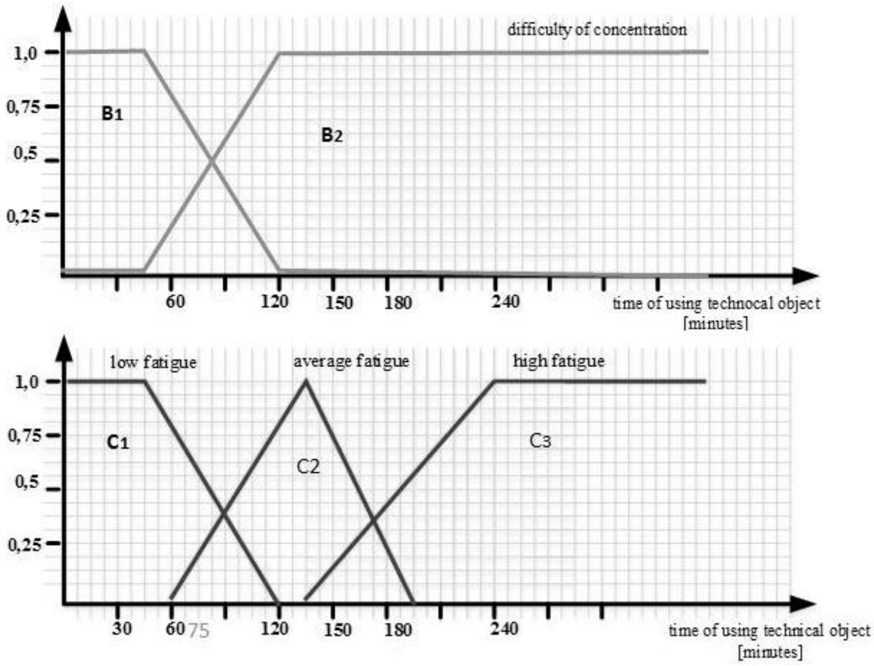

Fig. 3 Functions of dependencies (personal elaboration)

Assuming, alike W. Tarnowski, that "the system is a set of elements and relations between them. Elements of the systems are features of material elements of a material system, one can use their description in modeling phenomena being in one's center of interest, related with the production process. In view to the dynamic systems theory, the state of the process can be characterized with values of certain variables *X ={x1, x2, ..., xn}*, where *x є X* – systemic resources. They are called state variables (Tarnowski, 2004, p. 16). Thus, the state of the process is a vector *x = [x1, x2, ..., xn]*, which can have a status of critical systemic values and can be used for the description of parameters in the system analysis of production processes in studies for ecology.

The complex approach to the ecological modeling of production processes can be presented in following stages:

- Stage 1: Topological model of chain of actions (Niziński, p. 125), which can be prepared on basis of the technological chart, instruction chart of processing, normative chart of processing, operation and maintenance manual.

- Stage 2: Model of the process of exploitation as a sequence of states (scenario for processes of exploitation of technical devices) directed in the same time on the passage of time and on features of technical objects changing in time (Kaźmierczak, 2000, p. 167).
- Stage 3: Describing the tacit knowledge in form of a function, prepared for the concluding on basis of the fuzzy logics (fig. 3).
- Stage 4: Preparing the vector of the signal (observation) in a form of an ordered sequence of numerical data of parameters of signals (Niziński, 2000, p. 74).
- Stage 5: Fusion of data in a form of a diagnostic table with a diagnosis on the deficit of resources in the area of conclusions (Kościelny, 2001, p. 232).
- Stage 6: Modeling processes of concluding in a form of a decisive table (Kaźmierczak, 2000, p. 139); (Sławińska, 2011, p. 116).

5. CONCLUSION

Ergonomic studies make easier recognizing elements and relations in the system. They allow obtaining beneficent conditions for proceeding the assessment of safety in production processes. In the same time, they can be one of exploitation ventures, aimed at minimizing negative changes of indicators of the exploitation (resistance to damages, safety, readiness, efficiency). Thus, it is possible to declare that the system analysis of the chain of actions enriches information resources on the exploitation and affects the modification of the production process in the aspect of ecology, very often without the necessity of introducing changes in the construction of the system.

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BIOGRAPHICAL NOTES

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