To the question of the cyber-physical systems’ implementation in construction for the smart city’s transition to a new development level

L A Shilova
National Research Moscow State University of Civil Engineering, 26, Yaroslavskoe highway, 129337, Moscow, Russia

E-mail: ShilovaLA@mgsu.ru

Abstract. The article presents some aspects of the cyber-physical systems introducing methodology in construction, which includes three successive stages, to implement the transition of the “smart city” to a fundamentally new level of development, taking into account the main provisions of the new Urban Health socio-technological paradigm, and also an algorithm for assessing the possibility the CPS introduction using the information technology in order to reduce costs to achieve qualitatively new positive results while ensuring a comfortable living environment of the human society.

1. Introduction
The rapid change in the world leads to a natural change in the human environment. Half of the world’s urban residents live in the settlements with a population of less than 500 thousand people, and about one in eight lives in one of 33 megacities with a population of over 10 million inhabitants. Moreover, it is predicted that by 2030 there will be more than 40 such megacities in the world, most of which located in the developing regions. At the same time, it becomes obvious that the main global task is to change the paradigm of health, for the solution of which the concept of “Urban Health” can be implemented.

This concept is aimed at achieving a number of goals, which include the following:
- improving the quality of living quarters;
- creating the healthy cities;
- the urban mobility modernization;
- providing affordable healthcare in cities;
- providing the population with clean water;
- sanitary safety;
- city safety.

To achieve the set goals in our country is possible only with the use of the new information systems and technologies, which is a logical and reasonable step in the modern conditions of digital transformation.

The digital technology active development has led to a significant increase in the number of various devices with built-in processors and data storage facilities. All this happens against the backdrop of resolving the issues related to the digital technologies’ integration, such as the Internet of
Things, the World Wide Sensor Net, and the Smart Building Environment, in order to achieve the greatest positive effect in the everyday life of a person.

However, human cognitive abilities evolve much more slowly than machines. In this regard, there was a need to remove a person from the control loop, where it was necessary to make decisions after processing a huge amount of information, and transfer a part of the routine actions to the so-called cyber-physical systems, which are related to the Industry 4.0. A sufficient number of publications has already been devoted to this aspect [1-12].

However, it must be understood that in some cases the use of cyber-physical systems can enhance a person’s analytical abilities, then we will talk about the new interactive systems of a new level, where a person will remain in the control loop [11].

Cyber physical systems (CPS) are “the systems that include various natural objects, artificial subsystems and control controllers, which make it possible to present this set of elements as a whole” [11]. At the same time, it can be argued that cyber-physical systems work according to the cycle shown in Figure 1, and, provided that the system works correctly, the cycle ends with the new positive results by creating the new value.

![Cyber Physical System Cycle](image)

**Figure 1.** Cyber Physical System Cycle

An example of a cyber-physical system is the Tohiba virtual power plant, which, using the Internet of Things technology, coordinates the operation of the electric vehicles and energy storage from the distributed sources of renewable energy. The result of this system is energy savings.

There are other striking examples of the cyber-physical systems’ introduction in the so-called cities of the future, for example, in Singapore, a traffic management system can save tens thousands of working hours per year. CPSs are also being introduced in this country in the field of healthcare, for automatic recording of offenses, energy management, water supply, etc.
The main objective of this study was to identify the key stages in the cyber-physical systems’ implementation in construction in order to obtain a new positive effect aimed at implementing the Urban Health concept for moving the smart city to a new development level [11].

2. Methods and methodology
In [12], it was suggested that the “Smart City” is a coherent convergent socio-cyber physical complex which parameter management processes are optimally adaptive to their own state space”, in the popular scientific sense, it is a city that is optimally adaptive to humans, society, nature. This means that the question of the entities’ tetrad convergence “man” - “society” - “nature” - “technology” at the model level of goal-setting is raised. As it can be seen from Figure 3 during the implementation of this concept, the borders intersect, forming at the same time areas of the scientific research. It is fair to say that the research in certain areas is already underway and there are certain achievements, but the main goal here is to integrate all the achievements together to ensure the transition of the “smart city” to a new level of development.

![Diagram showing the tetrad convergence of man, society, nature, and technology]
Figure 3. The convergence of the “smart city” entities’ tetrad [11]

Thus, in order to achieve a new level of development of the “smart city”, it is necessary to change the civil construction project, adapting it to a specific individual, however, without causing any damage to the environment and without violating the boundaries of other people’s life.

The author of [12] developed a diagram of the relationships between the models of the “smart city” entities’ tetrad and the results of their convergence.

Figure 4. The connection diagram of the “smart city” entities models tetrad and the results of their convergence [12]

3. Results
The accumulated international positive experience in introducing cyber-physical systems allows us to conclude that the transition of the “smart city” to a fundamentally new level of development is possible today by combining the various systems. At the same time, in order to make the transition, it is necessary to go through several interconnected stages, taking into account the methodological foundations indicated above.

At the first stage, it is necessary to determine all the required changes to the construction project so that it begins to comply with the Urban Health concept, at the second stage it is necessary to assess the possibility of making these changes, and only at the third stage the developed solutions can be implemented.

In this paper, we will dwell in more detail on the second stage. In [13], the necessary and sufficient operating conditions for the cyber-physical systems in construction were determined:

- reliability and stability in emergency have become the situations under these conditions for civil buildings;
- reliability, stability in emergency situations and natural-technological safety have become the situations under these conditions for industrial buildings.

To evaluate these indicators, it is necessary to analyze a number of static and dynamic values, therefore, it is advisable to use the information model of the building and the simulation. The
algorithm for assessing the feasibility of introducing cyber-physical systems at an object is shown in Figure 5.

![Algorithm for assessing the CFS implementing possibility](image)

**Figure 5.** Algorithm for assessing the CFS implementing possibility

At the same time, the previous studies [14] indicate that the possibility of calculating parameters using the information model is determined by the fulfillment of a number of factors, such as:
- the information model development level;
- compliance of the information model with the current state of the facility, i.e., when calculating the indicators, it is necessary to use the building’s information model at the operational stage (provided that the calculation is carried out for the object that is already in operation).

4. Summary
The current level of technological development allows to lay the foundation for the implementation of the Urban Health concept today, which is aimed, first of all, at ensuring the individual’s health and increasing his life expectancy.

However, we should not forget that megacities are already built today and when implementing the concept, in most cases it is necessary to adapt the existing infrastructure, which includes both civil and industrial buildings, which will also lead to the new issues and certain difficulties.
In this work, some issues for introducing the cyber-physical systems in construction to implement the transition of a smart city to a new level of development are discussed. That includes three consecutive stages, and also proposes an algorithm for assessing the possibility of implementing CPS using information technology in order to reduce the costs in order to achieve qualitatively new positive results while providing a comfortable environment for the human life.

Subsequent publications as part of the second stage work will be presented:
- methodology for the development of a simulation model of a building object to assess the CPS integrating possibility;
- methodology for calculating the dynamic and static indicators (operating conditions) that determine the possibility of introducing CPS at a construction site.

References
[1] Li Z, Wang Y, Wang K-S 2017 Intelligent predictive maintenance for fault diagnosis and prognosis in machine centers: Industry 4.0 scenario” Advances in Manufacturing 5(4) 377-387 doi: 10.1007/s40436-017-0203-8
[2] Galletta A, Carnevale L, Celesti A, Fazio M, Villari M A 2017 Cloud-Based System for Improving Retention Marketing Loyalty Programs in Industry 4.0: A Study on Big Data Storage Implications IEEE Access 6 5485-5492. doi: 10.1109/ACCESS.2017.2776400
[3] Marini A, Bianchini D 2016 Big data as a service for monitoring cyber-physical production systems Proceedings 30th European Conference on Modelling and Simulation 579-586.
[4] Rojko A “Industry 4.0 concept: Background and overview” International Journal of Interactive Mobile Technologies 11(5) 77-90
[5] Liu Y, Xu X 2016 Industry 4.0 and cloud manufacturing: A comparative analysis ASME 2016 11th International Manufacturing Science and Engineering Conference 2. doi: 10.1115/MSEC2016-8726
[6] Tamas P, Illes B 2016 Process improvement trends for manufacturing systems in industry 4.0” Academic Journal of Manufacturing Engineering 14 (4) 119-125
[7] Pereira A C, Romero F 2017 A review of the meanings and the implications of the Industry 4.0 concept Procedia Manufacturing 13 1206-1214. doi: 10.1016/j.promfg.2017.09.032
[8] Thoben K-D, Wiesner S A, Wuest T 2017 “Industrie 4.0” and smart manufacturing-a review of research issues and application examples International Journal of Automation Technology 11 (1) 4-16. doi: 10.20965/ijat.2017. p. 0004
[9] Zhong R Y, Xu X, Klotz E, Newman S T 2017 Intelligent Manufacturing in the Context of Industry 4.0 A Review Engineering 3(5) 616-630. doi: 10.1016/J.ENGE.2017.05.015
[10] Wollschlaeger M, Sauter T, Jasperneite J 2017 The future of industrial communication: Automation networks in the era of the Internet of Things and industry 4.0 IEEE Industrial Electronics Magazine 11(1) 17-27. doi: 10.1109/MIE.2017.2649104
[11] Chernyak L.2014 Cyber-physical systems on the start Open systems. DBMS 2 10-13
[12] Volkov A 2020 Bionics and Urban Health: A New Level of Smart City Modelling IOP Conf. Series: Journal of Physics: Conf. Ser. 1425 012182. doi:10.1088/1742-6596/1425/1/012182
[13] Volkov A, Shilova L 2020 Cyber-Physical Systems in Construction of the Sustainable Urban Development E3S Web of Conferences 143 01019. doi:10.1051/e3scconf/202014301019
[14] Ginzburg A V, Shilov L A, Shilova L A 2020 The methodology of storing the information model of building structures at various stages of the life cycle Journal of Physics Conference Series 1425 (1) 012156. doi: 10.1088/1742-6596/1425/1/012156