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From analogue to digital tools of business control: succession and transformation

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Abstract. The article describes results of research work of conceptual framework and control practical tools at transition to digital economy. The fundamental principles of digitalization based on convergence of basic information trends in their state-of-the-art digital format are analysed. The best practices of Russian and foreign companies are examined and systematised. The author's view of combination of analogue and digital approaches in modelling, communication means and information technologies is given. Digital products typology is defined; their evolution is traced from digital copies of traditional products to their digital twins. The role of digitalization is substantiated in generating new markets and new conditions of their functioning, change of the existing ones, and also in generation of new approaches to analysis, forecast and control. Routes of transformation of control tools at invariability of control basic functions are outlined.

1. Introduction

The rate and scope of current transformations in economy define demand in learning its basic characteristics to develop tools of practical solution to newly occurred problems using theoretical results of research. In general terms of economic and process modes, the modern economy is called a “post-industrial” one [1, 2], specifying this in such terms as “knowledge economy”, “digital economy”. At that, the characteristics of knowledge and digitalisation are logically coexisting, as they register the difference of emphases only: the first characteristic makes emphasis on the resource constituent, the latter, on the method of its activation, i.e. the process constituent. The basis of both approaches is data as representation and method of knowledge transfer, its inclusion into economic progress factors with obvious attributes of substitution. Nowadays, “vulnerable” to knowledge are labour (the tendency of economy automation) and capital (the tendency of increase of the share of intellectual structural constituent).

With such a priority list, one can see the process of driver's action whose role is taken by information and communication technologies (ICT) [3, 4]. They are the ones providing new capabilities, including organisation of network interactions and production of services that give an opportunity to determine availability of network and service characteristics of modern economy [5], just as many other characteristics derivative from information communication development. Today, the question is digital economy with emphasis on the method of attracting knowledge to provide



innovative processes and economic progress. As digital economy is at the stage of formation, its conceptual framework and practical tools require independent research.

2. Research statement

The term “digitalization” is a collective one and it means the aggregate of interrelated changes influenced by digital technologies in all the areas and at all levels of economic and public life. For the life of individuals, these are mobile devices with “everything”, smart environment, i.e. “smart” home, transport, city; in public life this is Internet, in business these are adaptive technologies, crypto currency and smart contracts based on blockchain etc. [1, 6–9].

Digitalization shall necessarily influence control of these phenomena and processes as well. But while the processes of digitalization of household and business have been studied well enough as influence of digital technologies on control of macroeconomic systems [9–11], then the influence of digital technologies on control of companies and amalgamations has not been practically described in the existing works. The urge of bringing a positive component into liquidation of discontinuities stimulated research whose results are presented below.

3. Methodology

In the course of research, the foundations of digitalization were systematised, i.e. the apparatus of discrete mathematics, theory and practice of mathematical modelling, evolution of information technologies and communication. While making research, the author addressed to general economic and special information and analytical materials, appealed to the opinion of qualified experts, studied the best practices of foreign and Russian companies.

4. The main results

4.1. *Evolutionary combination of analogue and digital concepts in their modern state*

By using the notion “digitalisation” and the associated terms “digital technologies”, “digital solutions”, “business digitalization”, “digital economy”, “digital society”, one should firstly make the basic terminology definite. To our opinion, these terms do not fully reflect the essence of ongoing processes and phenomena observed. In particular, the attempts to give the generalised and at the same time operational definition of digital economy are numerous and varied. However, despite some discrepancies, all the researchers agree that formation and development of digital society is based on the achieved in the course of evolution and revolutionary transformations current level of development of information and communication technologies and their forecasted prospects. As such, it is in the area of communication and data transmission that the terms “digital technologies”, “digitalization” and their derivatives have occurred, where digital technologies were opposed to analogue ones.

Historically, analogue approaches and technologies based on the use of physical properties of objects and processes have been created first, and everywhere: in production, modelling information support and communication means. It is material physical properties that traditional production technologies are based on, where one can see apparent link between the composition and characteristics of resources and the final product. Traditional modelling is based on analogue principles, firstly, physical, where material models produce geometrical and physical properties of the original and always have real implementation. One may consider analogue information models classical ones as well, i.e. data cluster featuring the properties and status of objects (processes, phenomena), and also their links to the external world. The basis of this modelling method is information approach to getting knowledge about the environment.

The differences between analogue and digital approaches are obvious in analysis of the retrospective and current status of communication means and information support technologies [12]. The analogue technologies of communication means are those where a signal, irrespectively of its complexity, is transmitted and received “as it is”, without “loss of physics”. The main feature of analogue signal is continuity: it can have any value within a certain interval. The second feature directly following the first one is principal exposure to interferences; these interferences which are

accumulated with multi-stage building of path “signal source — signal receiver” inevitably and irreversibly distort this signal. It is to eliminate the influence of noise and interferences that they started to use digital approach with which continuous signal is transformed into discrete format as soon as possible, and all the rest processing and signal transmission are digital. The capability of presenting any continuous process in discrete form is the foundation of the current digital era; at that, the capability of going back to the initial signal configuration retains. The main advantage of new technologies is interference resistance, capability of transfer and reproduction of a signal with absolute accuracy, “bit-to-bit”.

Many practical changes of digital technologies are related to this fundamental property. In particular, the absolute accuracy of signal transmission has made it possible to have classified communication. This property also provided occurrence of 3D printing technology where a digital image of intended for reproduction object is transmitted with absolute accuracy as any other digital signal. The second, not less important advantage of digital communication technologies is software processing capability.

The world in which data processing and distribution in the most varied form reached the previously unprecedented levels had occurred only due to digital computers operating data presented as discrete. Data storage is less complicated in digital systems than in analogue ones for their interference resistance provides data storage and extraction without damage. In the analogue system, obsolescence and deterioration may distort recorded data; in the digital one, till general interference does not exceed a certain threshold value, the data might be accurately recovered. The digital computer systems are much easier to be traced for they can be controlled with the use of software; besides, it is possible to use complicated algorithms which are not feasible in analogue systems in principle or implemented, but with rather large expenses. The fact that initially computers were analogue and not digital ones calls attention as well. To say more exactly, both these approaches, i.e. analogue and digital ones, have been shaped, practically, at the same time. Occurrence and prevailing of analogue computers at a certain stage was predetermined by the logic of development of mathematical modelling itself and computational experiments.

The main advantage of discrete presentation of data is accuracy of transmission and understanding, which are limitations, at the same time. Presently, the capacities of standard computers are being developed continuously, but there is a class of tasks they cannot deal with due to resource limitation. And this problem cannot be solved by developing computational capacities; however, its solution might be provided by more up-to-date quantum computers, which, in the opinion of their developers, are more likely to be analogue than digital ones [13].

Presently, “digit” reigns in the world of computers: the majority of modern computers are digital ones. Simplicity, reliability, interference resistance, computational accuracy provided computer application for solution of a wide spectrum of tasks including economy and business. These are state-of-the-art communication means and information technologies [3] that in their current digital format are drivers for becoming of digital economy (figure 1).

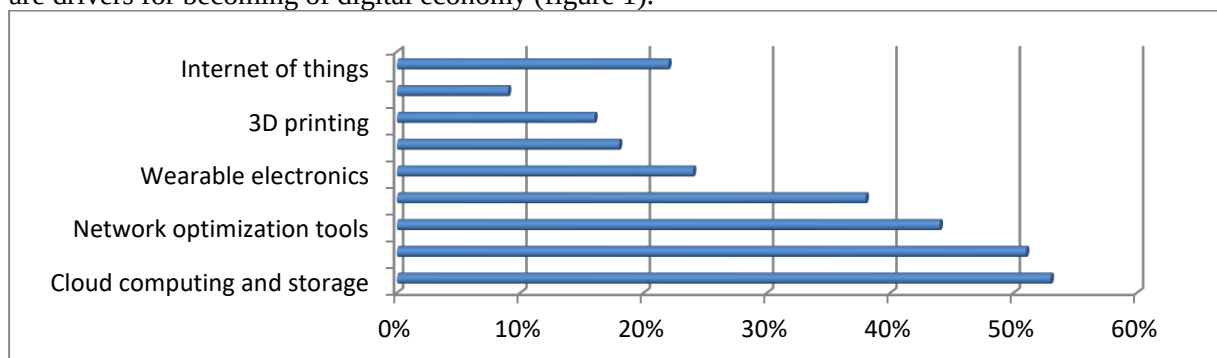


Figure 1. The scope of approving technologies, percentage of responding companies (compiled by the author using materials [13]).

Economy digitalization is the basis for totally new business, trade, logistics and production models, changes the communication and control format.

4.2. Digital Products

Understanding the phenomenon of digital economy suggests accurate and strict basic notions; as in any economy, the notion of product is the primary one. In the Report of the World Bank [15], the digital products are defined in a few senses. Digital product (service) is the following:

- 1) a product (a service) made and/or provided in digital space;
- 2) one of the product (service) properties occurring during implementation of digital processes with a product (service) image;
- 3) valuable data or access to electronic service which the buyers are ready to pay their money for.

Conclusions of many Russian researchers [16] correlate with this approach; that said, digital products are divided into groups taking into account the features of their production and consumption. The first group includes products initially developed in digital format and not having material prototype. The principal difference of this group from others is that there are no copies in it, only exemplars; all of them have the same value, different for various consumers only. The second group is made by digital copies of standard products keeping the functional qualities of the originals: digital books and documents, digitalized copies of the works of art etc. Here, one may talk about the original and the copy; at that, the original, as a rule, was valued much higher just because it was the original. The third group comprises digital images of ordinary (material) products, their information (digital) models created either during design, or at some other stage of their life cycle. The increasing data volumes, continuously modifying data collection and processing methods, in the opinion of analysts, will lead to such a situation that within the nearest future years millions of product units be brought into the markets that did not exist, and in principle could not have existed prior to the “pre-digital” era, the so-called “Digital Twins”. In a definite sense, digital twins are similar to ordinary digital models of material products, however, unlike the latter ones, they are not static copies, but their dynamic model representations and include the digital model as a constituent part (figure 2).

Information models of material products and digital twins do not replace their prototypes in consumption, but provide optimising their production and their more efficient control. In the world which with every new day becomes more and more digital the previous methods do not work any longer; control of design, production, products sale is often implemented just at the information level now [17].

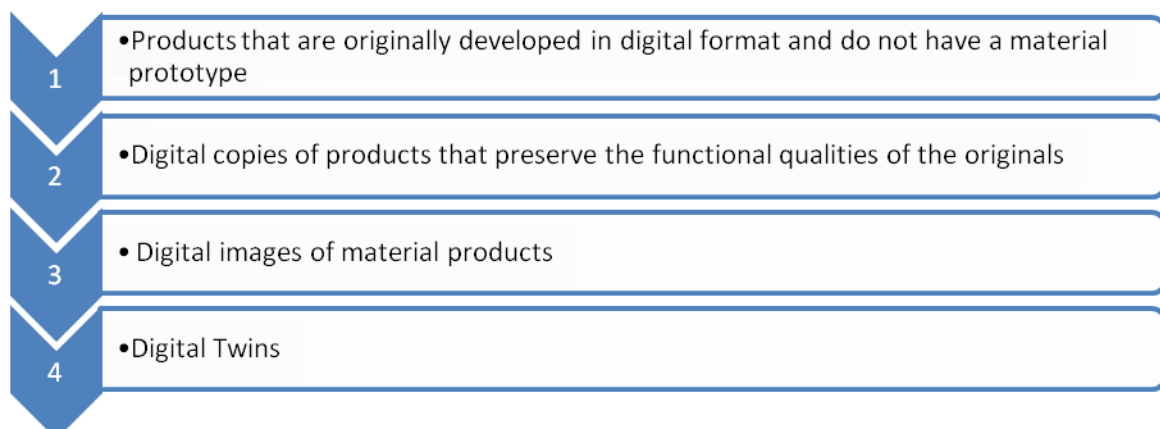


Figure 2. Types of digital products.

4.3. Control in Digital Economy

Generation of digital economy does not lead to change of principles and basic control functions, only decision making tools are changed. Transition to new control methods will firstly relate to design of

complex equipment, where traditional calculations and engineering graphics have been changed by digital modelling, and digital technologies will replace the today's full-scale modelling. It is expected that such a transformation will take place in many machine-building industry branches, i.e. in electrical power engineering, defence, production of agricultural equipment and other machines. The organization of production process itself is changing dramatically [1]. Modern industrial leaders have already got digitalized robotised equipment connected to Internet, with sensors and information systems.

Gartner analysts call development of digital twins, i.e. computer images of a specific physical object, their representations in the digital world, one of the main technological trends in 2018. A digital twin can include a digital model of an object, its geometry, bill of materials, product operational and maintenance manual, information on product behaviour in various conditions etc. This may also include an object link to other objects, software providing object control, monitoring of its current status and operation. Digital twin is a unique mediator between the physical object and its data.

More precisely, digital twin is a software analogue of a physical device which is a mock-up of internal processes, technical characteristics and behaviour of a real object in conditions of interference and environmental impact. An important feature of a digital twin is that for assignment of input impacts on it, data from on-line parallel device sensors are used. Operation is possible both on-line and off-line. Further, it is possible to compare data from virtual sensors of digital twin with real device sensors, detection of anomalies and their causes [18].

Within the framework of digital twins of a physical object, a unit of equipment or the whole process, mathematical model is created which is further used for analysis of object behaviour. Furthermore, a digital model is constantly modified to completely correspond to the current operating mode of a real plant. This gives a chance to find unforeseen changes in the processes, avoid damages and emergency cases that, as a result, provides substantial increase of reliability and efficiency of operation.

Direct analogy of digital twin technology to the methods of digital design which have been used in architecture for a long time already, BIM (Building Information Modelling), is traced. The concept of BIM consists in creation of 3D model associated with information data base in which each element can be assigned with additional attributes. The change of one of design parameters leads to automatic change of other associated parameters and objects. At that, the information model exists after building erection as well, provides control of all of its life cycle up to demolition. In production, digital twins are called a new reading of product life cycle control [18]. Their feature is in association to an object within the whole life cycle, in existence and change together with the object that provides material object control while manipulating their virtual copies.

A digital twin is unique, corresponds to one specific exemplar of a product and creates maximum complete and precise understanding of its operation. The digital twins' unique character principle reflects discrete approach to information organisation, practically; here the principles of Big Data are applied to a specific product. However, information from digital twins of a few exemplars of one product can be combined that will provide understanding of the general indices of products and model ranges as a whole. The most efficient application of digital twins is considered the one for products with the following features: demand in qualified specialised service (status check, monitoring, technical support); a long life cycle of product; a large number of exemplars of equipment installed; wide range and variety of operation conditions; product inaccessibility for servicing [19]. These requirements are also for products from various branches of industry: power engineering, aircraft engineering, machine-building, transport, medical equipment etc. Development of digital twins has become a logical result of development of concepts of digital production, industrial Internet of Things and Industry 4.0; it is the fourth industrial revolution which provided development of the technology. The concept of digital twins means connection of physical and digital world via interaction of equipment and analytical software with complete correspondence to the main principle of Industry 4.0, transition to use of cyber physic systems.

Household practice gives examples of digital twins' usage. Already by 2017, General Electric made more than 550 thous. digital twins of their products. In the same 2017, Boeing developed a specialised service unit for aircraft based on predictive analysis and digital twins. Thanks in large part to this, the company turnover is planned to be increased to 200 bln. USD by 2015 and profit is planned to be increased by 1.5 times [20]. Precedents of using technology in oil and gas industry are known, including the Russian one, where one of the main prospective optimisation trends provided by Industry 4.0 is, in the opinion of specialists, creation of digital twins of individual plants and even the whole production complexes.

5. Conclusions

Application of ICTs in their current digital format in the economic area provides not only upgrading of traditional branches and change of economy structure. Against penetration of information technologies and digitalization of economic processes, this creates basis for emerging new markets and new conditions of market functioning, transformation of the existing ones, and also generation of new approaches to analysis, forecast and control.

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