Multi-Criteria Approach in Multifunctional Building Design Process

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Abstract. The paper presents new approach in multifunctional building design process. Publication defines problems related to the design of complex multifunctional buildings. Currently, contemporary urban areas are characterized by very intensive use of space. Today, buildings are being built bigger and contain more diverse functions to meet the needs of a large number of users in one capacity. The trends show the need for recognition of design objects in an organized structure, which must meet current design criteria. The design process in terms of the complex system is a theoretical model, which is the basis for optimization solutions for the entire life cycle of the building. From the concept phase through exploitation phase to disposal phase multipurpose spaces should guarantee aesthetics, functionality, system efficiency, system safety and environmental protection in the best possible way. The result of the analysis of the design process is presented as a theoretical model of the multifunctional structure. Recognition of multi-criteria model in the form of Cartesian product allows to create a holistic representation of the designed building in the form of a graph model. The proposed network is the theoretical base that can be used in the design process of complex engineering systems. The systematic multi-criteria approach makes possible to maintain control over the entire design process and to provide the best possible performance. With respect to current design requirements, there are no established design rules for multifunctional buildings in relation to their operating phase. Enrichment of the basic criteria with functional flexibility criterion makes it possible to extend the exploitation phase which brings advantages on many levels.

1. Introduction

Contemporary cities disperse in a very dynamic way. Development of modern urban structures follows the tendencies of efficient space management which manifests itself in the form of a multifunctional building. At present more and more complex multifunctional objects are being designed, where their structure can be defined as a complex system. Currently architects are obliged to adjust the design of the building to the law and this is sufficient. However, due to the complexity of the designed structures, the multi-criteria approach is required, as presented in the paper.

Multifunctional buildings are absorbing an increasing number of people through an ever-expanding service sector. Urban centres are expanding mainly through the development of increasingly large areas. The development of urbanized areas naturally assumes the expansive character of urban agglomeration. This process can be determined organic because of total control over it nobody can handle. At present, spatial planning is concerned in control of urban sprawl. Opposition to expansive
urban sprawl should be the intensive use of existing space resources. The increase in investment in the currently used space will minimize horizontal development interfering with the environment [1]. Multifunctional buildings are one of the predominant buildings of today's urban agglomeration. However, it is difficult to introduce any systematic among objects that exist. It can be said that the integration of functions in one building is currently associated with the expectations of an investor who defines his demands in the project. From a theoretical and practical point of view, it would be beneficial to combine functions with respect to the wider environment. Such an approach is beneficial not only for functional reasons. The benefits of combining urban functions into an integrated one are significant. Multifunctional systems also have a social, economic and environmental dimension. Multi-criteria design approach is a systematic way to define the design process to reach the basic values of sustainable development [2] (figure 1).

![Figure 1. Scheme of influence of multifunctional building on sustainable development presented by Venn diagram. Own elaboration. Venn diagram based on[3].](image)

2. Multifunctional building

Multifunctional building is a structure that contains at least two different destination spaces, but most of present realizations contain a large number of them. In general multifunctional building contains a large amount of functions, mixed-used spaces that create a complex system. Multifunctional building allows to use the urban space in a more efficient and compact way [4].

Multifunctional buildings are absorbing an increasing number of people through an ever-expanding service sector. Urban centres are expanding mainly through their vertical development where in one place many different users’ needs intersect. The design process of new multifunctional buildings should be adequate to reflect the needs of the present society.

The structure of multifunctional building can be described structure composed of functional program (F) and technological systems (T) based on the construction system (C) as an internal set of elements.

Furthermore the building structure depends on external influences set, which include:
- weather conditions (W),
- social infrastructure (SI),
- transportation infrastructure (Tr),
- city logistics supply system (CL),
- waste disposal (WD),
- technical infrastructure (TI).

Finally, multifunctional building depends on the environmental elements set, such as:
- localization (L),
natural environment (NE),
management system (MS),
social aspect (SA),
economic aspect (E).

Presented three sets of elements create the whole structure of the physical multifunctional building structure. Figure 2. presents a network of influences between the multifunctional building based on the set of elements (MBEN). (The abbreviations are given in parentheses). This configuration of nodes and edges represent a theoretical view of influences which occur between elements.

3. Design process
At present, the multifunctional building design process is provided in a workflow based on individual architect practice. The project parameters are based on the minimal building codes, regulations and on the demands of the developer. To create an optimized multifunctional structure it is necessary to enlarge the design parameters. Creating a systematic design process network may effect in positive value for the built environment and natural environment.

Multifunctional building design is a process, where multiple stakeholders are involved. The following stakeholders participate in the design and assessment process, when the building’s essential function and infrastructure are defined:
- building owner (bo),
- tenants (t),
- facility staff (fs),
- occupants (o),
- neighbors (n),
- municipality (m),
- regulators (r),
- designer (d),
- risk manager (rm),
- insurer (i),
- fire brigade (fb). [5]
The design process should include a complex analysis of the life cycle. Analyzing the multifunctional building life cycle on figure 3, where successive phases are listed, it is worth of pay attention to the exploitation phase. In the time of dynamic functional changes there is a need to provide technological and functional change possibility as shown below.

Figure 3. Multifunctional building life cycle scheme.

The life cycle of the multifunctional building is defined by phases:

- initial work phase (p1),
- concept phase (p2),
- project phase (p3),
- construction phase (p4),
- exploitation phase (p5),
- waste phase (p6).

Despite the designer is the main architect of the project, it is important for the project final effect to include all stakeholders in the multifunctional building life cycle. Due to the life cycle phases each stakeholder brings to the project supplementary information. Integration of compiled information in the life cycle is presented on figure 4. This stakeholders -life cycle network (SLCN) is a virtual representation of life cycle phases (p1-p6) and stakeholders. These elements are defined by nodes and edges and they represent relation between them, where each life cycle phase refers to all elements of the network.

Figure 4. Stakeholders - life cycle network (SLCN).
4. Multi-criteria approach in a complex system design process

There is an urgent demand to define the actual criteria and methods for the development of multifunctional building structures. The complexity of multifunctional building design process need to use a systematic structure within the multi-criteria approach. System is a composite of people, procedures, and plant and hardware working techniques to aid in making systems safe throughout their life cycles [6].

Defined criteria for the multifunctional building design process are:

- Aesthetics (C1),
- Functionality (C2),
- Natural Environment Protection (C3),
- System Safety (C4),
- System Effectiveness (C5),
- Functional Flexibility (C6).

At present, most of these criteria exist in the design process. Frequently, they are used to satisfy the minimal requirements. The role of the main designer, architect, is to provide a progressive way to the multi-criteria approach, which in effect will cause optimization of the complex engineering system structure. For example, a new criterion of functional flexibility is introduced. Predicting changes in the building functional system can improve the whole designed engineering system. The criteria set is presented on figure 5. as a multi-criterion network (MCN), where they improve each other in the design system.

![Figure 5. Multi-criteria network (MCN).](image)

The multi-criteria approach in multifunctional building design process can be defined as an abstract mathematical definition, which present the system as a subset of the multi-element relation, the product of the Cartesian set of properties [7] [8]. Formula (1) defines the Cartesian product for the multi-criteria approach in multifunctional building design process (MBDPN):

\[
MBDPN \subseteq (MBEN \times SLCN \times MCN)
\]  

(1)

Where: \(MBDPN\) - multi-criteria multifunctional building design process, \(MBEN\) - Multifunctional building elements network, \(SLCN\) - stakeholders -life cycle network, \(MCN\) - multi-criteria network.

This Cartesian product is a compilation of the whole design process structure. Representation of this structure is a system, where are defined subsystems and relations between them. Figure 6 is a holistic representation of the network based on the equation (1). The presented network contains 66 basic nodes and 990 edges. The define the complex system of relations in the multifunctional building design process.
Figure 6. Multi-criteria approach in multifunctional building design process network (MCAN).

5. Results and discussions
The result of the presented analysis reveals the multifunctional building process design structure. Form of the multi-criteria approach is a complex network structure, where relations between all elements generate a theoretical base to optimise the design process.

In practice there are tools for optimization of the design process such as building information management (BIM), which is used in the design phase. Presented method is a holistic structure predefining the whole life cycle of a multifunctional building. Actually there are methods for measure existing buildings like building management system (BMS) and building performance evaluation (BPE). They are useful tools to bring them into the multi-criteria approach. Multi-criteria approach in multifunctional building design takes an advantage of systematic predicting the exploitation phase.

6. Conclusions
The presented material is the basic stage of further research in the field of complex multifunctional building system design process. Basic study defines the crucial criteria for the multifunctional building design process. Creating complex system based compiling the building process structure can give opportunity for optimization of the architect workflow as well as the designed building structure.

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