Cyber-Physical Systems In Construction For Sustainable Urban Development

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Abstract. The article reviews the current state of research works in the field of cyber-physical systems development in conjunction with «smart house» technology. The authors have collected statistical data on the articles and the papers about cyber-physical systems in construction from 2009 to 2019, which are presented in data base SCOPUS. These publications were analysed by the authors and as the result the countries leader in this field of studying were identified. The authors formulate a definition of a building cyber-physical system and determine the operating conditions of such systems. Finally, further research objectives were identified by the researchers.

1 Introduction

For a long time, mankind did not think about its environment and the development of technology has led to a significant negative impact on the environment. Over time, a clear understanding has emerged of the need to develop measures aimed at the optimal use of limited resources and the use of environmentally friendly - nature, energy and material saving technologies, as well as aimed at maintaining the stability of social and cultural systems, which was the basis for the development of the concept of sustainable development.

Today, the basis of sustainable development is a triune concept, which includes economic, social and environmental components and includes 17 goals and 169 related tasks. The main goals of sustainable development adopted on September 25, 2015 by 193 countries are presented in Fig.1.

The most interesting goal for the construction industry is the goal of sustainable development of cities and settlements, to achieve which there is already a good reserve, for example, scientists around the world have done a lot of research works in the field of energy and resource conservation. That fact is confirmed by a lot of publications in different countries [1-8].

There are a lot of research works in the field of urban development and a lot of attention is paid to the integration of new technologies in the design processes, the development of smart cities, etc.

The large-scale introduction of "smart house" technologies leads to the fact that a technological process is constantly going on in residential buildings and structures, which can lead to the new sources of emergency situations that have not been studied before and associated with it risks.

This is justified by the fact that existing buildings and structures must meet the current regulatory framework, which is currently not fully adapted to the use of new technologies.

Fig. 1. Sustainable development goals [https://www.un.org/]

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In addition, despite the fact that there are a lot of publications devoted to the management of "smart house" or "smart cities", both in Russia and abroad [9-17, etc.], there are few studies in the field of improving safety or the occurrence of risks during implementation smart technologies. Moreover, the available publications deal, as a rule, with the problems of ensuring the confidentiality of using technologies, information, etc.

At the same time, considering the entire residential buildings, in which each apartment is equipped with many different sensors and "smart" equipment, the concept of cyber-physical building systems arises, under which the authors accept a finite set of functional components (elements, objects, construction complex, computing resources integrated into the included physical processes) and the relations between them, allocated in accordance with a specific goal within a certain time interval [18].

2 Materials

As part of the research work on this topic, the international bibliographic and abstract database SCOPUS, which allowed forming a general picture of the current situation in the field of development of cyber-physical systems in construction from the point of view of sustainable urban development was used.

3 Results

Despite a significant number of publications presented in the Scopus international abstract database (more than 400 since 2009, including unpublished publications for 2020 (Fig. 2), a selection of publications was made using the keywords: "Smart city" and "Cyber-physical systems") studies of cyber-physical systems, the development of which is associated with the transition to the concept of "Industry 4.0.", are still at the initial stage.

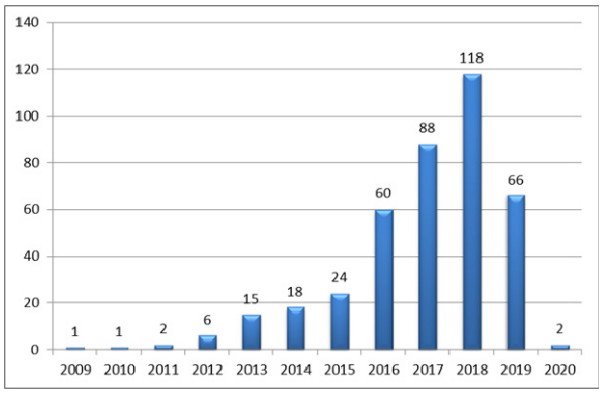

Fig. 2. Publications presented in the international abstract database Scopus in the field of development of cyber-physical systems

However, many of these publications are devoted to the problems of processing big data that are collected during the operation of such systems [19-25].

For example, the article [19] presents a discussion of open challenges and future directions for recognizing and mitigating uncertainty in this field.

A lot of attention is paid to the development of computer-aided design of cyber-physical systems of a building [26].

Some key defining characteristics of a Smart City as a Cyber-physical system are presented in [27].

It should be noted that most publications in the field of cyber-physical systems are published in the computer science field of knowledge, that fact is confirmed by statistics from the Scopus database and presented in Table 1.

Table 1. Distribution of publications by field of knowledge

№	Field of knowledge	Number of publications
1	Computer Science	323
2	Engineering	164
3	Mathematics	62
4	Social Sciences	55
5	Energy	38
6	Decision Sciences	33
7	Physics and Astronomy	24
8	Business, Management and Accounting	20
9	Materials Science	15
10	Environmental Science	13
11	Biochemistry, Genetics and Molecular Biology	6
12	Chemistry	6
13	Chemical Engineering	3
14	Earth and Planetary Sciences	3
15	Medicine	3
16	Economics, Econometrics and Finance	2

The percentage distribution of publications by the countries is shown in Fig. 3. It is worth noting that the United States is the leader in research works in this context - 117 publications for the period under review, Italy takes the second place with 39 publications and China has the third place with 35 publications.

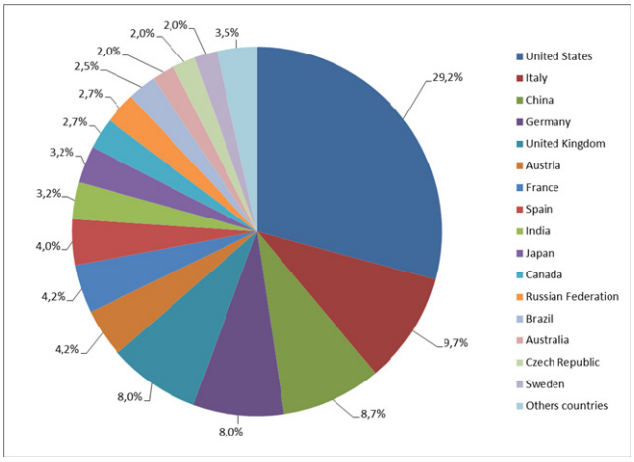

Fig.3. Percentage distribution of publications about cyber-physical systems and «smart cities» by country

At the same time, it can be argued that in publications the concept of "smart city" transforms the concept of a city, which becomes a "convergent socio-cyber-physical complex whose parameter management processes are optimally adaptive to their own state space" [28-29].

4 Conclusions

The fundamental condition for the operation of cyber-physical systems in construction will be safety - a condition in which there is no unacceptable risk associated with causing harm to the life or health of citizens, property, environment, life or health of animals and plants due to the destruction, damage to such an object.

An analysis of the publications showed that the integration of new technologies into building systems leads to the fact that the latter will consist of many heterogeneous elements, the stability of which directly depends on the influence of external and internal factors, and, therefore, such system can be considered as a complex system of probabilistic nature.

In addition, special attention must be paid to the reliability of such systems, which in this context will include concepts such as reliability, maintainability, durability, etc.

Thus, the analysis of publications allowed us to conclude that the use of cyber-physical systems in construction is possible only when these systems meet the requirements of safety, reliability and stability (Fig. 4), i.e. will be in a shaded area, the boundaries of which can only be determined by knowing their quantitative characteristics, which will form the integral concept of each of the requirements, and that will be the subject of further research.

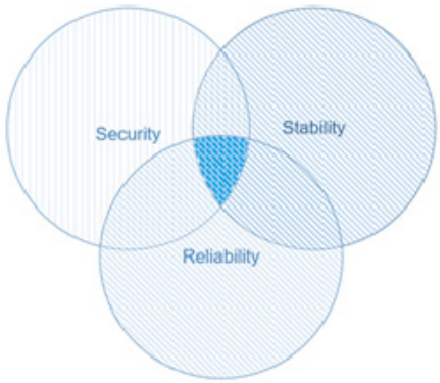

Fig.4. Graphical representation of the operating conditions of cyber-physical systems in construction

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