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Infographic Modeling of Reorganization of Digitalized Cyber-Physical Systems Throughout the Life Cycle of Construction Projects

Vitaliy O. Chulkov*

Department of Technology and Organization of Building Production, National Research University «Moscow State University of Civil Engineering», Moscow, Russia.
**Corresponding author. Email: vitolch@gmail.com*

ABSTRACT
In the near future, digitalized cyber-physical systems must become the basis of the processes and means of computer control of a variety of functioning parameters of a modern home, as well as instrumental monitoring of the dynamics of their change within specified limits. This goal was set by the Government of the Russian Federation, bearing in mind the need to significantly increase the volume and quality of health of the population, to ensure the necessary level of comfort for the functioning of people in their life and work. To ensure the achievement of this goal, it is necessary to have a clear idea of the current state of the problem in question, to simulate the possibility of its dynamic change at the scheduled time. Infographic models of anthropotechnics for managing the reorganization of construction projects throughout their life cycle, their physical engineering systems of high-tech service and computer systems of digital economy are proposed. A comprehensive combination of the capabilities of these components within the framework of digitalized cyber-physical construction systems allows us to hope for a timely and high-quality solution to the goal set by the country's leadership. There are no outdated digital monitoring and control platforms in Russia, unlike the foreign practice of digitalization. There is an opportunity to quickly and fully integrate new original domestic pilot-projects. An example of the possibility of introducing digitalization technologies for monitoring and control can be the control of changes in the adaptive norms of a particular person in a dynamically changing environment. The domestic and foreign practice of research in this field can be effectively combined with a currently actively developing study of cyber-physical systems and digitalization of their management.
Keywords: *digital management, multilayer infographic models, digital economy, cyber-physical systems, anthropotechnical management, computer monitoring*

1. INTRODUCTION

The pinnacle of modern development of cybernetics is the concept of ***cyberspace*** and ***cyber system***, in particular, the ***cyber-physical system*** (CPS). Digitalized [1, 2, etc.] cyber-physical systems [3-8 and others] are designed to comprehensively combine the capabilities of ***cybernetics*** (science and practice of managing and transmitting information in biological, technical, public and other systems [9-18 etc.]), high-tech physical ***engineering service systems*** [19, 20, etc.] and ***digital economy*** systems. [21-25 and others]. At different times, the applied science of 'informatics' (as a narrow field of cybernetics [26]), 'cyberspace' and 'digital space' (as virtual reality in computer technology, 1984-1988 [27, etc.]), 'model engineering' and infographic modeling were explained [28, 29 and others]. The electronic economy is distinguished from the traditional one by its significant ***dependence on the Internet of things*** [30], ***virtuality*** and the ***multilayer digital control*** [31] built into it, using telecommunication networks and computer equipment. Cyber-physical systems in construction are classified [32 and others] as ***applied cybernetics***; they imply the study of natural phenomena and technical processes from the standpoint of the needs and limitations of a functioning person (a designer, a builder or a user of the building).

2. RESEARCH METHODOLOGY

The systemic, comparative and qualitative analysis, infographic modeling and anthropotechnical management were chosen as the basis of the study.

3. RESEARCH RESULTS

Modern ideas record several interconnected levels of perception and comprehension, recognizing the feasibility of using a multilayer infographic model of activity formation (Fig. 1, 2 [34]). Fig. 1 shows a basic model of one layer of this model (which is usually called 'a stack' by methodologists), and Fig. 2 describes the principle of logical "assembling-disassembling" of such a multilayer model.

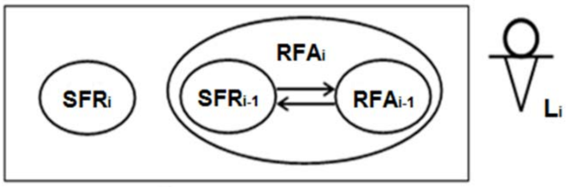

Figure 1 The model of one layer of 'the stack' (Chulkov V.O., [34])

Explanation of symbols

SFR$_i$ - a system-forming resource of the i-th layer of the 'stack', which provides conversion of a double set of the i-th layer into a workable functional activity system and the transfer of this system to the i+1 layer; **RFA$_i$** - the result of functional activity; **Д$_i$** - an agent responsible for layer i of 'the stack'.

When moving along the 'stack' from bottom to top, 'assembling' takes place (blocking, increasing the scale and significance of the activity under study), and when moving along the 'stack' from top to bottom, a sequential 'disassembling' takes place (downsizing and detailing of the activity under study). The basic model of the 'stack' layer (Fig. 1) is a double set (subject and object of the functional system of activity). The left component of **SFR$_i$** (the system-forming resource of the **i**-th layer of the 'stack' in Fig. 1) transforms the double set of the **i**-th layer of the 'stack' into a functional activity system and transfers this system to the **i +1** layer of the model.

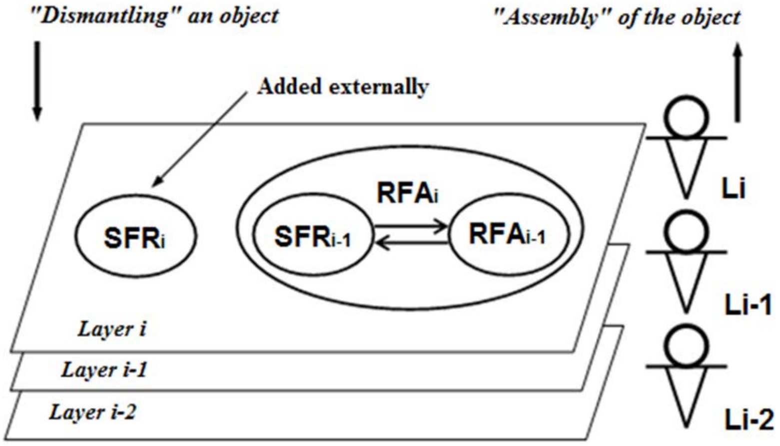

Figure 2 A fragment of a multilayer infographic model of activity formation (Chulkov V.O., [34])

The right component of **RFA$_i$** is a copy of the double set of the plane of **i**-1 level (the result of functional activity of **Д$_i$** in **i** -1 layer). **R$_n$** function of the transfer of RFA from n-1 plane to n plane:

$$R_n = F \{ SFR_i \leftrightarrow RFA_{i-1} \} = \{ SFR_i \leftrightarrow (SFR_{i-1} \leftrightarrow RFA_{i-2})\}.$$

Such transfer is performed by the agent who is responsible for layer **i** of the stack, realizing in it the functional activity displayed by this layer, and who is the main manager of the functional activity system implemented in this layer.

A fragment of the 'stack' (Fig. 2) can be continued in the direction of 'assembling' (from parts to the whole) or in the direction of 'disassembling' (from the whole to parts). The position of agent **Д$_i$** should be formalized to control the quality of the activity and its results. Not all activity positions marked with a human figure near the corresponding plane of the 'stack' are constantly occupied by actual actuators. In certain cases, the same person can alternately work in several activity positions. It is important that in each of the positions the person clearly understands and performs all his functions.

The transfer of **RFA$_i$** is carried out between adjacent layers (Fig. 3).

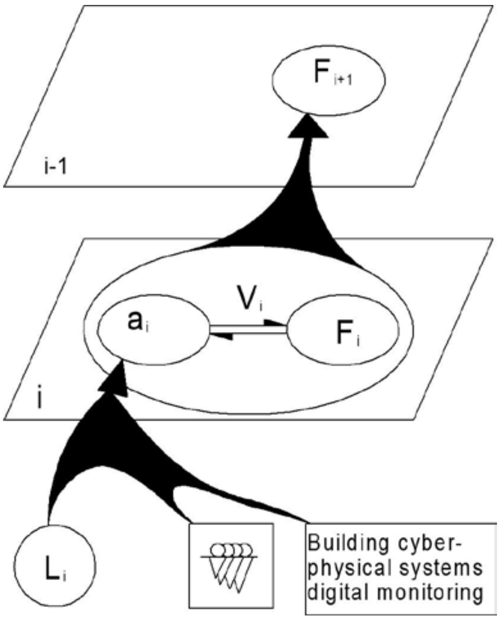

Figure 3 Interpretation of the multilayer model formation (Syrov S.V., Tuzova M.A., [34])

$\mathbf{SFR_i}$ can be considered as argument $\mathbf{a_n}$, and $\mathbf{RFA_{i\text{-}1}}$ can be considered as function $\mathbf{F_n}$. The transfer of argument $\mathbf{a_n}$ and function $\mathbf{F_n}$ from level to level formalizes function $\mathbf{R_n}$, which defines a special type of activity. The result of the activity of transferring function $\mathbf{F_n}$ and argument $\mathbf{a_n}$ from level **n** to level ***n+1*** is function $\mathbf{F_{n+1}}$ located on the right (unchanging) part of the plane of level ***n+1***:

$$\mathbf{F_{n+1} = F\ (f\ (h_n),\ a_n) \equiv F\ (\xi_n,\ V_n)},$$

where:
$\xi_n = \Sigma\xi_i - \Sigma\xi_p$ - used properties of objects of level ***n***;
ξ_i - potential properties of objects of the **i** -th level, $\mathbf{i = 1,n}$;
ξ_p - unused properties of objects of the **i** -th level, $\mathbf{i = 1,n}$.
On the right side of the plane, which is a region of level ***n***, there is function $\mathbf{F_n}$ formed at the previous levels of the ‘stack’.
This function depends on characteristics **h** formed up to **n-1** level inclusive of $\mathbf{f\ (h_{\ n\text{-}1})}$, and some argument **A** formed at level **n-1** and belonging to the documented area $\mathbf{D\ (a_{\ n\text{-}1}\ (d))}$, where $\mathbf{d \in B}$. Function $\boldsymbol{F_n}$ takes the following form: $\boldsymbol{F_n = F\ (f\ (h_{\ n\text{-}1}))\ (a_{\ n\text{-}1}\ (d))}$.
At level **n+1**, ‘the stacks’ form function $\mathbf{F_{n+1}}$, similar to a function of level **n** (that is, $\mathbf{F_n}$). Argument $\mathbf{a_n}$ for the formation of this function is image $\mathbf{A_n}$: $\boldsymbol{a_n = A_n = A\ (f\ (\xi_n),\ T_n\ (D))}$, where: $\mathbf{f\ (\xi_n)}$ is the function of choosing an object ξ from domain **D** corresponding to level **n**; $\mathbf{T_n\ (D)}$ is a function that transfers argument $\mathbf{a_n}$ from region **D** to level **n**; $\boldsymbol{V_n}$ is a function that sets the activity to ensure the relationship of the argument and function $\mathbf{F_n}$ at level **n**.
To go to level **n+1**, it is necessary that $\boldsymbol{\xi_n \geq W}$, where: **W** is the minimum value of ξ in the plane of level **n+1**. Plane **n+1** is a solution to function $\mathbf{F_n}$ with respect to argument $\mathbf{a_n}$, that is, $\mathbf{F_{n+1} = F_n\ (a_n)}$. The solution depends on characteristics $\mathbf{h_n}$ and the chosen region for argument $\mathbf{a_n}$.
In practice, the solution represents new properties of objects and processes $\boldsymbol{\xi_n}$ obtained as a result of activities at the previous level $\mathbf{V_n}$. Therefore, the solution can be written as follows: $\mathbf{F_{n+1} = F\ (\xi_n,\ V_n)}$.

4. DISCUSSION OF THE RESULTS

In relation to the cyber-physical systems of reorganization of construction projects within their life cycle [35], it is advisable to consider traditional and innovative types of construction reorganization [34]. According to the current state of these types of reorganization in the construction industry of the Russian Federation, the basic (most popular and widespread) reorganization type is **renovation**.
The interconnection of renovation with other innovative types of construction reorganization (recomposition, reversal, retrieval, etc.) can be formally defined by the ‘spider-graph’ model of Efimova S.M. [36, 37]. Figure 4 shows the ‘spider-graph’ model for innovative types of building renovation.

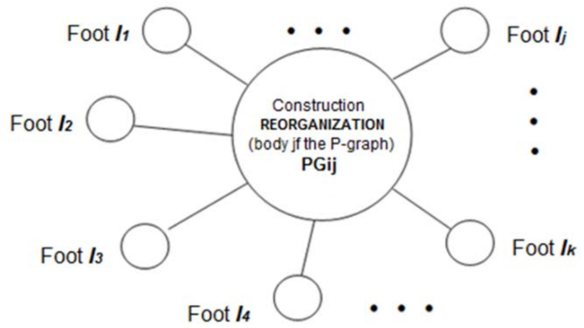

Figure 4 The infographic model of the ‘spider-graph’, showing the interconnection of innovative types of construction reorganization (Chulkov V.O., 2014)

The algebra of this formal model is different from Codd’s relational algebra [38] and allows one to subject both network and relational models to comparative analysis. Among many interconnected points (‘elements’ or innovative types of construction reorganization) of such a model, the pluralities united by a common relationship with one of the known points (which is called ‘the body of the spider-graph’, in our case it is **renovation**) are distinguished. The lines connecting this ‘body’ with all interconnected elements of the set are called ‘legs of the spider-graph’ (S-graph). S-graphs can be linked to each other by legs having the same marks.
Such idea of S-graphs’ formation is consistent with the totality of multipoint logics, united around one basic concept (single-point logic). An information field of the set of elements of different logics is defined by a network of linked S-graphs and denoted by the triad $\mathbf{(S, L, N,) = \{ S_t \}_t = \{ <s_t, \{ < l_{tk}, N_{tk} >_{tk} \}_k > \}_t}$, where: $\boldsymbol{S = \{s_t\}_t}$ is the set of names of the linked S-graphs; $\mathbf{L = \{\{ l_{tk} \}_k\}_t}$ is the set of all legs of the linked S-graphs; $\mathbf{N = \{ \{ N_{tk} \}_k \}_t}$ is the totality of marks marking these legs [36].

5. CONCLUSIONS

1. The most interesting are management situations where one or more logic points (Fig. 4) are ***priority***. It is necessary to rank and bring into correspondence such priorities, to establish the content and strength of communication of priority and non-priority points.
2. As an example, Fig. 5 shows a three-dimensional spatial model for determining the relationship of triads with the dominant role of one of the basic concepts. The number of priority points varies from 1 to **m** (where **m** is the dimension of multipoint logic). The number of models of the whole gamut of possible variants of priority points in the logic equals **m**+1.

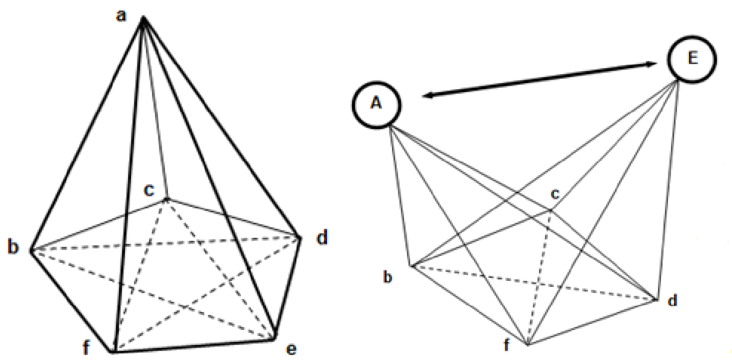

Figure 5 Spatial models of the relationship of triads (three points) with the dominant role of one of the basic concepts (left model) or with the dominant role of one of the dyads (right model) (Chulkov V.O., 2003)

The left model (Fig. 5) reveals connection of the triads with the leading role of one of the six basic concepts (a, b, c, d, e, f), in our case, this concept is **a** (labor resources and technologies). The right model (Fig. 5) reveals connection of the triads with the dominant role of two basic concepts (dyad A-E).

3. This series of models have the property of symmetry (the use of 'inverse', 'inverted' models). The boundary of occurrence of symmetric (inverted) models of multipoint logics is determined by the following expressions: for logics that have even values *m*: ***m / 2 + 1***; for logics that have odd values *m*: ***m / 2*** [39].

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