Modernization of Production Planning Methodology in the Context of Virtualization and Increasing Multi-Agent Meta-Environment

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Abstract—**The article is devoted to the problem of changing the production planning methodology in the conditions of the merging of external and internal environments of the enterprise, virtualization of resources in the global supply chain to ensure the flexibility of the production system. Platform homogenization of all participants of the supply chain leads to an increase in the number of agents affecting the production and technological cycle of modern production systems, which technologically complicates and reduces the speed of traditional production planning. Due to the fact that the quality of integration of the production system at all levels of the global supply chain depends on the speed and productivity of production, production planning must inevitably move to new methods of integration of large amounts of data, taking into account the growing multi-agent environment. In these conditions, traditional planning tools should be reengineered using multi-agent models in planning.**

Keywords—production planning, planning methodology, multi-agent modeling, meta-environment, production systems, platform integration.

I. Introduction

We are witnessing the evolution and complication of environmental reality on the basis of continuous technological transformation of the information and communication space.

By the beginning of the XXI century, the world economic mechanism was formed, the functioning of which determines the direction of development of national economies, and the regulatory economic functions of national states inevitably weaken.

Many believe that globalization is not just the internationalization of economic life, but the transition of the world economic space to a qualitatively different state. This metamorphosis is vaguely reminiscent of the transition of physical bodies from one aggregate state to another.

The change of the context content of the conditions of the world economy development is accompanied by a number of environmental factors that influence the adaptation of production systems.

Among these factors:

1) Broad ecosystem integration (integration of different types of economic ecosystems) based on the new context content of the world economy development conditions.

Transfer of the term "ecosystem" to the economy was accompanied by the transfer of its structural components. Any ecosystem is based on three components - cenosis, biotopes and communications, providing the ecosystem with energy and matter.

Consequently, in recent decades, the range of types of economic ecosystems is expanding. Today the species composition of ecosystems includes the following:

- business ecosystems;
- innovation ecosystems;
- venture ecosystems;
- digital platform ecosystems;
- national ecosystems, etc.

In this regard, it is appropriate to introduce another subspecies – production ecosystems.

The current state and qualitative transformation of the world economic ecosystem is not only due to a wide range of integration of multidirectional ecosystems-digital platforms, production, innovation, etc., but also the mutual integration of bio and technocenosis).

Integration of types of economic systems is also due to their mutual expansion.

In addition, integration is accelerated by moving all integrating ecosystems to a single information technology architecture and connecting them to a single information and telecommunication network.

2) Transfer of physical "space" parameters to the virtual space of digital eco-systems and networking.

Due to new products of information and communication technologies, digitalization, the objects of the material world are transferred to the virtual world through sign systems, when each material object begins to correspond to its virtual avatar and there is a mutual connection of qualitative changes in the state of the real-virtual object, both in the physical and virtual dimensions. As a result, physical space management is performed through virtual space, which allows to model, design and implement physical transformations of the object in real time, which not only virtualizes the category of "space", but also compresses the time of economic operations and transactions.

3) Digitalization (digitalization of crypto-technologies, phenomenon of blockchain).

Digitalization of crypto-technologies with the connection of technological resources of platforms, as well as the results of digitization and interactivity of tangible assets allows to compress technological transactions (conclusion and execution of economic contracts (smart contracts) to seconds, which leads to acceleration of commodity-money exchange on a planetary scale and affects the behavior of consumers and production systems

4) Reducing the time of economic transactions.

Digitalization of crypto-technologies with the advent of the phenomena of "blockchain", "smart contracts", the transfer of physical space to virtual digital platforms, distributed nature of concentration, storage and exchange of information data of a new type (Big Data) reduce the time of management decisions making and the time of execution of economic transactions.

5) The primacy of consumption in the dichotomous opposition "production-consumption".

As a result of global information openness of subjects of world economy, compression of speed of commodity-monetary exchange in the integrated platform ecosystems to seconds there is an increase in competition of producers for the consumer through scaling of the market of technological product innovations.

As a result of the expansion of technology platforms of communication between users, the exchange of goods, the creation of value are constantly being scaled, thereby changing the nature of supply and demand in the direction of strengthening the dictates of the consumer.

6) Changing the principles of the value formation mechanism.

The traditional (industrial) economy assumes a consistent and unidirectional value formation chain. The savings are achieved by the manufacturer by reducing margin costs due to the effect of scale, that is, due to the release of sufficiently large volumes of the same type of products. Its disadvantage is inflexibility, markets overstocking, negative impact on the environment. New laws of the economy based on informationalization, digitalization, platforming lead to the formation of ecosystems in which different market agents can interact together to create a common value (Shared Value). In contrast to the rigid production chains of the past, ecosystems are distributed, adaptive, open socio-technical systems with the properties of self-organization, scalability and sustainability (sustainable). The economy in this case is moving by the ecosystem participants: the greater their number and diversity, the wider the possibility of value sharing and, accordingly, the generation of a new one. However, the mechanism of value formation is accompanied by such new phenomena as:

- decentralization (distribution) of value creation;
- exchange of values networking;
- reduction of intermediary links and as a consequence - transaction costs.

The resulting changes create new problems for production systems, primarily associated with increased dynamism and unpredictability of environments, shortening the life cycle of products that are increasingly diversified in their consumer characteristics.

II. Literature review

The threats posed by the constantly changing environment for enterprises are reflected in the topics of scientific works that offer adequate methods of adaptation of management systems of organizations, their strategies to growing and constantly alternating changes. [1]

In this context, the objects of modern scientific research are: production flexibility in a wider supply chain [2], which means flexible strategy of the entire value chain, speed of reconfigurability of the entire supply chain [3], reconfigurability both of key resources of the entire chain, production systems themselves, in the last decade classified as “reconfigurable production systems” [4], and of individual elements of the control system. [5] The change in environmental reality due to technological modernization of the information and communication environment is moving towards its large-scale and comprehensive virtualization [3].

First, the internal environment of the production systems themselves is virtualized, the resources of which are transferred and concentrated in the cloud architecture due to special technologies, resulting in a new class of production systems – cloud production systems. [6]

Virtualization of the environment, in turn, is accompanied by the virtualization of the entire supply chain from supplier to customer, which takes the production system to a new level of integration, mutually-absorbing systems of internal integration (planning, resource, manufacturing and delivery) and external integration systems (of suppliers, customers, contractors, stakeholders) into a single seamless system and contributes to higher levels of production system efficiency for four well-established operational indicators: cost, quality, delivery and flexibility. [7] The benefits of combining internal and external integration systems within the growing demands of the supply chain have been explored by various researchers at different times.[8]

As part of this process, the internal environment of the enterprise becomes part of the external environment (carried outside the physical space of the enterprise), and the external environment, in turn, penetrates through the integrated network architecture of the enterprise and acquires all the characteristics of the internal environment. Secondly, the external environment itself is globally virtualized and concentrated on network platforms. [9] Both the internal and external environments of the enterprise thus become platform-based and include the following:

1) Platform environment for clients, customers and consumers of products (including social networks)

2) Enterprise supplier platform environment in the supply chain

3) Platform environment of enterprise resources that are virtualized and brought to the cloud, resulting in the phenomenon of cloud production systems.

4) Platform environment of enterprise stakeholders;

5) Platform environment of employees of the enterprise, both under direct employment contracts (social networks), and under contractor, subcontractor contracts (remote workplaces).

Thus, the internal and external environments of the enterprise merges on the basis of virtualization of resources and output of all participants of the supply chain of the enterprise into a single platform-cloud environment.

That is, the transformation of the environment into a meta-environment goes in the following direction - the virtualization of the environment of each actor in the supply chain and the transformation of its internal environment into a platform environment. As a result, there is a huge number of platforms that begin to integrate in the course of network exchange, which leads to:

- first, the exteriorization of the internal environment by bringing it into the external space in the form of information and communication platform;
- second, there is an integration of platforms of consumers, suppliers of resources, producers, stakeholders of production systems that leads to multiplication of agents of production system and accordingly production planning;
- third, due to the integration of platforms of participants in the global supply chain, the response time of production systems to consumer demands is drastically reduced. According to the reduction of response time, the requirements change not only to the reduction of the operating cycle (similar to just in time, which is called "today and now"), but most importantly to the speed of signals in the control system and, above all, in the field of production planning.

The main problem of the enterprise today, therefore, remains the flexible control of the speed of the production and technological cycle within the framework of bifurcation disturbances in the global supply chain in the context of an expanding integrated virtual environment as a multi-agent environment. [10] Management of multi-agent, including virtual multi-agent consumer system requires the use of adequate tools and, above all, multi-agent modeling, the experience of which in operational production planning in the literature today is well described. [11]

III. Research methodology

Using the factor analysis of competitive advantages of 30 leading industrial enterprises of Omsk region, which are leaders in various industries - from food production to complex aggregate equipment, as the general factors of success of enterprises representing different sectors of the economy were identified factors related to the quality of development of information and communication technologies in the direction of platform integration with various participants in the supply chain.

At the first stage, a diagnostic questionnaire was compiled for each company with questions of closed and open type, including about 250 questions, which were proposed to be answered by top managers responsible for their functional responsibilities for the implementation of the strategy and performance of the company. Thus, the main factors influencing the implementation of the main strategic goals were identified and classified – increasing market share, increasing number of consumers, reducing operating and transaction costs, etc. The main correlations between the observed variables were established.

In the future, the results were summarized in a matrix for all 30 companies and they allowed to identify the most significant factors that allow companies to achieve their strategic goals in modern conditions.

Additionally, the analyzed activities of companies on development of their server and network equipment, the state of software and information culture of key specialists confirmed the conclusions of the interviews and factor analysis.

IV. Results

In the conditions of increasing virtualization of production resources and strengthening of cross-platform integration, the main factor in maintaining the life cycle is the speed of production response to changes, dictating the need for advanced adaptation. In a series circuit changes - changes of consumer order (environmental factor) – change of production order (production factor) – change of resource order (resource factor) in the supply chain, production is the most vulnerable from the standpoint of speed of response.

If the first and third stages today, created instrumental and technological basis for fixing and change management, implementation of high-speed motion control of logistical resources (including technology-based blockchain, smartcontract, etc.) to their processing points, the second phase of change management (production) instrumental-technologically remains vulnerable.

As a result of the change in methodology, production planning should integrate all participants in the multi-agent supply chain through the management of large amounts of data within the framework of production order management, providing a solution to the main problem of modern production systems - the flexibility of production in global supply chains.

V. Practical significance

This article lays down the main methodological vector of transformation of the entire existing management system of modern production systems, and the production planning system in particular. Organized on multi-agent modeling, production planning, taking into account industry specifics, allows to increase the speed of response to changes in consumer demand and reduce the operational cycle of production as a result of seamless information integration of big data on the resources involved in the production process of various elements of the global supply chain.

VI. Suggestions

1) Production systems need to diagnose and audit the state of virtualization (with the participation of information and communication platforms) of both their own production resources and resources of all its actors (customers, potential consumers, suppliers, subcontractors, stakeholders) involved in the supply chain that forms the consumer value of products and services of the enterprise.

2) To start systematic virtualization of the production resources and creation of the cloud-production analog;

3) To integrate software and hardware based on Big Data technology information on the status and dynamics of resources of all platform participants (agents) of its supply chain and value creation;

4) On the basis of multi-agent modeling of software-integrated information resources of all its actors to transform the production planning system into an integrated multi-agent production planning system with the removal of the production planning function to the cloud environment, followed by its interactivity.

VII. Conclusions

Today we can speak about the termination of the standard division of the environment into external and internal due to sequencing of the internal environment, integration of stages, elements, participants of the global supply chain into a single cloud-based environment, based on its virtualization, which is based on expansion of various information and telecommunication platforms.

Changes in the environmental conditions of production activities increase the instability of financial and economic activities, which increases the need to find tools for rapid response to instant fluctuations in market conditions and flexibility in supply chains and value chains of production activities.

All of the above dictates the need to change both the management system itself and its intellectual core in the form of production planning and, accordingly, the revision of the entire methodology and, in the future, the entire technology of production planning of production systems.

The methodological basis of changes in traditional production planning systems in this article is proposed multi-agent modeling and big data management (Big Data) of all (expanding as a result of platforms multiplication) participants (agents) of the global supply chain of the production system.

References

[1] G. Zhang, Guoqing, T. Nishi, S. Turner, K. Oga, and X. Li, “An integrated strategy for a production planning and warehouse layout problem: Modeling and solution approaches,” Omega. Vol. 68, pp. 85-94, 2016. https://doi.org/10.1016/j.omega.2016.06.005

[2] P. Verstraete, P. Valckenaers, B. Saint Germain, H. Van Brussel, and K. Hedeli, “Integration of planning systems and an agent-oriented MES,” International Journal of Manufacturing Technology and Management, Vol. 8, No. 1/2/3, pp. 159-174, 2006. https://doi.org/10.1504/IJMTM.2006.008793

[3] D. A. Ivanov, A. V. Arkhipov, B. V. Sokolov, “Intelligent planning and control of manufacturing supply chains in virtual enterprises,” International Journal of Manufacturing Technology and Management, Vol. 11, No. 2, pp. 209-227, 2007. https://doi.org/10.1504/IJMTM.2007.013192

[4] Zh. Xiaobo, J. Wang, and Zh. Luo, “A stochastic model of a reconfigurable manufacturing system. Part 3: Optimal selection policy,” International Journal of Production Research, Vol. 39, No. 4, PP. 747-758, 2001. https://doi.org/10.1080/00207540010005754

[5] A. M. Deif and W. Elmaraghy, “Dynamic modelling of reconfigurable manufacturing planning and control systems using supervisory control,” International Journal of Manufacturing Technology and Management, Vol. 17, No. ½, pp 82-102, 2009. https://doi.org/10.1504/IJMTM.2009.023780

[6] N. Liu, X. Li, and Q. Wang, “A resource & capability virtualization method for cloud manufacturing systems,” IEEE, pp. 1003-1008, November 2011. [2011 IEEE International Conference on Systems, Man, and Cybernetics , October 2011] https://doi.org/10.1109/ICSMC.2011.6083800

[7] A. Oberweis and T. Schuster, “A meta-model based approach to the description of resources and skills,” AMCIS 2010 Proceedings, paper 383, 2010. [16th Americas Conference on Information Systems (AMCIS), August 2010]

[8] S. O’Reilly, A. Kumar, and F. Adam, “The role of hierarchical production planning in food manufacturing SMEs,” International Journal of Operations & Production Management, Vol. 35, No. 10, pp. 1362-1385, 2015. https://doi.org/10.1108/IJOPM-04-2014-0157

[9] L. Lopicic, Platform Revolution: The case of Automotive sharing platforms. 2018

[10] A. Jamalnia, J.-B. Yang, D.-L. Xu, A. Feili, and G. Jamali, “Evaluating the performance of aggregate production planning strategies under uncertainty in soft drink industry,” Journal of Manufacturing Systems, Vol. 50, pp. 146-162, 2019. https://doi.org/10.1016/j.jmsy.2018.12.009

[11] V. Gorodetsky, “Self-organization and multiagent systems: II. Applications and the development technology,” Journal of Computer and Systems Sciences International, Vol. 51, pp. 391-409, 2012. https://doi.org/10.1134/S1064230712020062