The assessment of autonomy indexes of socially significant elements of urban infrastructure for creating a safe living environment

L A Shilova
National Research Moscow State University of Civil Engineering (MSUCE), Yaroslavskoye Shosse 26, Moscow, 129337, Russia

E-mail address: ShilovaLA@mgsu.ru

Abstract. The main task of modern society is to ensure and maintain a safe environment for human life. However, the large-scale introduction of information technologies leads to the fact that a technological process is constantly going on in residential buildings and structures, which can lead to the emergence of new previously unexplored sources of emergency situations, and the risks associated with them. In this regard, the article presents an approach to assessing the autonomy of construction projects in the event of an emergency. The autonomy of a construction facility will be understood as the ability of a construction facility to perform its target function during its design life without external intervention in the event of an emergency. At the same time, it is proposed to describe the autonomy of a construction object by the following indexes: reliability, stability and an index of natural and man-made safety.

1. Introduction
The main task of modern society is to ensure and maintain a safe environment for human life. This fact is confirmed by a significant number of publications in this area [1-4]. For example, the paper [1] confirms the fact that the world community is concerned about population growth, depletion of natural resources and the problems of global warming. Considering that control and reduction of the negative impact of construction on the environment has fundamental importance, the work focuses on the research project titled "Energy efficient Lightweight Sustainable Safe steel construction" (ELISSA). This paper also presents the life cycle analysis of the building developed as case demonstrator. At the same time, the problems of environmental impact were analyzed both at the stage of construction of the structure and at the stage of dismantling.

The next work [2] is devoted to the development and technological research of an intelligent electrical building for creating a safe environment for human life. The authors of the study emphasize that the Intelligent Building is an important result of the use of computer technologies in the information age. This paper explains the basic concept of smart building, first describes the meaning and development goals of smart building with electricity, then analyzes the current situation of such buildings, identifies existing problems, and discusses key technologies of smart buildings. Finally, this paper examines the trends in the development of intellectual construction in general to ensure a comfortable living environment.
Also, in the process of creating a safe living environment, a lot of publications are devoted to green buildings and related to their construction factors (labor protection during the construction of buildings, safety, etc.) [5-11].

2. The relevance of research
The rapid development of science and technology leads to the active introduction of new technologies, especially in the industrial sector. At the same time, sometimes innovations led to significant environmental damage to many ecosystems, which, however, did not receive sufficient attention from society. Over time, humanity began to realize the depth of the possible consequences and make a conclusion about the need to develop measures aimed at solving the issue of the use of limited natural resources, calling for the use, for example, of renewable energy sources, for the introduction of environmentally friendly, nature-, energy- and material-saving technologies to support the stable development of social, cultural and ecological systems. This position is consolidated by the concept of sustainable development, which was put forward in 1987, and assumes such a development of mankind, in which the satisfaction of the needs of present generations is carried out without prejudice to the ability of future generations to meet their own needs.

If we consider this concept and its goals from the point of view of the development of the construction industry, then it is necessary to pay attention to the goal of sustainable development of cities and towns. To achieve this goal, leading research centers and scientists are conducting research aimed at introducing new technologies into the design, construction, operation, and disposal of construction projects [12-20].

Undoubtedly, in due time the development of the "smart home" concept was a significant and important achievement in this light. However, the large-scale introduction of smart home technologies leads to the fact that in residential buildings and structures a technological process is constantly taking place, which can lead to the emergence of new previously unexplored sources of emergency situations, and the risks associated with them.

In addition, at present time more attention is paid to the development of the information technology concept, which is focused on the introduction of computing resources into physical entities. Here, special attention is paid to cyber-physical systems that belong to the Fourth Industrial Revolution or the so-called Industry 4.0. The active introduction of cyber-physical systems in construction is also focused on creating a comfortable environment for human life. At the same time, the key technological trends at the heart of Industry 4.0 are: big data, cloud computing, the Internet of things, additive technologies, etc.

At the same time, in conditions of emergencies, socially significant elements of the urban infrastructure remain the most vulnerable. Wherein the concept of social infrastructure is quite extensive and includes a set of industries and enterprises that functionally ensure the normal life of the population. Based on this definition, it can be argued that housing, its construction, social and cultural facilities, housing and communal services, enterprises and organizations of healthcare systems, education, enterprises and organizations related to recreation and leisure, etc. can be classified as social infrastructure.

In addition, it should be noted that despite the fact that modern construction technologies allow creating sustainable and reliable construction projects, at the same time, in conditions of dense urban development, the safety of the living environment of the population, as a rule, is provided by the already existing infrastructure. In this light, the issue of ensuring the autonomy of the functioning of already existing objects, taking into account the definition of the properties that appear in these objects due to the introduction of new ones, including information technologies, becomes relevant.

In addition, the importance of solving the presented task of ensuring the autonomy of socially significant infrastructure elements is also due to the current situation with the COVID-19 pandemic, which began in 2019.
3. The basic principles for assessing the indexes of autonomy of socially significant elements of urban infrastructure

3.1. Basic terms and definitions

The term autonomy comes from an ancient Greek word that literally translated as "self-law" and it was used, as a rule, in psychology, philosophy and politics. However, over time, this term began to be used in various areas of human life. If we consider the term "autonomy" from the point of view of cybernetics, then it can be argued that it means that this or that part of it or a certain function is itself responsible for its regulation. This concept can be translated as "self-enforcement of the law."

The previous author’s studies make it possible to formulate the concept of the building object autonomy and determine the indexes that allow it to be evaluated. Thus, the autonomy of a construction facility will be understood as the ability of a construction facility to perform its target function during the estimated service life without external intervention even in the event of an emergency.

At the same time, the autonomy of a building object can be described by the following indexes [21]:

- **Reliability (R)** - the ability of a construction object to perform the required functions during the estimated service life [22];

- **Sustainability (T_{Sustb})** - the state of the object, in which the actual functional and technical characteristics of the building (structure) and its elements correspond to the range of permissible values, and the nature of the dynamics of their change does not imply the possibility of inconsistency during the calculated period of time [23];

An index of the natural and technogenic security (S) of an object - the state of the object protection from accidents and disasters caused by complex influences - hazardous natural processes, damage and destruction of technical systems, errors and unauthorized influences of operators and personnel, in which conditions are created for its normal functioning and strict observance on it established modes.

3.2. Classification of emergencies

It is customary to classify emergencies by reasons of occurrence, speed of spread, scale of the covered territory, severity, departmental affiliation, etc. The consolidated classification scheme of emergencies is shown in figure 1.

![Classification of emergency situations](image)

Figure 1. The consolidated scheme of classification of emergency situations

According to the sphere of occurrence of emergency situations, it can be technogenic, natural or environmental.

The source of technogenic emergency is a dangerous man-made incident: an accident or disaster at an industrial facility, transport, power and utility life support systems, treatment facilities, etc. The causes of natural hazards are: geophysical hazards (earthquakes, volcanic eruptions); dangerous geological phenomena (landslides, mudflows, avalanches, taluses, etc.); meteorological hazards
(storms, hurricanes, tornadoes, showers, snow drifts, frosts, etc.); marine hazardous hydrological phenomena (typhoons, tsunamis, strong waves (5 points or more) or abnormal sea level fluctuations); hydrogeological hazards (low groundwater levels, high groundwater levels); natural fires (forest, peat, underground fires of fossil fuels), etc. Environmental emergencies can arise due to changes in the state and properties of the atmosphere, biosphere, or hydrosphere.

According to the speed of propagation, emergency situations are usually divided into sudden (explosive), fast (rapidly), moderate, and slow spreading.

According to the scale of possible consequences, emergency situations are divided into object (local), on-site, regional, national, global, planetary.

In addition, it is customary to classify emergency situations by departmental affiliation, depending on the industry in which the emergency occurred.

Within the framework of the study, emergency situations are proposed to be considered as internal and external. An example of emergency sources with such a division is presented in table 1.

Table 1. The internal and external sources of emergency situations.

| The internal sources of emergency | The external sources of emergency |
|----------------------------------|----------------------------------|
| The level of technologies complexity used at the facility | Interruption of supply of energy carriers or technological products |
| The qualifications of users or personnel | Terrorism |
| Labor and technological discipline | Wars |
| Physical and moral deterioration of equipment | Epemics |
| Design and engineering flaws | Natural sources |

3.3. The approach to assessing the autonomy of construction objects

Each of the above indexes of autonomy is complex and can describe the state of a building object from different angles. In this regard, it becomes obvious that each index will consist of the parameter set. At the same time, according to the variety of construction objects types the number of parameters for each index may differ.

In general terms, the reliability of the construction object can be represented as follows

$$ R = [ r_1, r_2, r_3, \ldots, r_m ] $$

The sustainability of the construction object will take the following form

$$ T_{Sust.} = [ t_1, t_2, t_3, \ldots, t_m ] $$

Natural and technogenic security will be described as follows

$$ S = [ s_1, s_2, s_3, \ldots, s_m ] $$

Thus, according to (1-3) the autonomy of a construction object can be represented as the following matrix

$$ A_n = \begin{bmatrix} r_{n1} & r_{n2} & \cdots & r_{nm} \\ s_{n1} & s_{n2} & \cdots & s_{nm} \\ t_{n1} & t_{n2} & \cdots & t_{nm} \end{bmatrix} $$

In this case, the index $n$ means the standard or normal state of the parameter, and the number of parameters depends on the type of the object under consideration. To determine the level of autonomy
of a construction object, it is necessary to collect a matrix with the actual values of the parameters under consideration, which in the general case may have the following form:

\[
\mathbf{A}_f = \begin{bmatrix}
    r_{f1} & r_{f2} & \cdots & r_{fn} \\
    s_{f1} & s_{f2} & \cdots & s_{fn} \\
    t_{f1} & t_{f2} & \cdots & t_{fn}
\end{bmatrix}
\]  

(5)

Next, it is necessary to determine the difference between the matrices (5) and (4), i.e. perform the operation of calculating the matrix \( \mathbf{A}_c \), all the elements of which are equal to the pairwise difference of all the corresponding elements of the matrices \( \mathbf{A}_n \) and \( \mathbf{A}_f \), that is, each element of the matrix \( \mathbf{A}_c \) is equal to:

\[
a_{ci} = a_{fi} - a_{ni}
\]

(6)

If the resulting matrix contains negative values, then the autonomy of the object under consideration is not ensured. If all parameters in the matrix take the value 0, then the autonomy of the object is fully ensured.

Let us illustrate with an example. The standard indexes of the autonomy of the construction object under consideration include the following parameters:

\[
\begin{align*}
\mathbf{R} &= [1 \ 1 \ 1] \\
\mathbf{T}_{\text{sustb.}} &= [1 \ 1 \ 1 \ 1] \\
\mathbf{S} &= [1 \ 1 \ 1 \ 1]
\end{align*}
\]

Thus, the autonomy of the construction object under consideration can be represented in the form of the following matrix

\[
\mathbf{A}_n = \begin{bmatrix}
    1 & 1 & 1 & 0^* \\
    1 & 1 & 1 & 1 \\
    1 & 1 & 1 & 1
\end{bmatrix}
\]

1 - means that the parameter has a normative value;
0* - dummy zero, which indicates that the index is described by fewer parameters than the rest.

The actual state of the building object is described by the following matrix

\[
\mathbf{A}_f = \begin{bmatrix}
    1 & 1 & 1 & 0^* \\
    1 & 1 & 1 & 0 \\
    1 & 1 & 1 & 1
\end{bmatrix}
\]

Let us define the matrix \( \mathbf{A}_c \), which will describe the calculated value of the autonomy of the object under consideration

\[
\mathbf{A}_c = \begin{bmatrix}
    0-1 & 1-1 & 1-1 & 0^* \\
    -1 & 0 & 0 & 0^* \\
    1-1 & 0-1 & 1-1 & 0-1 \\
    0 & -1 & 0 & -1 \\
    -1 & 1-1 & 1-1 & 1-1 \\
    0 & 0 & 0 & 0
\end{bmatrix}
\]

The obtained result shows that not all indexes have a normative value, and there are some parameters that require improvement in order to ensure the autonomous operation of the construction site. At the same time, given that construction objects are complex systems, which are inherent in failures and failures, it is advisable to distinguish more than two states of autonomy. This fact is due to the fact that autonomy can be provided or not, however, for example, individual functions performed
by the object can be automated, and then we can say that the autonomy of the object is partially fulfilled.

4. Conclusions
Maintaining the indexes of autonomy within the framework of the normative values will speed up the process of creating a safe environment for the life of the population. At the same time, to achieve this goal, it is necessary to develop a classification of socially significant objects of urban infrastructure in order to empirically (based on statistical data on the functioning of complex systems) determine the number of parameters of the proposed indexes depending on the type of the construction object.

In addition, given that a technological process is constantly going on in residential buildings and structures, which can lead to the emergence of new previously unexplored sources of emergency situations, and the risks associated with them, special attention should be paid to studying these risks and identifying possible sources of emergency situations.

References
[1] Iuorio O, Napolano L, Fiorino L and Landolfo R 2018 Sustainability of modular lightweight steel building from design to deconstruction United States Wei-Wen Yu International Specialty Conference on Cold-Formed Steel Structures pp 515-27
[2] Zhang L-M, Liu B-C, Tang Q-H and Wu L-P 2014 The development and technological research of intelligent electrical building 6th China International Conference on Electricity Distribution pp 88-92
[3] Lazar N and Chithra K 2020 A comprehensive literature review on development of Building Sustainability Assessment Systems J. of Build. Eng 32 101450
[4] Hossaini N, Hewage K and Sadiq R 2015 Spatial life cycle sustainability assessment: A conceptual framework for net-zero buildings Clean Technologies and Environmental Policy 17 (8) pp 2243-53
[5] Ding W X, Zhao Y H and Ji X 2013 Applied Mechanics and Materials Analysis of the environmental benefits of green building 368-370 (1) p 1135-8
[6] Zhang X and Mohandes S R 2020 Occupational Health and Safety in green building construction projects: A holistic Z-numbers-based risk management framework J. of Cleaner Production 275 122788
[7] Sedayu A, Setiono AR, Subaquin A and Gautama AG 2020 Improving the performance of construction project using green building principles Asian J. of Civil Eng. 21 (8) pp 1443-52
[8] Ge J, Zhao Y, Luo X and Lin M 2020 Study on the suitability of green building technology for affordable housing: A case study on Zhejiang Province, China Journal of Cleaner Production 275 122685
[9] Liu Q and Ren J 2020 Research on the building energy efficiency design strategy of Chinese universities based on green performance analysis Energy and Buildings 224 110242
[10] Xie B-C, Zhai J-X, Sun P-C and Ma J-J Assessment of energy and emission performance of a green scientific research building in Beijing, China Energy and Buildings 224 110248
[11] Cianciarullo M I 2019 Green construction– reduction in environmental impact through alternative pipeline water crossing installation J. of Cleaner Production 223 p 1042-9
[12] AbouHamad M and Abu-Hamd M 2019 Framework for construction system selection based on life cycle cost and sustainability assessment J. of Cleaner Production 241 118397
[13] Xu J, Shi Y, Xie Y and Zhao S 2019 A BIM-Based construction and demolition waste information management system for greenhouse gas quantification and reduction J. of Cleaner Production 229 pp 308-24
[14] Iacovidou E, Purnell P and Lim M K 2018 The use of smart technologies in enabling construction components reuse: A viable method or a problem creating solution Journal of Environmental Management 216 pp 214-23
[15] Mesaros P, Spisakova M and Mandicak T 2018 Sustainable design of construction through waste management using building information modelling Int. Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 18 (6.4) pp 537-44
[16] Bilal M et al. 2016 Big data architecture for construction waste analytics (CWA): A conceptual framework Journal of Building Engineering 6 p144-56
[17] Guerra B C, Leite F and Faust K M 2020 4D-BIM to enhance construction waste reuse and recycle planning: Case studies on concrete and drywall waste streams Waste Management 116 79-90
[18] Yung P and Wang X 2014 A 6D CAD model for the automatic assessment of building sustainability International Journal of Advanced Robotic Systems 11 (1) A131
[19] Park J W, Cha G W, Hong W H and Seo H C 2014 A study on the establishment of demolition waste DB system by BIM-based building materials App. Mechanics and Materials 522-524 pp 806-10
[20] Cheng J CP and Ma L YH 2013 A BIM-based system for demolition and renovation waste estimation and planning Waste Management 33 (6) 1539-51
[21] Volkov AA and Shilova LA 2020 Cyber-Physical Systems In Construction For Sustainable Urban Development E3S Web of Conference 143 01019
[22] Standard GOST 27751-2014 Reliability of building structures and foundations. Fundamentals
[23] Shilova L A 2014 Information support for management of life supporting facilities taking into account the criteria of engineering and functional stability in the case of an emergency Information resources of Russia 6 (142) p 24-7