Effects of Supply Chain Digital Twins in the Development of Digital Industry

Simchenko N.A.[1], Tsohla S.Y.[2], Chuvatkin P.P.[3]

[1] Department of Economic Theory, V.I. Vernadsky Crimean Federal University;
[2]Department of Management of Entrepreneurship, V.I. Vernadsky Crimean Federal University;
[3] Department of Economics and Management, Sochi State University
[1]natalysimcheko@yandex.ru
[2]s.tsohla@yandex.ru
[3]lares@sochi.com

***Abstract*— The article is devoted to the study of the effect types of supply chain digital twins implementation in branches of industry. For the purposes of this article, the problem of implementing supply chain digital twins is considered in terms of the interests of various stakeholders and their contribution to the development of the supply chain Digital Twins market. The study of Digital Twins effects analysed the indicators of digital business transformation. It is proved that the digital transformation of Russian industry should be directly linked to the development of Digital Twins. Based on the analysis of the effects of Digital Twins development in the automotive, petrochemical, oil and gas, transport, and construction industries, a map representing the relation between interests of stakeholders and their contribution to the development of the Digital Twins market has been developed. This map contains both the interests of key stakeholders in the Digital Twins market and their possible contribution to the interests of each stakeholder group. The developed methodological toolbox is an important component of the formation of institutional support measures by the state for the development of the digital industry.**

***Keywords*—** *Digital Economy, Digitalization of Industry, Supply Chain Digital Twins, Stakeholders, Economic Effects.*

1. Introduction

For a supply chain, a digital twin can help cut costs and deliver value. Any Logistix (ALX) provides a platform to create your supply chain digital twin and enhance your operational and tactical decision making. The impact of the digital economy development on the functioning of economic systems is accompanied by changes in the functions of basic economic institutions in relation to the unprecedented adaptation of artificial intelligence technologies, the Internet of things, Digital Twins, 5G, big data and other breakthrough technologies. The essential change in the functions of institutions is inherently linked to the transformation of the economic effects of technological changes.

Despite the annual changes of emerging technologies rating based on their impact on the development of economies around the world, the technology “Digital Twins” was recognized as a crucial technology in 2018, according to Gartner [1]. At the same time, while in 2017 Digital Twins appeared on the upward trend of the Gartner Hype Cycle, in 2019 this technology was not indicated at all on the Gartner Hype Cycle curve [2]. This can be explained by the fact that Digital Twins are a source of reserved development of companies in the long term [3].

The research on introducing Digital Twins is closely related to determining the possible effects of their implementation. It is important to distinguish between social, organizational and economic effects of the supply chain Digital Twins introduction in connection with the rapid development of information and communication technologies. On the one hand, the risk of job loss in the context of digitalization seemed very logical both several decades ago [4], and now [15]. On the other hand, studies by T. Sheridan, T. Vámos, and S. Aida stated that automation simply results in a redistribution of jobs without much impact on employment [5]. The positive aspects of production automation are also linked to a clear division of tasks between people and machines, which can provide greater safety at the workplace, as well as free up time for additional creative solutions due to the redistribution of tasks for artificial intelligence [6].

At the same time, as S. Bodrunov rightly writes, “the level of public consciousness lags behind the level of technology achieved” [7]. In this regard, it seems very important to study both the social and

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

economic effects of Digital Twins adaptation in various industries, taking into account the interests and positions of various stakeholders.

2. Supply Chain Digital Twin

Gartner's digital supply chain twin represents a digital depiction of an organization's actual supply chain. At its core is a digital supply chain model that's essentially the same as a prescriptive analytics model used for advanced supply chain modeling. While prescriptive models work with real data, a digital supply chain twin takes this capability further in that inputs are fed into the model in real time. As a customer's order is processed, the order and associated transactions are automatically fed into the supply chain digital twin. To truly reflect the real world, its essential inputs which impact the supply chain are taken into account. For example, if production machinery goes down or a supply ship is late, this information should be sent to the digital twin of the supply chain. To avoid reliance on manual input, IoT devices can be used to detect that information. Provided the model has intelligence such as the duration of the outage or when the ship will dock, the digital twin in the supply chain can determine the right corrective action and support supply chain optimization.

3. Results

In the study on the effects of the supply chain Digital Twins introduction, it makes sense to rely on the works of K. Marx, who foresaw a change in the role of man in the production process in the XIX century. K. Marx pointed to “the transformation of the production process from a simple process of labour into a scientific process, placing the forces of nature at its service and forcing them to serve the human needs” [8]. Here we should also recall the article “Ironies of Automation” by L. Bainbridge, which states that since routine, simple types of work are subject to automation, the role of a person which will consist in managing more complex and unpredictable tasks in the production process is critically changing [9].

Economic studies on the impact of supply chain Digital Twins on the functioning of the economic system are carried out by different scientific schools over the past few years. The first definition of the Digital Twin concept was made by M. Grieves in the context of an industry presentation on Product Lifecycle Management (PLM). The Digital Twin in its original form is described as a digital information structure about a physical system, created as a single whole and connected with this physical system [10].

The leading scientific school for studying the effects of the supply chain Digital Twins introduction in Russia is [3, 11, 12]. The results of evaluating the supply chain Digital Twins introduction by leading scientists, representatives of various branches of science, are certainly of interest. While Prof. A. Borovkov conducts serious technical and technological research and supply chain Digital Twins developmental testing in the high-tech industry [11, 12], then Prof. A. Auzan carries out basic research supporting the assessment of the economic effect of introducing and the impact of supply chain Digital Twins on incrementing the added value of a business, the long-term competitiveness of corporations [3].

Fundamental changes in the Russian economic system have always been based on qualitative advances in material production technologies. As S. Bodrunov notes, “it is necessary to form a system of economic relations and institutions that not only ensure technological progress but also generate constant powerful material (and not only) impulses for their renewal” [13].

It is preferable to begin the study of the types of supply chain Digital Twins effects in the context of digital transformations of the industry by analysing the indicators of digital business transformation. Analysis and assessment of business transformation in the digital environment at the global level indicate that Finland is the leader in the business digitalization index, which has 100% broadband Internet coverage of organizations and the highest rates of using cloud-based services (65%) [16]. Moreover, electronic sales are carried out by less than a quarter of the country's organizations. The Republic of Korea comes second only to Finland. At the same time, the Republic of Korea ranks first in the use of RFID technologies (used by 43% of organizations) and demonstrates a low level of demand for cloud-based services (17%).

Table 1 shows data characterizing cross-country comparisons of key indicators of business digital transformation in countries in 2018.

Table 1. The development of digital transformation processes in countries throughout the world, 2018

Cou ntries	Performance						
	Popula-tion (millions)	Population density (people per km2)	GDP per capita (US$ 1,000)	Population coverage of LTE/ WiMAX (%)	Users of the Internet (%)	The number of domain names per 100 indivi-duals	ICT sector share of gross value added (%)
Russia	146,8	8,6	26,7	62,0	81	3	3,2
Australia	25,0	3,2	51,5	99,0	87	13	3,9
Austria	8,8	105,5	56,3	98,0	87	15	3,8
Brazil	209,5	24,6	16,1	83,1	42	2	3,1
United Kingdom	66,5	272,9	46,2	99,3	95	18	4,9
Germany	82,9	232,2	54,3	96,5	92	20	5,0
Denmark	5,8	134,5	56,1	100,0	98	23	3,9
Italy	60,4	200,5	42,1	98,0	74	5	3,6
Canada	37,1	37,1	47,9	98,5	93	8	3,7
China	1392,7	145,6	18,2	98,0	54	1	…
Norway	5,3	13,8	63,8	99,8	97	15	3,4
The Republic of Korea	51,6	516,2	40,5	99,9	82	3	9,6
USA	327,2	33,3	62,6	99,8	69	1	5,4
Finland	5,5	16,3	48,6	99,9	94	9	6,5
France	67,0	122	45,9	98,0	88	5	4,5
Sweden	10,2	22,6	53,1	100,0	92	17	5,7
Japan	126,5	334,8	43,3	99,0	91	1	6,0

Table 1 (cont'd)

The value of the business digitalization index in Russia is one third lower than Finland. Russia is in improved positions close to the average value for the compared countries in the use of cloud services. The RFID technologies distribution rate in organizations is half below the average level, ERP systems – one third lower. On average for countries under review, a third of organizations in the business sector are equipped with ERP systems. The highest results were achieved in Belgium, the Netherlands, Lithuania and Spain – 46-54%. In Russia, ERP systems are used by 21.6% of organizations in the business sector. Over the past three years, this indicator has grown by 6 percentage points.

Based on the data presented in table 1, we can conclude that the Republic of Korea (9.6%) is the leader in the indicator "share of the ICT sector in the gross value added of the business sector" among the reviewed countries in 2018. Finland ranked second (6.5%); Japan is third (6.0%). A comparison of countries according to such an important indicator of digital transformation as "the share of the population living in the mobile LTE/WiMAX signal reception area in the total population" showed that the highest values of this indicator (100%) are typical for Denmark and Sweden. Using the example of these two countries, let us pay attention to the absence of a direct correlation between population density and population coverage of LTE/WiMAX. In Denmark, for example, LTE/WiMAX population coverage is 100% with a population density of 134.5 people per km^2. At the same time, LTE/WiMAX population coverage in Sweden is 100%, but with a population density of 22.6 people per km^2. Here it can be assumed that a low population density is unlikely to adversely affect the growth of LTE/WiMAX coverage if large-scale reforms in the field of the digital transformation of business and industry are effectively implemented in the country. Let us note that while in Australia with a low population density of 3.2 people per km^2, the LTE/WiMAX population coverage is 99%, then in Russia, with a population density of 8.6 people per km^2, LTE/WiMAX population coverage is only 62%.

The digital transformation of Russian industry should be directly related to the development of Digital Twins. To build a twin's comprehensive model, numerical methods for modelling physical processes in object materials are used. This helps to predict the product response to operational loads, for example, using the Finite Element Analysis (FEA) method. Using this method, you can simulate the behaviour of complex systems by breaking them into many elements (cells) small enough to consider their properties as homogeneous. The method is widely used to solve the problems of the mechanics of a deformable solid, heat transfer, hydrodynamics and electrodynamics. CAD models (computer-aided design/drafting, computer-aided design tools) that carry information about the appearance and structure of objects, materials, processes, sizes and other parameters are also applied. FMEA models (Failure Mode and Effects Analysis, analysis of the types and consequences of failures) based on the analysis of system reliability are also used. They can combine mathematical failure models with a statistical database of failure modes. In fact, this is a methodology for analysing and identifying the most critical steps in production processes. Some experts identify three types of twins: Digital Twin Prototype (DTP), Digital Twin Instance (DTI) and Digital Twin Aggregate (DTA).

A key element of the Digital Twin is the matrix of targets and resource constraints. As soon as the usage of the products (for example, SuperJet aeroplanes) begins, they constantly inform the Digital Twin about themselves, and it becomes "smarter" every day receiving such feedback. It is important to distinguish between the concepts of Digital Twin and digital prototype. None of the digital prototypes have the task to pass full-scale tests the first time, tracking the data of hundreds of sensors.

The effects of using supply chain Digital Twins in various industries are presented in table 2.

Table 2. Features of the implementation of supply chain Digital Twins in various Russian industries

Industry	***Digital Twin***	***Effects***
Automotive industry	Unified modular vehicle design platform ("Cortege" project, Aurus Senat).	– a significant reduction in the volume of full-scale tests, which are used in the traditional design paradigm to fine-tune the product to the requirements, respectively, the test time and product costs; – reducing the time and costs of creating a new model; – ensuring a high level of passive car safety based on the development of multi-level matrices of targets and resource constraints, including more than 50 thousand characteristics.
Petrochemical industry	Engineering Data Management System (SMID)	– reduction of time losses, as well as the number of errors in the maintenance, repair and order of spare parts; – navigation through equipment for repairmen, preliminary planning of operations for design repairs carried out every 4-5 years.
	Production Simulation Model	– carrying out calculation studies and determining the optimal process parameters; – search for solutions to improve technological and energy efficiency; – calculation of parameters such as energy, heat transfer, as well as economic data: costs of additional equipment, the usefulness of modernization.
Oil and gas industry	Digital Twin with the use of a digital simulator for operators.	– prevention of accident situations; – implementation of a cybersecurity system to protect an enterprise Digital Twin from hacking.
Transport industry	Digital Twin of railway operations optimization.	– reduction of the costs of repair work; – identification of dual operations when managing the rolling stock; – increasing the efficiency of shipping management; – setting the equipment on 3D plants' layouts.

Table 2 (cont'd)

Construction industry	Digital Twin of a building.	– improving the building infrastructure management based on resource management, which is linked to the climate and production processes of the enterprise, such as electrical management (electricity control), control of water resources and heat supply.

The studies conducted make it possible to distinguish the following types of effects of the Digital Twin introduction in the development of the digital industry [17]:

– preliminary optimization of production, including the creation of programs for programmable logic controllers and virtual commissioning, which allows timely identification and elimination of errors before the start of actual operation, laying the foundation for individualized mass production
– preliminary testing and optimization of various components of the solution in the activities of a manufacturing company (system performance, mechanical part,

software, etc.);
- process optimization in the value chain;
- ensuring "guaranteed reserved development" of companies;
- ensuring technological superiority in the global market of technologies and services;
- creation of competent demand among industrial companies for the identification of sub-technologies;
- reducing the number of various types of tests (technical, rating, operational, etc.) of products.

Surveys conducted by Gartner analysts show that 13% of organizations implementing IoT projects already use supply chain Digital Twins, and 62% are either starting to create them or planning to do so. Gartner predicts that by 2021, half of the large industrial companies will use supply chain Digital Twins, which will increase the efficiency of these organizations by 10%.
Our self-made map of the correlation of interests of stakeholders and their contribution to the development of the supply chain Digital Twins market is presented in table 3.

Table 3. A map of the correlation of interests of stakeholders and their contribution to the development of the supply chain Digital Twins market

Stakeholders and their contribution to the interests of other stakeholders in the supply chain Digital Twins market	**Stakeholders**				
	Business	*Government*	*Universities, research organizations*	*Consumers*	*Investors*
	Interests of stakeholders				
	Rationalization of expenditures relating to testing physical samples	Ensuring a sustainable rate of economic growth	Breakthrough digital reform development	Improving the quality and optimizing the price level of final consumption goods/services	Return on investments
	Contributions of stakeholders in serving the interests of other stakeholders in the development of **supply chain Digital *Twins***				
Business	Reserved development and long-term competitiveness	Adaptation of breakthrough technologies in industrial development	Using Big Data to calculate and substantiate forecasts of technological development	The development of individualized mass production	Increase return on investments
Government	Formation of effective support institutions. Digital certification. Ensuring a territorial connectivity	The development of high-tech industries	Forming effective support institutions.	Price level optimization	Engaging small businesses in value chains.
Universities, research organizations	Justification for the reduction of the time and costs of creating a new product	Development of scientific and technological cooperation	Creation of "smart universities"	Improving the quality of education	Development of scientific and technological cooperation
Consumers	Demand generation for the development of platforms for attracting customers	Development of digital competencies and digital literacy	Economies of scale	Consumer qualities, the relation of value and price	Demand generation for the development of digital platforms
Investors	Improving the competitiveness of companies	Introduction of breakthrough technologies	Development of the digital innovation ecosystem	Increasing the customers' loyalty	Maximum return on investments

It should be noted that the correlation map of interests and the contribution of stakeholders to the development of the supply chain Digital Twins market, developed by the author team, allows us to systematically compare the interests of key stakeholders with their possible contribution to serving the interests of each stakeholders group.
The analysis of the effects of supply chain Digital Twins introduction requires paying special attention to institutional effects as the results of implementing reforms of the industry's digital transformation. When considering the institutional effects in the development of the regional innovation infrastructure, suppose that the institutional effects can be divided into two groups: 1) effects that can be identified based on the

analysis of quantitative dynamics and geographical distribution (inertial effect, represented in the form of rejection of new institutions); 2) effects similar to the manifestation of the Goodhart's and Campbell's laws, which can be identified to a certain extent as opportunistic behaviour when an agent meets the requirements formally and is only interested in preferences [14]. At the same time, the institutional effects of personal preferences of decision-makers using formal methods are almost impossible to identify.

Thus, supply chain Digital Twins become an effective catalyst for the development of modern industrial companies. Thanks to them, technical support of the system is greatly simplified, resources are saved, the risks of errors and failures are minimized, which extends the period of stable operation of the product. This enables the business to get the highest possible return on investments, increase competitiveness and generate customer's loyalty.

4. Conclusion

When considering a digital twin supply chain solution, it's essential to evaluate how applications offered can meet your supply chain needs. What's absolutely critical is to be able to model your supply chain accurately. The rapid development of digital technology has a significant influence on the development of the economy and society. Breakthrough digital technologies lead not only to the transformation of production processes but also to the opening of new markets, a fundamental change in business models, and the development of a platforming economy. Solutions based on digital technologies make it possible to optimize processes, simplify scientific and technological cooperation, promote the territorial connectedness, and the involvement of small enterprises in value chains. Intangible assets (information, knowledge, competencies) become the key resource of the digital economy, which leads to an increase in the importance of the service sector and the development of the As-a-service paradigm (PaaS – Platform-as-a-Service, IaaS – Infrastructure-as-a-Service, DaaS – Desktop-as-a-Service), etc.

However, despite the importance of supply chain Digital Twins technologies adoption in the development of high-tech industries, the impact of new solutions on the economy is still relatively small in terms of effects for long-term development. One of the determining factors that can accelerate the development of digital technologies and increase their contribution to socio-economic development is the updating of the legislative framework both at the national and supranational levels, including the introduction of new tools, such as regulatory sandboxes, test polygons, legal recognition of basic concepts and definitions of the digital economy in laws and regulations.

Acknowledgement

The reported study was funded by RFBR according to the research project №19-010-00346.

References

[1] Gartner: Hype Cycle for Emerging Technologies. 2018. – Available at: https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/ (date of access: 24.02.2020).

[2] Gartner: Hype Cycle for Emerging Technologies. 2019. Available at: https://www.gartner.com/smarterwithgartner/5-trends-appear-on-the-gartner-hype-cycle-for-emerging-technologies-2019/ (date of access: 24.02.2020).

[3] Auzan, A.A. Digital Twins, Digital Shadows and Digital Piracy. 2019. Available at: https://www.youtube.com/watch?v=Tx9Ws4680vM (date of access: 02.03.2020).

[4] Rodd, M. Introducing automation into manufacturing – a philosophy. 10th Triennial IFAC Congress on Automatic Control, vol. 20, no. 5, part 5, pp. 285-290. 1987.

[5] Sheridan, T., Vámos, T., Aida, S. Adapting automation to man, culture and society. Automatica, vol. 19, no. 6, pp. 605-612. 1983.

[6] Dearden, A., Harrison, M., Wright, P. Allocation of function: scenarios, context and the economics of effort. International Journal of Human Computer Studies, vol. 52, no. 2, pp. 289-318. 2000.

[7] Bodrunov, S.D. Noonomy: monograph. – M.: Kul'turnaya revolyuciya, p. 432. 2018.

[8] Marx, K. A Contribution to the Critique of Political Economy. – M.: Progress Publishers. 1977.

[9] Bainbridge, L. Ironies of Automation. Automatica, vol. 19, no. 6. pp. 775-779. 1983.

[10] Grieves, M. Origins of the Digital Twin Concept. 2016. Available at: https://www.researchgate.net/publication/307509727_Origins_of_the_Digital_Twin_Concept (date of access: 14.03.2020).
[11] Borovkov, A.I., Ryabov, Yu.A., Kukushkin, K.V., Maruseva, V.M., Kulemin, V.Yu. (2019). Digital twins and Digital Transformation of Enterprises. Vestnik Vostochno-Sibirskoj Otkrytoj Akademii, no. 32, pp. 1-38. 2019.
[12] Borovkov, A.I., Ryabov Yu.A. Digital twins: definition, approaches and development methods. Proceedings of the scientific and practical conference with foreign participation "Digital Transformation of Economics and Industry", pp. 234-245. 2019. Available at: https://elibrary.ru/item.asp?id=38525740 (date of access: 14.03.2020).
[13] Bodrunov, S. D. The future. New Industrial Society: Reloading: monograph. – SPb.: INIR im. S.Yu. Vitte, p. 328. 2016.
[14] Kolmykova, T. S., Mal'cev, A. A. Institutional effects and the effectiveness of the operation of innovation infrastructure facilities. Region: systems, economics & management, no. 4 (43), pp. 24-32. 2018.
[15] UNESCO science report: towards 2030. 2016. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000235406 (date of access: 12.04.2020).
[16] G. I. Abdrahmanova, O. E Baskakova, K. O. Vishnevskij, L. M. Gohberg. Trends in Internet development in Russia and foreign countries: analytical report. Higher School of Economics. – M.: NIU VShJe, p. 144. 2020. Available at: https://issek.hse.ru/mirror/pubs/share/345060549.pdf (date of access: 11.04.2020).
[17] How supply chain Digital Twins Help Russian industry 2020. Available at: https://rb.ru/longread/digital-twin/ (date of access: 06.03.2020).