Methodological approach to the digitalization of adoption decisions for the renovation of urban environment

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Abstract. The article substantiates the feasibility of applying BIM technologies and digitalization methods for planning complex multi-aspect renovation of urban infrastructure facilities, as one of the directions for creating smart cities. Moreover, as an effective approach, it is proposed to use the method of system analysis, including the development of a model of the urban environment, the establishment of indicators characterizing the state of the objects of urban areas, the methodology for choosing solutions for updating the objects under consideration, etc. Implementing a systematic approach to digitalization of planning the renovation of urban areas, an action plan has been developed in the form of separate strata-layers that sequentially regulate and ensure an effective order and content of decisions made.

1. Introduction

Currently, there is a tendency to plan the transition of modern cities to the state of “smart city”, “smart territory”. [1-6).

Smart City is an artificially created environment, which is an integration of physical, digital and human systems aimed at ensuring comfortable living conditions and life of society [1-6].

One of the ways to create a “smart city” is to carry out multidimensional renovation (MR) of the urban environment because, as a rule, a significant number of urban infrastructure in Russia have significant moral (M) and physical deterioration (Ph) which cannot comply with the modern look of the city as well as the prevailing requirements and standards.

MR is understood as a set of actions (maintenance, overhaul, reconstruction, rehabilitation, demolition, etc.) implemented on the basis of the adoption of functional, technical and technological solutions aimed at reducing the Ph and M objects of the urban environment.

Effective implementation of actions and decisions on MR is possible only with the use of advanced technological approaches which is the deep digitalization of all city objects as well as methods, circuits, decision algorithms for transforming the urban environment [1, 7, 8].

Currently, in the construction industry there is a tendency to switch to BIM technologies for the design of buildings and structures [9-13]. In this case, BIM is considered as an information model of a building or structure, as an approach to managing the life cycle of an object with a continuous “seamless” cycle of design, construction, operation, updating and disposal. This provides for the comprehensive collection and processing of all architectural design, technological, economic and other information about the object [1, 9-13].

When planning an integrated MR of the urban environment, the principle of BIM technologies should be applied to the entire set of city infrastructure facilities located in the territories to be
updated. Moreover, BIM technology “originates” not from the design and construction of new buildings or structures but from the design of the development of existing facilities operation with possible options for their MR.

A feature of the properties of numerous objects located in urban areas is their qualitative diversity - residential and public buildings, communication engineering and road networks, parks, squares and other objects as well as a different level of their condition according to Ph and M, according to their importance in the formation the modern look of the city which makes it difficult to choose a rational option for an integrated MR urban environment.

The effectiveness of a systematic approach to solve similar, complex problems with a powerful source data base has been theoretically substantiated and practically confirmed [14-17]. In accordance with this, when planning the MR of the territories of the urban environment based on a systematic approach, 2 main design tasks should be solved.

1. The choice of such a composition of urban areas as a system that provides a complete and adequate system representation (modeling) of these territories (system synthesis task).

2. Justification of such values of the parameters of the components and objects of the system as a whole (the task of parametric synthesis) in order to satisfy the given requirements – decent living conditions and the life of society [18].

With a systematic approach to planning the digitalization of urban areas and the corresponding implementation of the 2 main design tasks of updating, the scheme of actions in the most general form can be represented in the form of separate strata – layers that regulate and ensure the effective order and content of decisions on actions [19].

The first stratum includes the identification of the problem – this is the digitalization of the MR of urban areas, ensuring the quality and safety of society (see Figure 1).

This problem is formulated on the basis of existing national and priority programs and projects “Housing and urban environment”, “Housing and communal services and urban environment”, “Digital economy”.

Considering these projects on a city-wide scale, it is advisable that the administrative authorities (the apparatus of the governor, the mayor’s office, etc.) form a group of relevant highly professional specialists who implement and control the entire program of actions outlined in the following strata and based on the passports of national programs and projects. The involvement of specialists in various fields in the development of MR plans is dictated by the need to take into account the formed material and technical potential of the city under consideration, the possibilities of the existing city administrative and financial system, capable of providing investment income from federal and other sources, as well as the need to establish contacts with the population of urban areas based on work experience for renovation in Moscow.

Figure 1. The content of the 1st stratum – highlighting the problem of digitalization multidimensional renovation of urban areas.
In accordance with the provisions of the systematic approach, these factors can be classified as “external environment” – see Figure 1.

The second stratum, which is a database, should contain a set of techniques, models, relevant regulatory and special reference information that ensure effective MR planning – see Figure 2.

![Figure 2. The formation of the necessary database.](image)

The initial component of the stratum is a system model of the urban environment site, which is a system-integrated city planning formation (CPF) [20, 21], which includes all types of objects – buildings, structures, engineering and road communications, parks, squares, etc.

CPF is modeled by its content and form. The content is represented by a subject hierarchical structure and a multilayer graphic structure, and the form is expressed by a cartographic image – see Figure 3 [22, 23].

It is advisable in the subject structure to provide “drop-down” menus for existing facilities represented in BIM technologies and containing all the necessary information for planning their renovation, including various scenarios with achievable indicators of decreasing Ph and M and estimating consumption used resources.

At this stage, BIM is implemented for already designed and constructed objects that have a certain Ph and M, and are intended for MR, because before choosing any method of renovation, it is necessary to obtain reliable information about their condition and, best of all, to do this in the form of digital 3D models with the necessary informative applications.

Corresponding BIMs should contain 3D models of these objects both in separate layers of the considered territories and with the possibility of combining layers, which will provide an opportunity to comprehensively design and analyze various options for renovating the urban environment.

The second stratum should also contain a system of performance indicators that adequately assess the state of both individual facilities of the CPF and the CPF as a whole. This problem has been methodically solved; physical deterioration, obsolescence, technical comfort (TC) of the objects in question can be taken as such indicators [22, 24].

The CPF technical comfort is the convenience of the technical construction of the social environment, assessed by its degree of compliance with sanitary and hygienic norms, safety rules and standards of this environment, and other indicators established, if necessary, by qualified specialists – experts [24].
These performance indicators are keys to the development and application of subsequent MR planning techniques.

The second stratum also includes a set of private methods for isolating individual CPF from the territory of urban development and the formation of separate classes – clusters of CPF and its objects similar in value to the considered indicators $Ph$, $M$, $TC$ for subsequent planning of making effective decisions on actions.

Figure 3. A model of the form and content of a system-integrated city planning formation.

The formation of such clusters will make it possible to use for each cluster a set of homogeneous technical and technological solutions for MR actions and will facilitate the organization of a flow method of work.

Second stratum also contains methodologies that determine decision-making thresholds for specific actions for renovation of facilities on the territory of the CPF which can be taken on the basis of an analysis of the values of the totality of indicators $Ph$, $M$, $TC$ and resource consumption.

These indicators are determined on the basis of archival databases, neural network methods, according to regulatory sources, the method of expert estimates using the Harrington verbal-numerical scale [25].

Third stratum is the development of algorithms for conducting an integrated MR of urban areas in the presence of restrictions on consumed resources.
On this stratum, in the form of generally accepted representations of algorithms (language of flowcharts, set-theoretic language, etc.), the initial data and solutions to the actions contained in the first 2 strata are described in accordance with Figure 4 (figure 4 shows only a part of the developed algorithms).

Figure 4. The set of planning algorithms comprehensive renovation of urban areas.

Developed algorithms include algorithms for calculating Ph, M, TC and resource consumption; algorithms for allocating the shape of the urban environment site in the form of CPF for subsequent MR planning; classification algorithms for CPF and its constituent objects according to indicators Ph, M, TC; classification algorithms for CPF objects – buildings, structures, engineering networks, etc. according to structural, materials science, planning features as well as a number of other algorithms that describe the composition of the second stratum.
In the third stratum, the decision-making process is also algorithmized by comparing the calculated values of $\Phi$, $M$, $T$, resource consumption with their normative threshold values. As a result, a selection of rational MR options is provided both for specific objects and for the entire area of the urban environment, presented in the form of CPF.

Fourth stratum is the development and debugging of computer programs implementing the entire set of algorithms over the generated database and for making decisions on choosing rational MR options for the entire set of objects on the territory of the CPF – Figure 5.

On the fourth stratum, the developed algorithms are encoded in the accepted programming language, private debugging of each program that implements each algorithm, complex debugging of the entire set of programs, testing of the whole complex of programs with various options for the volume and accuracy of setting the source data.

![Figure 5. The set of computer programs for planning multi-faceted renovation.](image)

2. Conclusion
The necessity of an integrated MR of urban territories, as one of the directions of creating “smart cities” – Smart City is justified.

It is proposed to increase the efficiency of MR of the urban environment by digitalizing decision-making on actions to implement MR.

It is proposed to use BIM design technologies for planning MR of urban environment objects.

A systematic approach has been developed to the planning of digitalization of urban environment MR, including the formation of 4 consecutive strata that regulate the effective order and content of decisions on actions for the implementation of the MR.

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