

Modeling of digitalization of management in cyber-physical systems of reorganization of residential territories

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Abstract — Digitalization of management and decision-making automation reduce the number of managerial personnel, increase the reliability of management, ensure the effectiveness of made decisions, increase profits and save resources. In Russia, unlike the foreign practice of digitalization, there are no outdated digital monitoring and managing platforms, which allows to quickly and fully integrate new original domestic developments at all hierarchical levels of management. The most important directions of digitalization are government, the interaction of citizens and the state, the interaction of the state and business. One of the current directions of reorganization of residential territories - the renovation of residential quarters of large cities is an example of the possibility of introducing digitalization technologies of management. In this direction, the Moscow government demonstrates an open information exchange and the quality of services to the population. In construction renovation, the study of cyber-physical systems and the digitalization of their management are relevant. For this purpose, it is proposed to use multilayer hierarchical infographic models, illustrating the ontology of terms and definitions of the science of interconnections and management in society, technology and the environment (cybernetics).

Keywords — digital management, multilayer models, digital economy, infography, anthropotechnical management.

I. INTRODUCTION.

The term and definition of “cyber-physical systems” is associated with cybernetics, which studies the general trend of the processes of management and transmission of information in biological, technical, public and other systems. The term “cybernetics”, proposed by Andre-Marie Ampere (1834), laid the foundation for the study of systems in all areas of human activity. At the end of 19th and the beginning of 20th centuries, the economist, philosopher, politician and scientist A.A. Malinovsky (his literary pseudonym was “Bogdanov”) proposed to consider the social, biological, physical, organizational and a number of other sciences as a *system of interrelations* in order to search for organizational principles, underlying all types of systems. Bogdanov called this direction of research “*tectology*” [1, 9, etc.]. The tectology by A.A. Malinovsky - Bogdanov anticipated the general theory of systems (1930) L. Von Bertalanffy, medical cybernetics (1935) by P.K. Anokhin and technical cybernetics (1948) by N. Wiener. The ontology of terms and the interrelation of medical and technical cybernetics are shown in figs. 1 and 2. The most constructive direction of system research was *system*

analysis (USA, 1948). The pinnacle of the modern development of cybernetics is the concept of *cyberspace* and *cyber system*, in particular, the *cyber-physical system* (*cyber-physical system - CPS*).

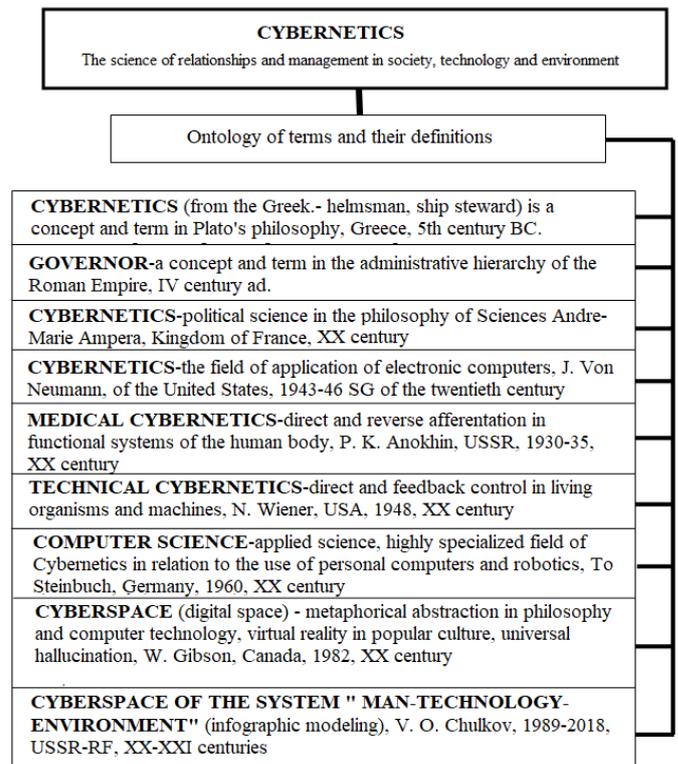


Fig. 1. The ontology of terms and their definitions in cybernetics (V.O. Chulkov [2])

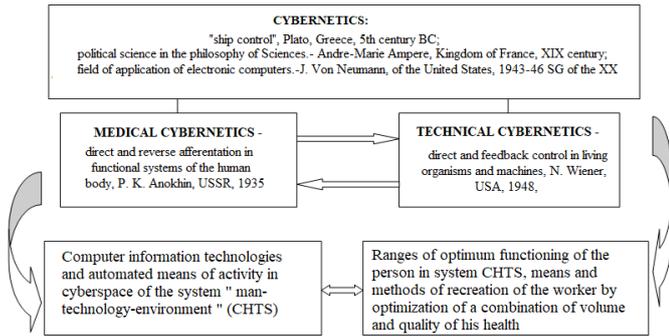


Fig. 2. The interrelation of medical and technical cybernetics in cyberspace within the framework of the "man-technology-environment, MTE" system (Chulkov V.O., [2])

The term "cyber-physical systems" was introduced (2006) into the scientific and practical circulation by the director of integrated and hybrid systems of the National Science Foundation of the USA Helen Jill, highlighting the distinctive feature of the NSF CPS Workshop seminar, organized by her. The organizers of this seminar successfully revised the role of built-in systems, which allowed to begin the rapid development of CPS in a couple of years [12]. It was shown, that a new discipline is needed to create CPS, capable of working in the real world - model engineering (model engineering) or infographic modeling [2].

A cyber-physical system is "... an information technological concept, which implies the integration of computing resources into physical entities of any kind, including biological and man-made objects. The computing component in CPS is distributed throughout the physical system ... and is synergistically linked to its elements" [10, 11]. Computers track and manage physical processes using feedback loops, and physical processes affect calculations [3]. In the design and construction field, CPS appeared in heating, ventilation and air conditioning systems.

N. Negroponte proposed (1995) the concept of electronic (digital) economics and introduced the concept of digitalization [4]. This served as the basis for the creation of digital technologies in various fields of activity and led to the rapid development of digital management [5], in particular, in construction [6, etc.]. The electronic economy is distinguished from the real economy by virtuality and dependence on the Internet (in particular, on the Internet of things [13], fig. 3), telecommunication networks and computer equipment.

There are theoretical and applied cybernetics. Cyber-physical systems in construction belong [7] to applied cybernetics, which explores the nature of physical and biological knowledge and focuses on the observer of technical, natural and social phenomena. In construction, it is the designer, builder, or user of a building.

By 2025, the annual contribution of the Internet of things to the global economy could be between \$ 4 and \$ 11 trillion.

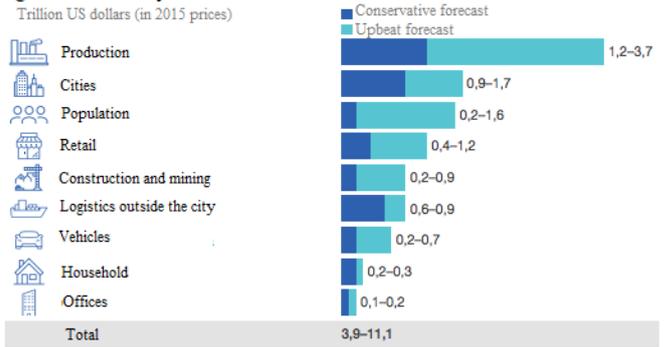


Fig. 3. The projected annual contribution of the Internet of things to the global economy and the development of digital management in cyber systems (according to the forecast by McRinsey Global Institute, [5]).

One of the options of modeling digitalization of management in cyber-physical systems of reorganization of residential territories - multilayer hierarchical modeling will be considered below. Multilayer digital management [8] is associated with the digital economy, the principles of which can be topologically transformed into principles for assessment of activities in the cyber-physical system "man-technology-environment". The infographic model of the "man-technology-environment" system demonstrates the interrelation of technical and medical cybernetics.

II. RESEARCH METHODOLOGY.

Systemic, comparative and qualitative analysis, infographic modeling and anthropotechnical management are selected as the basis of the research.

III. THE RESULTS OF THE EXAMINATIONS

3.1. Hierarchical model of digitalization of management in cyber-physical systems of reorganization of residential territories.

By analogy with the hierarchy of human needs by A. Maslow (1943) and its graphic interpretation by F. Kotler (1976) in the form of a "pyramid of needs" in the practice of marketing and management, a multilayer hierarchical infographic model of digitalization of management in cyber-physical systems of the reorganization of residential territories and objects, located on them, is built (fig. 4).

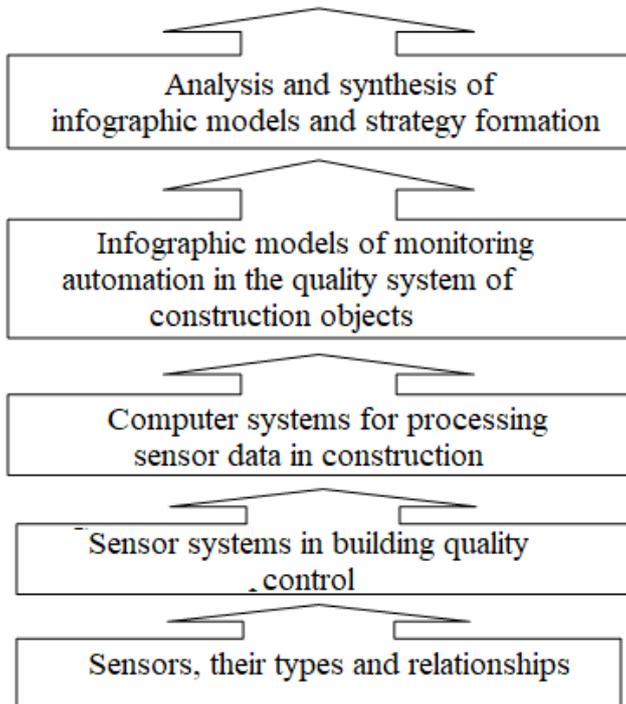


Fig. 4. The hierarchy of digitalization of management in cyber-physical systems of reorganization of residential territories and objects, located on them (Chulkov V.O., 2019).

Each layer of the proposed hierarchy has its own concept, has an informative functional load and has a known objective (achievable result). The previous layer of the model is included in the following layer as a component. Ascent to the following layer of the hierarchy makes sense with an unambiguous perception of the contents of the previous layer, understanding its functional significance and achieving its objective (result).

The implementation of the first two layers of the hierarchy ensure the formation of the third layer (the cyber-physical system), which is modeled on the fourth layer using infographics [14, 21, 22, etc.].

The upper fifth layer of the hierarchical model corresponds to the space of anthropotechnical management [15]. Here, infographic models of the fourth layer are analyzed on the basis of a creative approach, new knowledge is extracted from them, and a variety of cyber systems are synthesized in the industrial scientific and production environment of activity as a cyber-physical information system [16].

3.2. Multilayer infographic modeling of reorganization in the cyberphysics of residential territories with P-graphs.

Construction reorganization, and, in particular, one of its most relevant types - renovation, is advisable to model with P-graphs (spider-graphs, according to S. M. Efimova [17], designation of P-graph).

The algebraic model of the P-graph differs from the models by Codd E.F. (Codd E.F.) and allows, by manipulating informal relations, to create formal descriptions of working with data, based on multi-sorted calculus of first-order predicates with n-tuple terms. The body of P-graph (fig. 5) corresponds to the name of the elementary information unit.

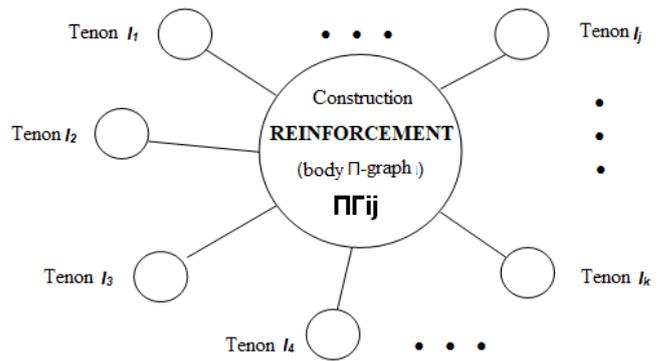


Fig. 5. The structure of a single-layer "spider-graph" of the building reconstruction (Chulkov V.O., 2017).

Each P-graph leg is assigned a natural number (the number of leg or its "mark"). P-graphs can be "linked" to each other by legs, having at least one identical mark in the sets, marking them.

Such link (both in single-layer and in multi-layer infographic models) allows to enter the relation between specific values of different elementary information units.

A multilevel network structure scheme can be presented as a set of dependencies, which set some network structure of a complex functional database object. A P-graph is assigned to a domain, and a connection of P-graphs is assigned to a n-tuple and ratio. A P-graph leg can be assigned either a specific attribute value or a whole n-tuple of some ratio.

Will consider two types of topology of transferring an information object from a layer to a layer of a multilayer infographic model of building reconstruction [18]:

- without changing the status of the transferred object (for example, the P-graph leg of one layer of the model corresponds to the P-graph leg of another layer of the model); this type of topology is called a "cylinder" (fig. 6);
- with a change in the status of the transferred object (for example, the P-graph leg of one layer of the model corresponds to the P-graph body of another layer of the mode); this type of topology is called "cone" (fig. 7).

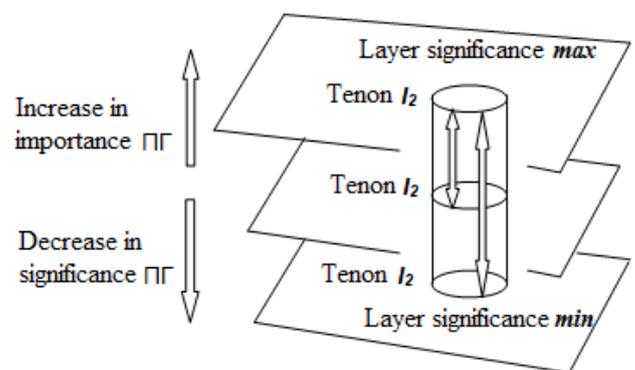


Fig. 6. Topology model $lij \leftrightarrow lij$ (transferring an object from one layer to another layer without changing the status of the object, with the disposition of layers according to their significance for the researcher), the conventional name of this model is "cylinder" (Chulkov V.O., 2018)

Using the proposed topology models (“cylinder” and “cone”) in their various combinations allows to form a variety of infographic models of building reconstruction in the cyberphysics of the reorganization of urban residential territories (fig. 8).

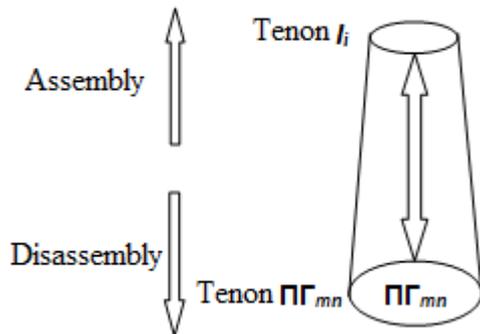


Fig. 7. Topology model $I_{ij} \leftrightarrow \Pi\Gamma_{ij}$ (transferring an object from one layer to another with a change in the status of the object), the conventional name of this model is “cone” (Chulkov V.O., 2018)

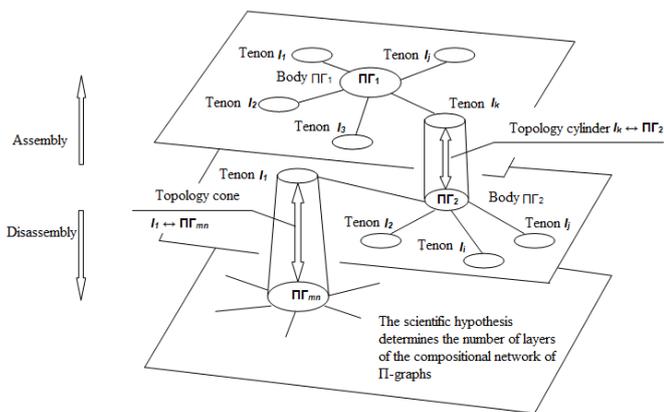


Fig. 8. The variety of uses of the topologies “cylinder” and “cone” in their different combinations in a multilayer infographic model (Chulkov V.O., 2018)

Cyberphysical information systems (CPIS, [6]) ensure coordination and close connection of computing and physical resources, harmoniously combine organizational, technological, design, mechanical, electrical, biological, socio-economic and other engineering models with computer models a reasonable reconfiguration of the information flows of intelligent management depending on the arising influences and limitations.

V. CONCLUSIONS.

1. Unlike traditional built-in systems, fully functional CPS are not autonomous structural objects, but a network of interacting components with physical input and output.

2. Scientific and technological progress ensures the interrelation of the computing and physical components of activity in the "man-technology-environment, MTE" system, based on intelligent management. This increases the adaptability, efficiency, functionality, reliability, security and usability of CPS.

3. The research of CPS allows to identify specific issues of their application. For example, it is necessary to develop new mathematical methods for quasi-parallel calculations.

4. Cyber-physical systems are effective for managing

of cyberspace.

At different stages of development, CPIS showed itself as built-in real-time systems, distributed computing systems, automated management systems of technical processes and objects, wireless sensor networks, etc.

In cyber-physical building systems, the ability to transform information from a digital form into a visual infographic model for its analysis, creative perception, extraction of new knowledge and the subsequent synthesis of assessments and decisions, is important.

IV. DISCUSSING THE RESULTS.

The term CPS began to be actively used in the German project Industry 4.0 on computerization of industry. CPS is a complexly distributed subsidiary system, the physical and software components of which interact in a lot of ways, among which there are fundamentally new management methods and systems, that depend on the context of functioning. Management and control in CPS is carried out on the basis of computer algorithms in the Internet of Things (IoT) [19], taking into account the problem of large amounts of data and from the interrelations. Advantages of CPS are intelligent management and dynamic self-programming in real time mode.

As the environment of functioning of CPS, the Internet of things assumes the creation of a new type of industry in which things, products and people with detectors (sensors) will be able to manage this production in an information environment, common for them. In other words, a thing or technical object must be able to connect at any time, anywhere with any something or someone, using any path, network or service [20]. Countries, where the young generation has skills to function in information technologies of activities, are able to create completely new production concepts. For example, in construction, the "smart home" concept combines wireless sensors in the CPS for managing lighting, ventilation, air conditioning and security.

CPS integrates the technological trends of the interrelation of man, things and cybernetic resources, locally used in different fields of activity, by changing the existing relations between producers, suppliers and consumers. CPS use transdisciplinary approaches, combine methods of cybernetics, mechatronics and design for complex distributed systems and solving complex problems. CPS are not effective for simple tasks, this is the field of application of linear methods of calculations.

5. The study of the two upper layers (infographic modeling and anthropotechnical management) of the hierarchy of digitalization of management in cyber-physical systems of the reorganization of residential territories (fig. 4) is an relevant scientific issue, that needs to be solved. The Association "Infographic basics of functional systems" of the Russian section of the International Academy of Sciences is actively study this problem.

References

- [1] Bogdanov A.A. Tektologiya. Vseobshchaya organizatsionnaya nauka.- V 2 knigakh.- M.: Ekonomika, 1989. Kn. 1 - 304 s., Kn. 2 - 351 c.
- [2] Levin B.A., Kazaryan R.R., Chulkov V.O. Infografiya antropotekhnicheskogo menedzhmenta: Nauchnoe izdanie: v 3t. / Pod red. V.O.Chulkova.- M.: FGBU DPO «Uchebno-metodicheskiy tsentr po

- obrazovaniyu na zheleznodo-rozhnom transporte», 2016.- 932s., il.
- [3] Lee E.A. The Past, Present and Future of Cyber-Physical Systems: A Focus on Model Cheng AMK, ed. // *Sensors* (Basel). Vol. 15(3), March, 2015, 4837-4869.
- [4] Negroponte N. *Being Digital* / N. Negroponte.- NY : Knopf, 1995 [Elektronnyy resurs]. URL: <http://inance.ru/2017/09/cifrovaya-ekonomika/> (data obrashcheniya: 10.08.2019).
- [5] [Elektronnyy resurs]. Natsional'naya tsifrovizatsiya. <https://rostec.ru/analytics/natsionalnaya-tsifrovizatsiya/> (data obrashcheniya: 10.08.2019).
- [6] Khalin V.G., Chernova G.V. Tsifrovizatsiya i ee vliyanie na rossiyskuyu ekonomiku i obschestvo: preimushchestva, vyzovy, ugrozy i riski // *Upravlencheskoe konsul'tirovanie*.- №10.- 2018.- S.46-63
- [7] Volkov A.A. Kibernetika stroitel'nykh sistem. Kiberfizicheskie stroitel'nye sistemy // *Promyshlennoe i grazhdanskoe stroitel'stvo*.- №9.- 2017.- S.4-7.
- [8] Mnogosloynnaya model' vychislitel'noy seti.- <http://iteranet.ru/itnovosti/2014/03/18/mnogosloynnaya-model-vychislitel'noj-seti/> (data obrashcheniya: 1.07.2019).
- [9] Chulkov V.O. Stanovlenie sistemnogo podkhoda v stroitel'stve. *Effektnoe nachalo. 1961-1980*.- M.: SvR-ARGUS, 2015.- 224s., il.
- [10] Kiberfizicheskaya sistema.- [https://ru.wikipedia.org/wiki/ Kiberfizicheskaya_sistema](https://ru.wikipedia.org/wiki/Kiberfizicheskaya_sistema) (data obrashcheniya: 6.05.2019).
- [11] B.G. Sanfelice. *Analysis and Design of Cyber-Physical Systems. A Hybrid Control Systems Approach // Cyber-Physical Systems: From Theory to Practice* / D. Rawat, J. Rodrigues, I. Stojmenovic.- CRC Press, 2016.- ISBN 978-1-4822-6333-6.
- [12] Chernyak L. Kiberfizicheskie sistemy na starte // *Otkrytye sistemy. SUBD*.- 2014.- №2.- S.10-15. URL: <https://www.osp.ru/os/2014/02/13040038> (data obrashcheniya: 6.05.2019).
- [13] Chernyak L. Internet veshchey: novye vyzovy i novye tekhnologii // *Otkrytye sistemy. SUBD*.- 2013.- №4.- S.14-18. URL: <http://www.osp.ru/os/2013/04/13035551> (data obrashcheniya: 10.05.2019).
- [14] Chulkov V.O. Infografiya: Nauchnoe izdanie: v 5t.- Seriya «Infograficheskie osnovy funktsional'nykh sistem, IOFS» / Pod red. V.O. Chulkova.- M.: SvR-ARGUS, 2007-2008.- 95,9p.l.
- [15] Chulkov V.O., Kazaryan R.R., Levin B.A. Infograficheskie modeli antropotekhniki upravleniya: Modul'nyy kurs lektsiy. 120 moduley. Uchebnoe izdanie v 3t. / Pod red. V.O.Chulkova.- M.: Russkaya shkola, 2017.- 75 p.l.
- [16] Losev K.Yu. Kiberfizicheskie sistemy stadii proektirovaniya v zhiznennom tsikle ob'ekta stroitel'stva. Sbornik materialov seminarov, provodimogo v ramkakh VI Mezhdunarodnoy nauchnoy konferentsii «Integratsiya, partnerstvo i innovatsii v stroitel'noy nauke i obrazovanii» (g. Moskva, 14-16 noyabrya 2018 g.) / M-vo nauki i vysshego obrazovaniya Ros. Federatsii, Nats. issledovat. Mosk. gos. stroit. un-t.- Elektron. dan. i progr.- Moskva : Izdatel'stvo MISI – MGSU, 2018.
- [17] Efimova S.M. Ob algebraicheskom podkhode k probleme predstavleniya znaniy.- *Voprosy kibernetiki. VK-100. Situatsionnoe upravlenie i semioticheskoe modelirovanie*.- Akademiya Nauk SSSR. Nauchnyy sovet po kompleksnoy probleme «Kibernetika».- M.: 1983.- S.54-73.
- [18] V Chulkov, A Yurgaytis (2019) Multi-layer infographic model of the cjnstruction reorganization in cyberphysics.- *E3S Web of Conferences* 110,0 (2019) <https://doi.org/10.105/e3sconf/201911001080-2018> 10 10 SPbWOSCE 80 80
- [19] Tsvetkov V.YA. Kiberfizicheskie sistemy // *Mezhdunarodnyy zhurnal prikladnykh i fundamental'nykh issledovaniy*.- 2017.- № 6-1.- S. 64-65; URL: <https://applied-research.ru/ru/article/view?id=11623> (data obrashcheniya 29.09. 2019).
- [20] Yastreb N.A. Industriya 4.0: kiberfizicheskie sistemy, razumnoe okruzhenie, Internet veshchey.- https://techno.vogu35.ru/docs/2015/Industria_4_0_Yastreb.pdf (data obrashcheniya 29.09. 2019).
- [21] Shaitura S.V., Stepanova M.G., Shaitura A.S., Orlov K.V., Galkin N.A. Application of information-analytical systems in management // *Journal of Theoretical and Applied Information Technology*.- 2016.- V. 90.- № 2.- S. 10-22.
- [22] Losev K Yu, and others (2017) Infography use to requirements specification for the design of the building EMMFT 2017 IOP Publishing IOP Conf. Series: Earth and Environmental Science 90 (2017) 012197. 5p. doi :10.1088/1755-1315/90/1/012197