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An Alternative Approach to Reducing Aging of Innovative Industrial Products in Terms of Industry 4.0

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Abstract **- The rapid progress in the field of industrial and information-communication techno-logies and their impact on production systems are putting increasing pressure on the engineering structure. That is why modern technological deve-lopment has created conditions in which innova-tive obsolescence already takes precedence over physical. A particularly important point in this direction is the correct determination of the degree of influence of innovative aging on products and processes in order to establish its impact on the technical, economic and social results of industrial activity. In addition, the impact of this process is globalizing, resulting in innovative obsolescence of technology and lagging behind the level of advan-ced technologies from modern ones world-wide. The further use of innovatively obsolete equipment and technological processes leads to certain losses, the amount of which will depend on the degree of this lag. This report proposes an alternative approach to reducing the innovative obsolescence of industrial products by modernizing and creating sustainability in the engineering space. At the same time, innovative progress in the future will put increasing pressure on the technological structure and on the distinctive features of this process. A theoretical attempt has been made to calculate mathematically innovative aging, and the impact of destructive innovations is difficult to capture with this model.**

Keywords - innovative aging, engineering space, modernization.

I. Introduction

Industry 4.0 is a concept that encompasses several aspects of the fourth industrial revolution. It should be noted that the main innovation of Industry 4.0 is the redesign of technological and organizational processes as a result of the integration of different sources of information with management and production pro-cesses. It is the result of non-traditional use and a combination of existing technologies to create new business solutions that satisfy customers. The develop-ment of the production capacities is related to the service life of the machines and their physical and innovative obsolescence. This obsolescence can be partially predicted and controlled if the following alternative actions are performed: monitoring their reliability and renewal, reducing downtime, improving machinery and equipment, improving the production cycle, monitoring and, if necessary, adjusting the monitored indicators [1].

The condition and development of the equipment in the process of its operation depends on the change of its parameters. This change can be managed if the influencing factors are studied and the relative share of the dominant parameters in determining the capacity of the equipment itself in the particular company is determined. Innovative aging is linked to the life cycle of innovation. At the current stage of technical deve-lopment, two factors have a significant impact on innovative aging:

- innovative development in the field of machinery and technology in the industries producing means of production;

- designed and implemented in the production of new, more modern, more productive and with better technical and economic indicators machines in comparison with the previously produced ones.

Taking into account these factors that characterize the quality side of innovative development allows to reveal not only the mechanism of its impact on the indicators of production efficiency, but also its impact on different aspects of the production process [2]. Process reengineering is not always the optimal solution, but it is a tool for their improvement and leads to economic, technical

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and environmental effects. Digitalization is entering all spheres of life and will inevitably affect the technological processes in the industry and in particular the innovative aging. The time for registration of a Patent or Utility Model is not a constant value, and the innovations do not stop, which is a prerequisite for the delay of their registration. A new approach is needed for their registration, thus there will be no factor delaying the introduction of innovations in industrial practice. This can be solved with the help of a Global Database in which to innovate and move forward without bureaucratizing the process and wasting time and resources. The innovative obsolescence of industrial products is the subject of research by a team of the following authors Dimitar Damyanov, Siika Demirova, Beata Vlahova in their works, to which I belong [1, 2, 12].

The impact of innovative development is globali-zing, as a result of which there is an innovative obsolescence of technology and lagging behind the level of commissioned technologies from modern ones. The further use of innovatively obsolete equipment and technological processes leads to certain losses, the amount of which will depend on the degree of this lag. Thus, there is a certain relationship between productivity as a world-class level and technical development. It is expressed in the achieved technical stages of development, taking into account the differences in the respective levels and the increase of productivity. The indicators determining the technical levels and productivity are closely related and interdependent, as they are defined by technological development at a given time, which in turn is a result of the achieved productivity of technology as a degree of development of scientific and technological progress. The physical essence of these dependencies is expressed in shortening the periods of creation of new technical solutions, inventions, technologies, modern constructions, know-how, etc. and increasing their productivity in absolute and relative terms for each new period. Therefore, the periods of innovative obsolescence of technology become shorter over time, and technical levels - higher for each subsequent period. These are objective technical laws, which with the technological development mark accelerated steps for each subsequent period. The future development of industrial activities will be characterized by ever higher technical levels and higher productivity, rapid innovative aging and global intensification of processes and activities. At the same time, these dependencies form new spheres, generating a new environment of development, flexibly balanced by the influence of internal and external factors. Now we can not talk only about individual innovations and innovation processes, but about innovative production, considered in a complex way. The impact of the external environment determines the basic requirements for the technological behaviour of companies and creates the prerequisites and conditions for a new attitude to innovation as an integral and necessary part of the global development of industry and society. The impact of innovative development is globalizing, as a result of which there is an innovative obsolescence of technology and lagging behind the level of commissioned technologies from modern ones. The use of innovatively obsolete equipment and technological processes leads to certain losses, the amount of which will depend on the degree of this lag. The future development of industrial activities will be characterized by ever higher technical levels and higher productivity, rapid innovative aging and global intensification of processes and activities [7]. Technological development and more precisely its consequences, manifested in the form of innovative obsolescence of products and processes, lead to a kind of attitude of manufacturers to seek ways and means to improve and change their parameters.

II. Exposition

The essence of the problem - innovative aging and modernization

Modernization is one of the most effective forms of rapid implementation of new technical and technolo-gical advances in the practice and process of renewal of production in the conditions of Industry 4.0. Therefore, modernization will mean the improvement of those components that determine the level of the product or process, which will give it advantages inherent in simi-lar products and processes, but with more modern parameters and higher productivity. By innovative obsolescence we will understand the lag of the level of the put into operation equipment and technologies from the newly produced innovative machines and techno-logies [2]. As a consequence of this lag, they become more uncompetitive, which leads to certain losses.

Innovative obsolescence imposes conditions that companies must comply with. This stems from both the technological attitude and the strong impact of consumer interest in new products [4]. That is why more and more companies are starting to apply flexible technological and organizational forms of behavior to the surrounding industrial and market world. In essence, this means that a global innovation policy is beginning to take shape, the manifestation of which is beginning to take flexible technological and organizational forms in specific companies [5]. This policy is increasingly adapting to the global industrial behavior of innovations as a resource for their future development. The main directions, providing an effective way out of the limitations imposed by the rapid innovative obsolescence in the creation of competitive innovative products, are actively applied by many companies in the automotive and electronics industries [3]. This new approach, quickly adopted by industrial companies, is already showing its advantages in the competitive qualities of both industrial products and in increasing the efficiency of its application.

The rapid innovative obsolescence of products and services poses to humanity the solution to the problem of eliminating the harmful effects of its impact. This is especially necessary when issuing protection docu-ments, such as patents, where the term for their issuance is longer than the emergence of a new innovative solution [6]. Or we can say that the innovative product is innovatively obsolete before it is even put into operation. With the current development of information and communication technologies, this problem can be solved with the creation of a European or World Information Center, with open access to a database. Thus, to grant patents only for such products and technologies that have a proven long innovative life. For all other inventions, open access to them should be made and used for a fee [10].

We can summarize that innovative development, innovative aging and modernization are interrelated manifestations of the same process, they are constella-tion-bound. In addition, innovative obsolescence can be studied, controlled and controlled through moderni-zation methods and forms of application. To this end, an approach and a way to determine the magnitude and extent of innovative aging can and should be proposed. Also to determine in a timely manner the coefficient of modernization of technical means that are not equipped in the enterprise. The aim of this thesis is to analyze the impact of technologies in the environment of Industry 4.0 on the sustainability of the integrated engineering space throughout the production chain, with the industrial benefit to focus on the synergistic effect of its overall application [7].

Modernization as conditions for integration of engineering components in the production chain

The development of engineering is inconceivable without the computerization of the management of engineering processes. The role and goals of the engineering processes in the modern conditions, through the sphere of production, turn to the requirements of the end user, flooding him with powerful flows of individualized products. The requirements for the quality of the processes are also increasing, and they must be faster, more accurate, more economical. Characteristically, the information support of the engineering and reengineering (modernized) process has been radically changed. Currently, the integration of reengineering activities is carried out primarily with the introduction of information systems [8].

One of the main requirements in this direction is the correct formulation of the concept of information flow and information system. The information flow is a set of information modules that are distributed in the engineering system and between it and the external environment, necessary for the management and control of engineering operations. Modern engineering information flow can only exist in the form of electronic media. Therefore, the automation of engineering components, or the modernization of these activities as an element of company development are also considered as a complex solution with automation of company activities [11]. The characteristic here is that the engineering chain includes both the internal company connections and those that define the external influences for the need to modernize the automation equipment. In this way, the information engineering activity forms a fully integrated information space.

The functional dependence between the engineering information systems (EIS) and the internal and external connections can be expressed by the following formula:

$$EIS = f(S_v, S_w) \quad (1)$$

Where:

S_v - internal interconnections;
S_w - external interconnections.

The internal-structural interrelations are studied and arranged by significance and belonging according to certain features to the engineering information system. These are the interrelationships between the engineering of technology and the material flow realized through the Internet of Things. Therefore, this is the possibility to use a digital engineering and reengineering information system, which is related to machines and automation equipment within the company. This includes the construction of a reengineering virtual model in virtual reality with a mirror image - software implementation.

External links are related to the types of engineering subsystems, including those with external suppliers, customers, etc. throughout the engineering chain.

The second no less important issue is the construction of engineering information systems in terms of their functionality (functional structure).

Before talking about the functionality of the engineering information system, they must determine the types of information flows that penetrate the system itself. The specificity of the engineering information system is determined by the fact that the flow management is performed both within the industrial company and between the various participants in the engineering and reengineering chain of the intelligent innovative and flexible Industry 4.0.

In this regard, information flows are divided into two main types:

- Strategic (coordinating) and
- Functioning.

Individual functions (functional subsystems) can be included in both types of data flows (in inventory management).

The strategic (coordinated) flow also includes key functions of the logistics information system, which is part of the digital engineering system [12].

Digital intelligence in the engineering and modernized information system

The methodology of digital intelligence forms a set of requirements that are necessary for the future functioning of the engineering and reengineering information system in the environment of digitalization and Industry 4.0. This requirement is imposed from the point of view of preliminary construction of the technical levels of the system. In this aspect, the engineering information system adapts the following levels:

- Technical level of the system (electronic levels of engineering and reengineering information system of a specific industrial company);

- Technical level of the site (virtual or real engineering or reengineering information object);
- Artificial intelligence (control intelligence), which includes: a range of functions that artificial intelligence can perform (1… .n) and functions that have a complete replacement of man (F of the total number of n-functions) by introducing engineering and reengineering information systems.

Formation of engineering and modernized information depots for storage in virtual reality of information modules

This includes the possibilities for self-differentiation of functions in the re-engineering information systems and their adaptation as modules for incorporation in other processes, which are characterized by the following engineering activities:

- Approach for construction of information depots for storage of information systems built into the reengineering process.
- Delivery of information services via the Internet (embedded information systems - software). They are coded independently and separated by functions and purpose systems (software product), offered on the market as a commercial product for the needs of engineering and reengineering.
- Approach for building engineering and reengineering information systems in the cloud.
- Offering virtual engineering and reengineering reality in the cloud [13].
- Cyber security of processes.

In order to more accurately and correctly account for the benefits and effects of innovative development and innovative aging, the development of the problem should be considered comprehensively. This means that the qualitative nature of components such as the degree of innovation, innovation activity, innovation obsolescence and alternative solutions to rapid innovation aging should be considered as a comprehensively integrated solution approach. The integration nature of this approach is based on the fact that it involves more influential factors that affect the efficiency of innovation activity of industrial companies [12].

The structure of the solution includes several models defined as:

- Model for determining the degree of innovation;
- Model for innovation activity [15];
- Model for innovative aging;
- Model for alternative solutions.

Model for determining the degree of innovation

Mathematical models can be applied to determine the degree of innovation of products and processes, and specific indicators are used to solve them, defining the concept of innovation as novelty, applicability and commercialization.

- Technical indicators (novelty);
- Indicator determining the consumer nature (applicability);
- Commercial realization (market).

The model for determining the degree of innovation is used to calculate the novelty in cases where it is sufficient for a particular purpose of research to focus on the innovative nature of the problem.

In the development of innovative products, technical, consumer and market indicators or

$$C_{imo} = C_{teh} + C_{pot} + C_{mt} \quad (2)$$

are used, and the degree of innovation is defined as the sum of the results of the separated indicators, taken as relative weights subject to the condition:

$C_{teh} \leq 1$; $C_{pot} \leq 1$; $C_{mt} \leq 1$;

$C_{ino} \leq 3$ - Degree of innovation.

Technical indicator (C_{teh}) (novelty) - calculates the savings of materials, labor, energy, quality improvements, etc. of the new product compared to the old or similar.

User indicator (C_{pot}) - the number of users (C_{pot}) who will accept the new product is predicted and we use empirical dependencies for diffusion of innovations.

Market indicators (C_{mt}) - for sales and include three components: C_{inv} - investment (production) costs; C_{kk} - quality and C_{eko} - ecology.

Model for innovation activity [1

The definition of innovation activity for a given period of time, with pre-set parameters, can also be modeled [16]. The model of innovation activity reveals how products are perceived as attractive between real and potential consumers. The innovation activity model can be widely used in product and technology forecasting. The mathematical basis of the innovation activity model is the diffusion model. The wording of the model is based on:

$$S(t) = m.f(t) \quad (3)$$

Where:

f(t) - the degree of change of the received or introduced activity;
m - potential;
S(t) - the sale or degree (value) of the change in the accepted introduced activity, i.e. perception.

Then the innovation activity can be expressed by S(t) or:

$$S(t) = \frac{m(p+q)^2}{p} . \frac{e^{-(p+q)^t}}{1+\frac{q}{p}.e^{-(p+q)^t}} \quad (4)$$

p - the coefficient of innovation, taking into account external influences or advertising effect;
q - the coefficient taking into account the internal influences or the effect of the functionality;

Values of p and q are experimental.

The model is suitable for use in a wider range of innovative products, although the solutions vary widely, mainly in pricing and advertising [1, 2].

Model for innovative aging

Innovative obsolescence is measured by the degree of depreciation of some of the functions of old machine constructions compared to those of newly manufactured innovative ones. Their determination is performed in the following sequence according to the formula:

$$M = W.C \quad (5)$$

Where:

M - innovative aging (depreciation of the functions of old machines) (BGN);

W - initial value of the old machine (BGN);

C - Coefficient taking into account the level (%) of innovative obsolescence (0 ^ 1).

C moves in the range $0 < C < 1$, where:

C = 1 has no innovative obsolescence (the machine is 100% innovative).

C = 0.5 the machine is half innovatively obsolete or 50%.

C = 0 the machine is completely innovatively obsolete or 0% innovative.

C - defines innovation only in the range from 0 to 1.

C = (1 - E) where:

E - degree of innovation of the machine at a given time (at the time of measurement).

Research and determination of the coefficient for innovative aging and modernization

The study was conducted in the following areas:

- Dynamic change in the value of the new industrial product to the value of the old product at certain intervals.
- Dynamic change of the productivity of the new industrial product (of certain indicators) to the productivity of the old industrial product.

Degree of innovative aging

The degree of innovation (E) determines how much more innovative a machine is (%) with the comparable machine. It is defined as follows:

$$E = \frac{D_1}{D_2} \quad (6)$$

$$D_1 = \frac{V_1}{V_2} \quad (7)$$

$$D_2 = \frac{Q_2}{Q_1} \quad (8)$$

Where:

D_1 - ratio of the value of the new machine to the value of the old one.
D_2 - ratio of the productivity of the new machine to the productivity of the old one.
V_2- Value of the new machine.
V_1- Value of the old machine.
Q_2- Productivity of the new (innovative) machine.
Q_1- Productivity of the old machine.

We replace and receive:

$$K = 1 - \frac{D_1}{D_2} \quad (9)$$

Additional explanations to the main indicators given above:

1. The ratio $\frac{D_1}{D_2}$ must be positive (+), which indicates that we have innovation, or the degree of innovation of the machine is growing. With a negative ratio (-) the conclusion is that the innovation of the machine decreases or the machine is not innovative. In essence, this means that D_2 must take precedence over D_1 or the price of the new machine must be in optimal proportion to the price of the old machine. And the productivity of the new machine must always be higher than the productivity of the old machine.

2. For $V_2 = 0$ and $Q_2 = 0$ then both $D_1 = 0$ and $D_2 = 0$;

3. Determining the duration of the production periods of the types of machine constructions such as:

- Conventional or class A, these are traditional machines and class A_1, these are machines for which the reliability /warranty/ service life indicators are the same over time.
- Mechatronic (on a modular basis) with an optimal ratio between the indicators reliability/warranty period/service life.
- Machines for cyber systems.

4. The ratio (1- E) can be at the nth degree, when we follow the development of the innovation process of innovations with world novelty.

n_1 - the next innovation against which it is measured (serves as a base).

h - scale factor (from 0.5 to 1.00) or range of manifestation.

h = 1, at n = 1, only applies to world-class innovations.

h = 0.5 at n = 0.5, only applies to innovations with a regional scale of innovation impact.

Then:

$$C = (1 - E) = \frac{D_1}{D_2} \tag{10}$$

TABLE 1 BASIC DATA

Indicator	Contents	Value
V_2	New price	500 to 450
Q_2	Productivity of the new machine	150 to 100
V_1	Old price	300 const
Q_1	Productivity of the old machine	100 const
$\frac{V_1}{V_2}$	Price ratio	$D_1 = \frac{V_1}{V_2}$
$\frac{Q_2}{Q_1}$	Productivity factor	$D_2 = \frac{Q_2}{Q_1}$
K_n	Modernization coefficient	K_n

The following results were obtained, shown in Figures 1, 2 and 3.

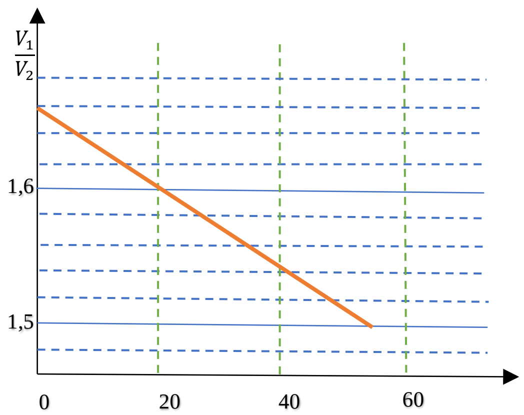


Fig. 1. Price ratio (D_1)

The results from the above graphs show the following:

Initial $\frac{V_1}{V_2} = 1.66$ and final data $\frac{V_1}{V_2} = 1.5$ are shown in Fig.1.

Fig. 2. Productivity factor (D_2)

Initial $\frac{Q_2}{Q_1} = 1.5$ and final data $\frac{Q_2}{Q_1} = 1$ are shown in Fig.2.

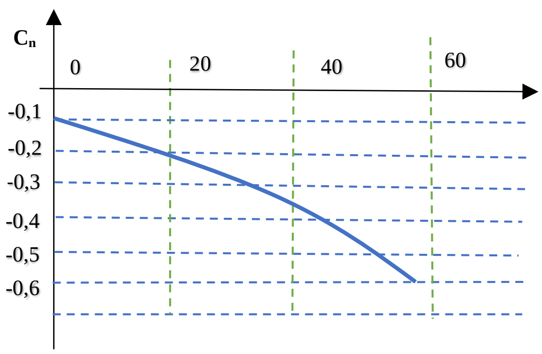


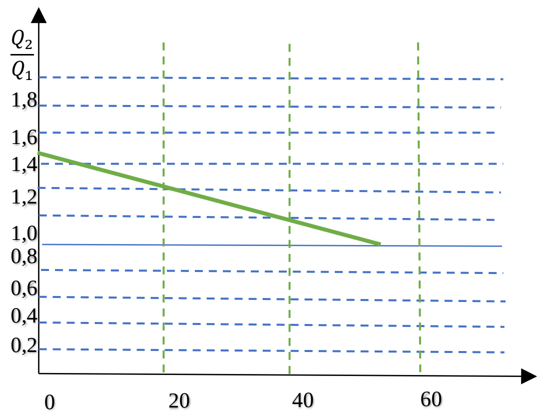
Fig. 3. Modernization coefficient (K_n)

Initial C_n = -0.11 and final data C_n = -0.5 are shown in Fig.3.

The strategic policy of industrial companies is inconceivable without a well-developed, assessed and meaningful policy for technical development, which takes into account the innovative aging, as a major factor in this development [9]. It is theoretically substantiated and practically proved that moderniza-tion approaches and methods can largely eliminate the harmful effects of innovative aging. Therefore, industrial policy actually forms the concept of technical and economic indicators of the company and is a major factor for its prosperity [14]. It should not be overlooked that the rapid technical progress in the field of industrial and information technology and its impact on production systems will put increasing pressure on both their structure and the distinctive features of this process. Borders will increasingly blur and the structure of production will change significantly. The striving for complex improvement of the technolo-gical, auxiliary and information activities will be more and more necessary as a main factor for the development of the modern production. This means that based on new communication and computer advances, nanotechnologies and other technical solu-tions, the structure of production will change globally. In the future, production will be considered as a whole, including technology, technological and information processes, as well as functionally integrated production components, throughout the engineering cycle. The study presented in this topic analyzes the impact of technology on the sustainability of the integrated engineering space throughout the production chain and the role of modernization in this process.

III. CONCLUSION

Based on the above, it can be concluded that the defining characteristics of engineering information



systems are derived, which define a higher level in the functional spectrum of engineering systems. They create an opportunity to expand the scope of the integrated engineering information space. In this direction, the guidelines for the formation of re-engineering information depots for storage of information modules in virtual reality are determined.

In conclusion, it can be said that innovative development, innovative aging and modernization are interrelated manifestations of the same process. In addition, innovative aging can be studied, controlled and controlled through modernization methods and forms of application. For this purpose, an approach and a way of determining the size and calculating the amount of innovative obsolescence of products and processes and determining the coefficient of modernization are proposed. A toolkit for practical use and application of the coefficients is also proposed.

The constellation connectivity of innovative development, innovative aging and modernization are decisive for this process. It is important to note that innovative obsolescence can be studied, mastered and controlled through modernization methods and forms of application. This is achieved by determining the magnitude and calculation of the amount of innovative obsolescence of products and processes and by determining the coefficient of modernization in technology and systems.

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