Cognitive model of digital production development

Alla Brom and Yuliya Maslennikova
Bauman Moscow State Technical University, Moscow, Russian Federation, 105005
maslennikova.yuliya@yandex.ru

Abstract. The aim of the work is to develop a cognitive model that reflects clear, structured, formalized, obvious relationships between the social – economic factors of digital production. The main problems of industrial enterprises are reflected, digital industrial technologies are studied, the main factors of influence on their development are considered, methods of assessing the impact of factors on the development of technologies are studied, and the cognitive model is developed. The practical significance of the paper lies in the possibility of using the presented cognitive model by industrial enterprises. This will improve the efficiency of digital technology implementation and the use of available resources.

1. Introduction
The global industry is entering an era of industrial change. Nowadays, we increasingly associate production systems with such concepts as "Smart production", "Internet of things", "Big Data", etc. [1-2]. Industry 4.0. entails the emergence of new industries and changes in existing ones, enterprises become more flexible and adaptive. Many authors raise the topic of industrial transformation within the framework of digitalization of economy in their works. [3-4]. The emergence and spread of digital solutions in the Russian Federation are at a low level. The reasons may be in the complexity of implementation, the historical technological gap from Western partners, a low level of investment in digital innovation, digital inequality inside the country, reducing of healthy competition. To increase competitiveness in the global market it is necessary to move Russian production systems to a new level. The sources of the evolution of production systems are not only automation technologies, but also social changes generated by the transformation of the digital economy. [5-6]. Moreover, these processes are interrelated. However, these factors are weakly obvious and not formalized. For clarity, we consider the mentioned problem by the example of industrial company OOO «Voenvno-promishlennaya companya» (OOO «VPC»). The company develops and manufactures armoured vehicles, multi-purpose and lightly armoured vehicles, special vehicles for security and law enforcement.

An original and innovative aim of this paper is to model the socio-economic processes of digital production. Industrial enterprises will be able to discern imperfections and gaps in the strategy of digital technologies implementing and to improve the transition to a new production level efficiency.

2. Research Method
Many authors use statistical-mathematical methods to evaluate the effect of various factors. Deterministic and stochastic methods are simple methods of calculating the factors influence. To calculate factors that do not have a direct impact on the resulting indicator regression and linear programming, correlation and ranking methods are used. [7]. However, these methods do not provide
a full picture of interactions between the factors themselves and the development of the resulting indicator.

The authors will use the method of system dynamics, namely the construction of a cognitive model. American scientist R. Axelrod proposed the methodology of cognitive modelling for the analysis and decision-making in difficult certain situations. [8]. The essence of the cognitive approach is reflected in the preparation of a simplified model that shows the complex and unpredictable trends of the situation development. To analyse the behaviour of a complex system, a scheme of cause-and-effect relationships is constructed, which is called a cognitive map or a directed graph. Connections can be positive and negative, what means that the increase (decrease) of one factor leads to an increase (decrease) of the other, and the increase (decrease) of one factor leads to a decrease (increase) of the other. Firstly, to build relationships, the target factors of influence on the resulting indicator are selected, then additional factors and leverages. After that, it is necessary to find out what factors and leverages have a connection. The completion of the construction is a functional graph; here we characterize the relationships by quantitative or linguistic variables that take values in the interval [0; 1]. Further, the cognitive method allows us to analyse the system from two sides: in terms of its structure and in terms of its dynamics. Static analysis is studying the structure of mutual influences of cognitive map factors. This analysis allows us to identify the factors with the strongest impact on the result indicator, i.e. the factors whose values need to be changed. Dynamic analysis shows the development of the situation in time.

3. Results and discussions

3.1. Machine-to-machine technology

The most striking trend among the digital production technologies is the industrial Internet of things, which includes the technology of machine interaction (Machine-to-machine). [9]. Machine-to-machine (M2M) is a technology that allows enterprise devices to communicate with each other without human assistance, using wired and wireless sensors. The technology M2M realize the opportunity to improve the quality of products and reduce the degree of defects, in equipment diagnostics and optimization of repair time, eliminating unnecessary preventive maintenance, to avoid downtime, to ensure effective service, including the customer’s site and to reduce operating costs of production. The technology allows transferring large data in real time. It helps to monitor constantly the quality of ongoing assembling processes, to simplify and speed up logistics processes, to minimize unwanted costs.

OOO «VPC» faces the same problems, as well as other industrial enterprises, namely: low level of competitiveness, unjustified size of expenses, obsolescence of fixed assets, lack of innovative activity, big expenses of a time resource, low level of service. The digitalization of production can help plants to overcome these barriers. It is interesting to investigate the influence of social-economic factors on the introduction of M2M technology on the example of wheeled combat vehicles assembling. Assembling as a component of the production process is a complex multi-level process described by an assembling scheme. Assembling of wheeled combat vehicles is classified into nodal, aggregate and general. Thanks to M2M technology, a model of the assembling process will be transferred to all necessary equipment. The technological process model of assembling is a complex of works description of installation and connection of components in order to obtain a design that meets the specified requirements. It is a computer model that is implemented in the information environment. During the assembling process, it describes the changes in assembling unit, the interaction of operations, the transitions from one type of work to another. The technological process of assembling design scheme is described by the following formula [10]:

\[
S(A1T)p1TA Sn(T1A) \rightarrow Sp(T1A)
\]

Where S(A1T) is the technological model of an assembling unit, the initial product description;
Sn(T1A) is a process design model formed by the elements of the generating environment technological design;
Sp(T1A) is the model of technological process - the result of transformation implementation;
pITA is a procedural-algorithmic environment of technological design.
Such a scheme describes the process of obtaining the technological process model based on the model of the assembling unit. It will be transmitted to each equipment by using sensors.

3.2. Cognitive model composition
A development of M2M technology at OOO «VPC» will be called as the level of digitalization of production in the cognitive model. We select the target factors affecting the level of digitalization of production: Implementation period; Level of investment; Level of personnel qualification.
Authors start building the cognitive model with separate feedback loops. Figure 1 shows the first cycle reflecting the impact of the level of investment.

![Figure 1](image1.png)

**Figure 1.** The impact of the level of investment on the development of digitalization of production.

It is an amplifying loop, which reads as follows: "The higher the level of investment, the higher the level of digitalization of production; the higher the level of digitalization of production, the higher the quality of products, the higher the quality of products, the higher the government demand, which causes an increase of investment. Let us continue the construction of the contour with the target factor «Level of personnel qualification» in Figure 2. In addition to a cycle, this graph shows the leverages «Age», «Availability of additional training» and «Quality of education». Furthermore, there is a negative connection, so the loop is stabilizing.

![Figure 2](image2.png)

**Figure 2.** The impact of Level of personnel qualification on the development of digitalization of production.

We need to combine these contours taking into account the following target factor – implementation period. It is influenced by previous factors – the level of personnel qualification and the level of
investment. When the contours are combined, we can see an additional link between the level of investment and the availability of additional training. With adding a new factor and a new relationship, instead of two loops we have five cause-and-effect contours. Next, we add letter designations to factors and quantitative weights to the identified relationships. The result is a cognitive model. (Figure 3.)

The following step, we make up a matrix of effects. For example, the relationship between "Level of digitalization of production" (A) and "Product quality 0" (E) will be reflected in the matrix as $S(A;E) = +0.7$, where $S$ is a general designation of the whole matrix, A and E are the designation of factors by row and column, respectively. Or, the relationship between "Level of personnel qualification" and "Implementation period" will be reflected as $S(D;B) = -0.5$. All values are shown in table 1.

What happens if we change one of the factors by a certain amount? Figure 4 shows the development of each factor in dynamics with an increase of one of the leverages «The government demand» by 10%. The graph clearly shows the qualitative relationships between various factors and the level of digital technologies development at the enterprise.

![Cognitive model of digital production development.](image)

**Figure 3.** Cognitive model of digital production development.

|    | A   | B   | C   | D   | E   | F   | G   | H   | I   | J   | K   |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| A  | 0   | -0.7| 0.8 | 0.8 | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| B  | 0   | 0   | 0   | -0.5| 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| C  | 0   | 0   | 0   | 0   | 0.6 | 0   | 0   | 0   | 0   | 0   | 0   |
| D  | 0   | 0   | 0   | 0   | 0   | 0.8 | 0   | 0   | 0.6 | 0   | 0   |
| E  | 0.7 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| F  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| G  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.7 | 0   | 0   | 0   |
| H  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| I  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | -0.2| -0.8|
| J  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| K  | 0.5 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |

Indeed, with a Government demand increase by 10%, the flow of investment increases by 6% and there is an increase of the level of digitalization of production by 4.8 %. The product quality increases, there is a possibility of additional training. However, let us pay attention to the 10th period. It is here that the development of digitalization of production stops. It turns out that despite the growth of
governments' demand, increasing funding in technologies, the gradual reduction of implementation time and improving the quality of education, the level of personnel qualification, as the most important social factor is not growing. This is due to the continuously decreasing level of adaptation, which is influenced by the age of the workers and the factor of job cuts. In addition, implementation period is almost not accelerated, because it is also depends on the staff. This leads to the conclusion that managers are building digital policy incompetently and do not care about the digital culture within the company. Only people, namely highly qualified personnel is able to make the enterprise digital. Therefore, the company should consider the introduction of technology as a system that depends on many factors and does not start working immediately. The company needs to pay close attention to the components of social processes, because a person is the most important resource of the enterprise.

![Graph of dependence of the social-economic factors of the digital production.](image)

**Figure 4.** Graph of dependence of the social-economic factors of the digital production.

### 4. Conclusion

A cognitive model of implementation of the digital technology M2M to the industrial enterprise is developed. It has a clear structure and qualitative relationship between factors influencing the evolution of digital production technologies. The practical application of this model will improve the efficiency of implementation of digital industry.

### References

[1] I. Alpackaya, D. Alpackiy, *Perspectives and consequences of implementation and development digital economy*, MATEC Web of Conferences **193**, 05087, (2018).

[2] E. Lyapuntsova, Y. Belozerova, , I. Drozdova, G. Afanas'Ev, E. Okunkova, *Entrepreneurial Risks in the Realities of the Digital Economy*, MATEC Web of Conferences, **251**,06032, (2018)

[3] M. James. *Changing roles in the electronic age - the library perspective*, Libr. Acquis. Pract. and Theory. No 1. P. 15-21. (1998).

[4] V. Akberdina, A. Kalinina, A. Vlasov, *Transformation stages of the Russian industrial complex in the context of economy digitization* Problems and Perspectives in Management 16(4), p. 201-211, (2018).

[5] E.A. Tishina, , E.Y. Rezantseva, , D.V. Reut, *The concept of digital transformation of the society*, Proceedings of 2017 10th International Conference Management of Large-Scale System Development, MLSD, 8109697, (2017).

[6] Y.L. Maslenikova. *Problems of low retraining of specialists in the transition to the sixth*
technological mode. Management systems for the full life cycle of high-tech products in mechanical engineering: new sources of growth: materials of all-Russian science.-prakt. conf. M.: PH BMSTU, P. 116-119. (2018).

[7] V. I. Loyko, E. V. Lutsenko, A. I. Orlov, Modern digital economy. Krasnodar: Kubgau, 508, (2018).

[8] R. Axelrod, The Structure of Decision: Cognitive Maps of Political Elites. Princeton. University Press, (1976).

[9] A.V. Manzhirov, Some problems in mechanics of growing solids with applications to AM technologies. Journal of Physics: Conference Series 991(1),012056, (2018).

[10] O. S. Samsonov, Modelling of processes of engineering and design to the Assembly of aircrafts. Technology of mechanical engineering.No. 9. P. 18-26. (2007)