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DIGITAL ECONOMY AND DIGITAL TWINS. MAIN RESEARCH AREA

The connections between the digital economy and its components such as digital twins of an enterprise, product, and enterprise suppliers are investigated. A method is proposed for constructing a digital twin on the basis of formalized knowledge about it and the subject area in which this twin exists. The digital twin of an enterprise allows not only analyzing the process of creating and releasing a product, but also improving the production itself, saturating it at the digital level with the latest technological, managerial and intellectual means.

Keywords: *digital economy, digital enterprise, digital twin, information model, knowledge, levels of digital transformation.*

Introduction

The penetration of digitalization processes into all spheres and processes of our existence has determined the changes that are observed today in our world and which permeate all areas related to the processes of management and representation of the world around us. This is especially evident in those sciences, which by their nature are associated with social relations in society. First of all, this refers to such an important area called economics, which includes the processes that lie on the border between society and technical objects.

Digitalization not only identified new opportunities for performing economic processes, but also opened a new world of researching these processes, set new tasks for the transition to the description of economic processes.

This article is devoted to the consideration and study of methods for transforming economic structures that underlie the transition to the dominant digital task of economic processes and their relationship with digital forms of representing economic relations. First of all, this refers to new ways of digital representation of production systems and production products, which are called digital twins.

The Sequence of Economic Transformations

Over the past few hundred years, the economic development of mankind is mainly determined by its industrial position. In turn, industrial change is an evolutionary process distributed over time of the gradual accumulation and transformation of conditions and means that contribute to the continuous development of social and technical concepts, which, in turn, determine the gradual transformation of the entire economy, industry, social conditions and the very form of society's existence.

Ultimately, the process of change leads to a qualitative leap, to a radical transformation of the used technological solutions that determine industrial production. At the same time, the living conditions of people, science, culture, social relations in society are changing significantly. This leap is generally regarded as an industrial revolution.

This revolution manifests itself in the form of scientific and technical discoveries, which are gradually used in the form of new means of production, improving technological processes, creating new products and at the same time changing the living conditions of people. The periods determined by the life cycle of these revolutions overlap, since new means and technologies arise within the widespread use of previous achievements, and the transition to the next stage is associated with the spread of new means, with the creation of new production processes, with a possible increase in the standard of living, development new social relations that were impossible at the previous stage.

The life cycle of the first industrial revolution can be estimated at about 200 years, starting at the end of the 17th century, from the work of Denis Papin, who created a diagram of a steam engine in 1690 (not counting a number of other inventions), and the end of the 19th century, when steam was replaced by electricity. At the same time, if we connect the beginning of the cycle with the first legislative acts, which were adopted in England for the first time in the middle of the 17th century, providing the opportunity for the development of industry, then the life cycle can be increased by 50 years.

During the first revolution, innovation swept through major industries. Steam engines and a steam engine have raised the energy level of enterprises. In the textile industry, machines were created (Arkwright, Hargreaves, Cartwright), which significantly increased the productivity of weavers. Metal-cutting machines appeared, railways were built using steam locomotives (from Trevithick to Stephenson), the first steamer was built (Fulton). Transatlantic telegraph communications have been established, and paper-making machines have been created.

Suffice it to recall the names of Euler, Gauss, Riemann, Faraday, Ampere, Maxwell, Edison, Hertz, Marconi, Popov, Mendeleev, Kirchhoff, and a number of other prominent physicians, economists, mathematicians, philosophers, engineers.

Numerous discoveries of the 18th—19th centuries at the same time served as the basis for the beginning of new fundamental changes that determine the life cycle of the subsequent second industrial revolution.

This life cycle is generally estimated to begin somewhere in 1870 and ends 100 years later in 1970. It should be noted that its duration can be increased by 20—30 years if we associate it with the main discoveries that led to new decisive industrial transformations. This is the age of electricity, mechanical engineering, the use of atomic energy, the age of cars, airplanes, the latest chemistry and physics, and biology. Large international corporations arose, monopolizing the production of entire industries in different countries, from metallurgy to chemistry and pharmaceuticals, oil refining, rail transport and communications.

New branches of science arose – genetics, chemistry of artificial fibers, atomic physics, pharmaceuticals of antibiotics, etc. The production of rocket technology was rapidly developing, which showed its capabilities by launching satellites into Earth orbit, and man into space.

The social structure of society, living conditions and provision of people have changed. Third world countries with large human and material resources were involved in social transformations, in conditions when production from the main capitalist countries began to move to their territories (China, India, the countries of Southeast Asia, Brazil).

And, naturally, elements of the future civilizational structure began to emerge, which already refers to the third industrial revolution – a variety of computers. Therefore, this revolution is sometimes referred to as the Digital Revolution. Its life cycle covers the period from 1960 to 2020, a period during which computing technology and related areas of means of production captured all the main industries, science, construction, and transport. The appearance in society of elements associated with this revolution was noted back in 1973 by D. Bell. [1]

The main innovations during this period are associated with the creation of various types of personal computers, the creation of the Internet, the development of microelectronics, mobile devices, computer networks, smartphones, numerous software systems, the development of new technologies using computer technology and artificial intelligence, the widespread use of robotics in industrial production.

The era of the digital revolution is based on the major scientific and technical achievements of mankind, which have changed the methods and technologies for processing information that accompanies all processes, all human activities in the modern world. The transition to digital data and the universal use of computers, to new information technologies necessary for working with digital data, has determined a qualitative leap in human interaction with the outside world. Information technologies have become not only a means of processing information, but, at the same time, a powerful factor in the transformation, presentation and management of processes taking place in the world, including in society. Moreover, these technologies change not only the interaction of a person with the environment, but also the inner world of a person, his capabilities and consciousness, his education and culture.

As in all previous cases, in the depths of a society engulfed in a digital revolution, new elements have arisen, which are currently characterized as the fourth industrial revolution (Industry 4.0) [2, 3]. Analysis of the past three industrial revolutions shows that the life cycle of each subsequent revolution is shorter than the revolution preceding it. Estimating this ratio, we can make the following conclusion:

"The life cycle of each new industrial revolution is half the life cycle of the previous one."

This statement is indirectly confirmed by the words of K. Schwab [2] that the expected fourth revolution is developing at an exponential rate. And the fourth revolution itself is at the intersection of the latest technical and information technologies, and artificial intelligence, penetrating into all areas of information processing and use.

Digital Space and Digital Economy

The economy can be characterized as a set of economic objects together with a set of relations and processes connecting these objects in the framework of the economic activity of society, including the production, distribution, exchange and consumption of the results of this activity. Therefore, it is natural to consider the representation of the economy, its modeling and study within the framework of a certain economic space, just as it is done today for other natural processes: physical, chemical, biological, social.

In recent decades, a new approach has developed in the knowledge of the world, based on the widespread use of computer technology and networks connecting technical devices to solve problems arising in the course of human activity. What previously could only be done by a person who relied on his intellect can now be done by a programmed computer. And the approach itself, based on digital information processing, was called "digitalization".

Accordingly, in relation to the economy, the concept of “digital economy” (DEC) arose. There are different definitions of DEC [4, 5]. In a narrower sense, the DEC can be considered as “activities for the creation, dissemination and use of digital technologies and related products and services; digital technologies - technologies for collecting, storing, processing, searching, transferring and presenting data in electronic form ”[4]. In this form, the DEC is seen as part of the overall economy, using digital products and technologies, and extending economic relations to them.

At the same time, it is more natural to use a general approach associated with the concept of intelligence, as the ability to simulate the environment and solve problems in it using the constructed model. Then it is possible to give an extended definition of the DEC, introducing the digital space as a model of the economic space, and the *digital economy as the functioning of economic objects, processes and technologies represented in this digital space*. It is this definition that is most adequate to modern approaches to DEC.

It should be remembered that in the digital space, in reality, various information structures and forms are given, including graphics, ontology, images and other descriptions that can be extracted from this representation, where they are given in digital form.

In the context of DEC, it seems natural to rely on the digital assignment of all the constituent elements associated with this economy. And if we are talking about a production component — a plant, a factory, an enterprise, then about the virtual representation of the constituent elements included in the production process, both element wise and in combination with the parts that form the product of this component itself. At the same time, this includes the use of the constructed digital representation for the analysis and management of real economic processes in their digital form.

The global process of increasing production efficiency presupposes detailing and high productivity of all components that determine the performance of technological operations and the accompanying and supporting processes. The tasks of ensuring the production and supply of appropriate materials, parts, equipment in modern conditions of high complexity of manufactured products requires the trouble-free operation of all production components, both at the level of production of the product as a whole, and at the level of individual components of this product. This also includes the digitally provided organization and management of the product creation process.

The ability to simulate the execution of the entire process of creating and coordinating the interaction of its individual operations, ensuring and matching all engineering solutions plays an important role. Especially in the context of the uniqueness and complexity of the product being created, not to mention the cost characteristics. For example, a new missile being created can cost millions, and its death during testing inflicts a serious financial and sometimes technological blow on the manufacturer, even if the product is insured.

Digitalization and the associated intellectualization of production allow a new approach to the implementation of production processes, while simultaneously monitoring and checking those characteristics of the processes that have remained associated with the person performing these processes, with his biological and physiological capabilities. "Digitalization of industrial production implies the integration of a number of breakthrough technologies: virtual modeling, the Internet of Things, robotics, artificial intelligence, big data, cloud and edge computing technologies, predictive analytics, and new communication standards" [4]. The Comprehensive Internet and drone technologies are now starting to embrace digital manufacturing.

At the same time, breakthrough technologies are superimposed and coupled with digital modeling of those real objects that take part in the implementation of the production process: production centers, machine tools, infrastructure, means of supply and delivery, means of process automation. For these objects, digital twins are created, which are digital models of objects, and can be used for digital modeling and virtual representation of production processes.

A digital twin (DT) is a digital representation of an object together with the necessary information and software that reflects the external and internal characteristics of the object and sets the methods and formats for the internal and external interaction of the components of this object in the process of its functioning.

The development of digital twins seems to be a rather difficult task, although the result should be a product that virtually combines engineering and technological solutions used at all stages of the product life cycle. Most importantly, product development at the virtual level is integrated into a coherent whole with its actual creation, testing, validation and management of all processes carried out in the manufacture and sale of the product.

The construction of a virtual copy of any economic object or process for its subsequent analysis and research can be considered as a new economic method that allows you to find out and check how this product fits into the economic environment. This method has already been effectively applied in construction, from the development of architectural solutions to the analysis of the reliability of buildings and structures, in the design of automobiles, in the space field, in the construction of smart cities, in transport, in healthcare and medicine.

In this paper, we will only consider the direction of creating a DT for enterprises and their products (products).

The Digital Twin of the Enterprise. Build Levels

Each of the above definitions reflects the idea of its authors on the understanding of DT, based on their ideas about DEC and ways of transition to digitalization of production systems. Therefore, the answer to the question of how to build a DT depends on how to represent the digitalization process and how to move from a conventional enterprise to a digital one?

Different approaches and different methods are possible here. This paper proposes a method for constructing a DT based on the use of knowledge about the enterprise and formalization of the enterprise as an economic object based on this knowledge. It is assumed that knowledge for the subject area, which in our case is the enterprise in question, can be specified in the extended form proposed in [12]. In this case, the enterprise is described as a set of its constituent objects W.

For each object $X \in W$, knowledge ς_X about it is specified by a set $\varsigma_X = [\Lambda, L, T, \Omega](X)$, where Λ is the description of the object in the form of its attributes, is the description of the object L in the form of a logical formula, is the set of connections T of the object with other objects of the subject area, and Ω is the description of the object at the level of ontology associated with the given subject area.

The structure of an enterprise is specified as a pair (W, R_S), where R_S is a relation connecting objects from a set W. This relationship is built on the basis of a set of relationships $\bigcup_{X \in W} T(X)$ defined by knowledge about the enterprise.

The structure of an enterprise is the basis for digitalization, in which for each object its digital representation is built, and for each link – a program representing it. The constructed digital representation is viewed as a digital twin defined by the original structure. In this twin, sets of objects can be distinguished along with their transformations-links, which form various processes of production of a product – design, technological, production and logistics – in their digital representation.

Additionally, in the DT, the individual characteristics of the objects under consideration can be set in the form of data. These features are included in the form of additional features specific to this particular object. They can relate to both the external and internal environment, and be considered as knowledge related to a specific enterprise.

Let's move on to the implementation of the DT. It is possible to consider various levels of construction of enterprise structures, from the most general, reflecting only the basic characteristic properties of this area, to more detailed ones, which can determine a complete description of the object's activities, recorded in digital form and presented, most often in visual form (for example, in 3D format) for its perception and interaction with a person. The DT can be presented in software form if it is assumed that it is oriented towards a certain software environment (for example, a control system). Therefore, considering the DT, it is always necessary to indicate the form of presentation of the enterprise, based on the perception of the environment, taking into account which the twin is created.

In the future, the concept of DT will be used both for the enterprise and for its product without further clarifying what the double refers to, if this is clear from the context.

As an economic object, each enterprise exists in a certain environment, which we will call the external environment of the enterprise. The external environment includes economic factors, communication external conditions, scientific and technical factors, and structures associated with the external business environment: consumers, suppliers, competitors, financial infrastructure and investors. At the same time, the enterprise itself, which carries out production activities, includes a set of production and service units in the form of main, auxiliary and auxiliary workshops, storage facilities, services, various design and technological bureaus, accounting and financial departments [15]. This is the internal environment of the enterprise, within which we will consider the problem of building a DT. Since the internal environment can be represented at different levels of the task, then the DT for it is set at different levels of aggregation.

The most aggregated first level of the enterprise's DT is set by general knowledge about its external and internal environment. This level defines the problems that arise or may arise before the enterprise. And also the main task is formulated – building a strategy of the enterprise's behavior: it is necessary to determine what and how the enterprise should do for its further development.

At the second level of DT creation, the constituent components of the structure of the internal environment of the first level are divided into their structural components: workshops – into sections, lines, storage facilities – into separate warehouses and storerooms. Both at the first and at the second levels, their data, knowledge, programs are set, from which digital representations of individual structural elements are formed. Each such representation is considered as a complete digital characteristic of the considered structural element. At the level of these indicators, the structural element is considered as a whole, and the indicators should show its compliance with the main tasks solved by the enterprise.

Finally, at the third level of building a DT, individual lines and machine tools, means of production support, and logistics components are considered as structural elements (an example for the workshop of a machine-building enterprise). All components are equipped with cyber-physical sensors and are organized into a system consisting of interconnected sensors and computing devices. The network of sensors, controllers, calculators and other devices of the cyber-physical system are the basis for receiving and transmitting to the common database the necessary information about the state in the digital representation of each structural element of the third level.

This digital domain is seen as the implementation of the "Industrial Internet of Things", including associated hardware and software. The Internet of Things (and now the Comprehensive Internet) is the main link between the physical and digital world, providing interaction between all kinds of products, things, services, both among themselves and with people who are part of the real world.

In the Internet of Things, every thing that corresponds to the real world enters the network with its own digital representation and identifier, which allows it to be included in the network as an integral part of this network. Since each such thing – a machine tool, equipment, a robot, a 3D printer, logistic means, a control computer – during its creation is focused on performing specified functions and, at the same time, for a warranty period in its life cycle, then to monitor its condition in it sensors are switched on, firstly, signaling both the performance of specified functions, and secondly, about the real state of the object and its components.

The first group of sensors collects data characterizing the ability of the object to perform its technological functions. In other words, these sensors show how and what the object is equipped with so that it can perform a given operation of machining a part or workpiece. The second group of sensors reports data on the state of the object, on its serviceability and on the absence of signs of violation of the state of the object necessary for operation.

This data is collected and fed over the network to computing devices, forming huge amounts of information that characterize technological equipment in detail. The collected data in the framework of the Industrial Internet of Things (IIoT) serves as the basis for the digital representation of production processes in the enterprise. A digital image is created, which presents the technical and technological data of production processes, from logistics to quality management. This image can also include those components of the product sales management system that are applied during the production process.

Simultaneously with IIoT, information technologies are developing, which ensure the storage and processing of gigantic amounts of information coming from all structural elements (Big Data) that form the third level of the enterprise's DT. These are decentralized and parallel data processing technologies, united within the digital image of the enterprise structure.

Digital Twin of Product

A separate level of DT consideration is associated with those products or articles that are produced at the enterprise. In this sense, the twin of a product is its digital representation, which includes a collection of data, knowledge, programs, a representation that allows you to explore and model the behavior of the product, to ensure the implementation of its functionality, reliability and lifetime in good condition without breakdowns and violations.

These properties are an integral part of the overall product quality assurance.

Product digital twin includes:

- Geometric and structural model of the object.
- A set of design data for parts, assemblies and the product as a whole.
- Mathematical models describing all physical processes occurring in the product.
- Information on technological processes of manufacturing and assembly of individual elements and the product as a whole.
- Product lifecycle management system.

The digital twin is used at all stages of the product life cycle, including design, production, operation and disposal "[8].

In our opinion, the control system given in this definition does not apply to the DT of the product. This is a higher level of digital representation associated with the organization of production, and not with the virtualization of the product. The rest of the elements in this definition are the necessary components of the DT, which, however, need to be replenished by indicating in what form the presentation of the product will be considered.

Just like in a production DT, a product DT is determined by knowledge about that product, and can be viewed at various levels of possible representations. Various options are discussed here. The most popular is the three-level representation of the DT in the form of prototypes, instances and aggregators, which was defined in the work of M. Grieves, presented in 2002 and devoted to "mirror views", which later became known as DT. Note that other directions in the construction of DTs are also possible, noted in [13].

DT prototype (DTP) is a presentation of a product in the form in which it is imagined by designers and technologists in the development process. DTP reflects the constructive essence of the product, its type, main constructive systems, their interaction. At the technology level, technological solutions, physical attributes and properties are described, what tasks are solved by individual structural elements, materials and construction features are indicated. Moreover, work at the level of DTP can be demonstrated in the virtual space. Therefore, its developers can see in the virtual space whether the product performs the functions for which the pro-duct was created?

The use of a prototype allows, on a virtual level, to make both constructive and design changes that are necessary to optimize the selected solutions.

The next level is a DT exemplar (DTE), which presents specific solutions related to the production of a product: selected materials, equipment and features of individual parts, the implementation of individual stages of production and the resulting problems. Manufacturers of components may be indicated, even specific batches of subsystems used. In contrast to DTP, the considered level of the instance is concretized; everything that distinguishes the general project from a specific implementation is included in it. DTE accompanies the product throughout its life cycle. It can be adjusted if, during the repair or modernization of the product, replacements or restoration of some components were made in it. In this sense, DTE is individual as much as they differ from each other, for example, cars of the same model, but produced even by the same plant, but at different times. This is especially important because during the life cycle for individual parts and elements of a product, manufacturing technologies can change and improve. And the product may contain new components that are significantly different from those with which it was completed during production.

In the digital economy and the use of DT, the amount of information that comes from various elements that characterize production increases significantly. Thus, new indicators are defined that can be used to improve the quality of products related to the operation of enterprises. As a result, a new section of the enterprise economics arises, associated with the processing and analysis of structures that form in real production, and supported in the digital space by direct measurements. An example is the concept of a DT aggregator (DTA).

DTA is a DT of a group of products created and operating under relatively similar conditions. This is a one or several batch of products that were made from the same parts under the same conditions. DTA allows you to analyze the work of individual products in relation to their group presentation. This term was previously absent due to the impossibility of conducting such a comparative analysis as a standard operation aimed at making the product itself and improving its quality.

But now the situation has changed. In the conditions of the DE and the existence of the DTE, one can actually check on a virtual level how the created product meets the goals set, compare its quality for the work performed, conduct statistical assessments of the conformity of the product made to its DTP. At the same time, the tasks of assessing the reliability of the created product and assessing possible deviations and violations of the aggregator from the given prototype can be set.

The very concept of DTA in the DE forms a new economic indicator, which determines the real value of the created product or its modification, embedded in the DTA, within the framework of those economic decisions that are used in the DE. For example, how successful was a batch of cars equipped with the appropriate engines, chassis and electronics, in terms of their operation in a certain region of the country. DTA can be used to benchmark different batches of the original product.

At the same time, the comments and requirements of consumers for the created and operated product can be analyzed. And since the working conditions of each individual exemplar may differ from each other, then the comments can cover different sides, although the product itself remains basically the same.

How the Digital Twin of the Enterprise Environment is Created?

The complexity of building and operating the enterprise's DT was the main factor that delayed its widespread use in modern industry for a decade. But now this direction of digital representation is developing successfully. Especially considering the possibility of creating and replenishing libraries containing individual modules, which can then be used to build a specific representation of the DT. Here it should be borne in mind that the enterprise's data center is not only the task of production processes in a multimedia environment, but also the simultaneous display of flows and transformations of information accompanying the operation of the enterprise, along with a demonstration of how this information is related to production and supporting processes. In addition, when creating a DT, an essential factor is the problem for the solution of which this twin will be used [11].

DT development technology depends on the object itself for which the twin is being developed. As an example, consider an example of building a

DT for such a component of the external environment of an enterprise as a supplier. In the general view of the external environment, the following types of products are associated with suppliers that may be required during the operation of an enterprise. These are raw materials, semi-finished products, auxiliary materials (for example, wire, fasteners, welding components, bolts, etc.), production materials (fuels and lubricants, coolant, electricity), components [15]. These types of products are part of the knowledge of the object in question. In knowledge, they are specified in the form of features of an object.

For each of these types of products, a system of indicators is introduced that allows the supplied product to be included in the production process implemented at the enterprise. At the same time, these indicators are used as the "digital skeleton" of the DT.

The scorecard includes the following elements:

- What is supplied (nomenclature);
- The number or volume of supplies;
- Quality characteristics of the supplied products;
- Contractual terms and their observance;
- Financial indicators related to supplies (prices, terms, performance);
- Possible deviations and irregularities related to supplies.

Note that each of the elements under consideration can be characterized by a separate set of values that detail this indicator and link it with the production technology used at the enterprise. This is the body of data that goes into the definition of supplier knowledge.

Now it is necessary to define the form in which this twin will be set for interaction with the supplier. This form is determined by the following three tasks that arise when using the supplier's products in the enterprise:

- Qualitative compliance of the products supplied by the supplier with the technological conditions of its use.
- Acceptable benchmarking with other suppliers of similar products (market analysis).
- Analysis of the possibility and necessity of the enterprise's transition to another supplier of similar products, supplemented by a market analysis for the selected indicators.

Accordingly, the supplier's DT for the main enterprise is knowledge about its products, which allows to effectively solve the assigned tasks. The formation of this view is based on an analytical platform that is used to analyze data about a specific supplier and other possible manufacturers of similar products, based on data obtained from the Internet. The analyzed data are also considered in the context of their possible use for solving these problems.

The analytical platform defines a method for setting up a domain based on knowledge about objects obtained from the external environment. This environment contains information about various objects. But only one object is needed to develop a digital model and use it. This choice is based on the preliminary analysis of the information performed by the analytical platform.

The construction of such a platform is already related to the method of solving problems in the subject area, which is an integral part of the general understanding of intelligence.

The basis for presenting the DT under consideration from the external environment of the enterprise is a graphical interface that allows you to set and compare indicators in diagrammatic form that are an integral part of the supplied product. To solve the first problem, the constituent elements of the diagram can be opened in additional windows, showing the values of individual indicators and comparing them with each other. At the same time, the analytical platform shows how these indicators correspond to the expected values (first task). And if the indicators change, how significant are these deviations for the products manufactured by the enterprise.

In addition, possible deviations of individual indicators from the expected design and technological requirements are analyzed. It shows how the deviations of the product received from the supplier affect the products manufactured by the enterprise, at the level of quality, price and market characteristics.

Data obtained from external sources about other manufacturers of similar products is collected in a separate file. A list of possible suppliers is displayed.

In this list, you can select several possible suppliers, which are then compared according to a given set of indicators and the selected comparison function (utility function). A suitable type of diagram is selected for the user, which allows using the utility function to visually arrange potential suppliers (second task).

The third task is connected not only with general data about the supplier's products, but also about contacts between the potential supplier and the enterprise. It is possible that the manufacturer of a particular product does not have the capacity or resources to place its products on the free market.

Either there are economic or legal obstacles that prevent the conclusion of an agreement between enterprises on the supply of products.

Or the terms of possible deliveries must be agreed upon, which would satisfy both parties. The current state of these problems is displayed in a diagrammatic form (graphical interface) for the information of interested parties.

The file system, graphical interface and analytical platform, using the Internet and cloud storage, form the basis for building data centers and enterprises, and products from the angle of their tasks. However, the challenge remains to develop intelligent tools that would provide the analytical platform with the necessary information.

This is complicated by the current state of the presentation of information on the Internet, the heterogeneity of the platforms and systems used, approaches to the presentation of information in networks, and new technologies for creating products.

The approach to building a DT for suppliers can be applied to other components of the external environment: customers, partners, investors, competitors. These components differ from each other in the indicators that characterize them. But the principles of building their DT are the same as the supplier's DT scheme discussed above.

Conclusions

Currently, the digital transformation of production is the main resource that allows you to transfer production to a new level of development and improvement. Digital representation is associated with the possibility of not only transforming the production itself, but also accelerating the time to market a product, releasing the most advanced products today, operational modeling and technological improvement of products at the digital level.

The basis for building a DT is the use of an analytical platform that works with information coming from the Internet. The very interaction with the DT is based on the use of a graphical interface that allows you to reveal individual details of the components of the external environment.

The enterprise's data center allows not only analyzing the process of creating and releasing a product, but also improving the production itself, saturating it on a digital level with the latest technological, managerial and intellectual means. A virtual production world is created for the enterprise, in which it is possible to imagine, study, accelerate and optimize all production processes on a digital level. Digital modeling is changing the overall approach to manufacturing.

The creation of a digital model of manufacturing and supporting processes serves as the basis for optimizing the entire production by replacing or eliminating costly and unproductive operations associated with the preparation and debugging of the entire process of creating a modern product. Digital virtualization of production is becoming a new stage in the production cycle along with design and technological development.

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ЦИФРОВА ЕКОНОМІКА І ЦИФРОВІ ДВІЙНИКИ. ОСНОВНИЙ НАПРЯМОК ДОСЛІДЖЕНЬ

Вступ. Роботу присвячено дослідженню методів перетворення економічних структур, які покладені в основу переходу до домінуючого цифрового подання економічних процесів та їх зв'язків з цифровими формами економічних відносин.

Мета роботи — запропонувати основні етапи, які визначать перехід від звичайних підприємств до їхнього цифрового подання (цифрового двійника) в умовах трансформації до цифрової економіки.

Метод дослідження. Метод побудови цифрового двійника заснований на послідовному перетворенні предметної галузі — підприємство та пов'язане з ним зовнішнє середовище, в якому розв'язуються завдання, що стоять перед підприємством. Ця предметна галузь задається як знання про окремі її складові. А самі знання в процесі перетворення можуть бути подані в цифровій формі.

Результат. Визначено основні етапи можливого цифрового подання підприємства та рівні побудови цифрових двійників. На прикладі об'єкта, який відноситься до зовнішньої галузі підприємства — постачальника складових компонент продукту — показано, як може бути здійснено перехід до цифрової форми цього об'єкта.

Висновок. Цифровий двійник підприємства дозволяє не тільки розробляти процес створення й випуску продукту, а й удосконалювати саме виробництво, насичуючи його на цифровому рівні новітніми технологічними, управлінськими та інтелектуальними засобами. Для підприємства створюється віртуальне виробниче середовище, в якому на цифровому рівні можна уявити, вивчити, прискорити та оптимізувати всі виробничі процеси. Цифрове моделювання змінює загальний підхід до виробництва. Створення цифрової моделі виробничих і забезпечуючих процесів служить основою оптимізації всього виробництва та кінцевого продукту. Цифрова віртуалізація виробництва стає новим етапом виробничого циклу поряд з конструкторськими і технологічними розробками.

Ключові слова: *цифрова економіка, цифрове підприємство, цифровий двійник, інформаційна модель, знання, рівні цифрового перетворення.*

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ЦИФРОВАЯ ЭКОНОМИКА И ЦИФРОВЫЕ ДВОЙНИКИ. ОСНОВНОЕ НАПРАВЛЕНИЕ ИССЛЕДОВАНИЯ

Вступление. Работа посвящена исследованию методов преобразования экономических структур, лежащих в основе перехода к доминирующему цифровому представлению экономических процессов и их связей с цифровыми формами экономических отношений.

Цель работы — предложить основные этапы, определяющие переход от обычных предприятий к их цифровому представлению (цифровому двойнику) в условиях трансформации к цифровой экономике.

Метод исследования. Метод построения цифрового двойника основан на последовательном преобразовании предметной области — предприятие и связанная с ним внешняя среда, в которой решаются задачи, стоящие перед предприятием. Эта предметная область задается в виде знаний об отдельных ее составляющих. А сами знания в процессе преобразования могут быть представлены в цифровой форме.

Результат. Определены основные этапы возможного цифрового представления предприятия и уровней построения цифровых двойников. На примере объекта, который относится к внешней области предприятия — поставщика составляющих компонентов продукта — показано, как может быть осуществлен переход к цифровой форме этого объекта.

Заключение. Цифровой двойник предприятия позволяет не только разрабатывать процесс создания и выпуска продукции, но и совершенствовать само производство, насыщая его на цифровом уровне новейшими технологическими, управленческими и интеллектуальными средствами. Для предприятия создается виртуальная производственная среда, в которой можно представить, изучить, ускорить и оптимизировать все производственные процессы на цифровом уровне. Цифровое моделирование меняет общий подход к производству. Создание цифровой модели производственных и обеспечивающих процессов служит основой оптимизации всего производства и его продукции. Цифровая виртуализация производства становится новым этапом производственного цикла наряду с конструкторскими и технологическими разработками.

Ключевые слова: *цифровая экономика, цифровое предприятие, цифровой двойник, информационная модель, знания, уровни цифрового преобразования.*