Model of infrastructure development of housing and utilities

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Abstract. Theoretical premises of sustainable development of the housing-and-municipal complex (HAMC) in a perspective of harmonious functioning of a triad of influence: economic-social-ecological (ESE) influencing factors are presented. The mechanism of implementation of technological innovations and creation of digital doubles, by object digitization of JKK with forming of a virtual system of vital maintenance is developed. The example of calculation with a different object combination of a system is presented to JKK showing complexity of obtaining adequate result without application of simulation models. It is proved that developing forecast model of the separate period of functioning it is necessary to represent risk scenario "a tree of events", with simulation of result of adaptive adaptation to the changing conditions and assessment of coherence of elements of a triad of ESE.

1. Introduction

Questions of the organization and management of construction are in details stated in the standard regulating documents which are updated taking into account the latest technologies, introduction of new materials and use of various means of technical maintenance [1,2].

Building of infrastructure in the most developed urbanized zones demands not so much improvement of quality of construction works how many modernization of the mechanism of the organization and management of the operational period of these objects, through its orientation to the consumer, his inquiries with optimization of business processes. Improvement of any system is based on experience of introduction innovative the practician, harmonizations of the previous achievements with future innovations.

Construction objects belong to objects of the superlong period of operation that demands deeper study of this period not so much for a single object, how many for complexes of objects, establishment of efficiency of sustainable development of the urbanized zones. Theoretical base of scientific research in the field of assessment of the competitive status of territories are developments of such scientists as M. Porteta, I. Ansoffia, A. Anuchinoj, O.N. Belenovoj, S.N. Glagoleva, A.G. Gradova, E. Korol, A. Rudycheva, E. Shchetinina and etc. [1-5].

2. Theoretical prerequisites of sustainable development of a housing-and-municipal complex in a perspective of harmonious functioning of a triad of influence of ESE
Structural personification of JKK is carried out step by step.

Structurally JKK has standard saturation the real estate objects of different function territorially stated taking into account zones of inclination and alienation, these are buildings of inhabited appointment, production and social structures, highways and the ave. Historically formation of these zones in terms of equilibrium development of triad of influence of ESE, happened taking into account the effective period of existence, so for components [12]:

- "economic" - is considered the vital period of existence of 50 and more years;
- "social" - the vital period of JKK in foreshortening of appeal to various age groups of the population, within 25 years of active (constant) stay in JKK borders;
- "ecological" - the vital period of change of ecoloading can be reduced to 5 years, and the variability is presented by the range of seasonal change of microclimate eco systems. In this analysis it is about complex indicator bio - and vegetable environment and firmness of buildings.

Obviously system contradiction demanding realization of preservation of comfortable living conditions for the person and natural identity of the environment.

The adopted programs of strategic development are already focused on smoothing of the revealed contradictions, i.e. intensive capital investments in the social sphere with vector on restoration of natural identity have begun, however the positive result is not possible without deep scientific and technical study of problem with representation of the adequate model of medium-term and long-term character considering characteristic risks.

It is offered to consider the available technological innovations and to realize the gear of creation of digital doubles, by object digitization of JKK and formation of virtual system of vital maintenance, the offered algorithm is presented on Figure.1

![Figure 1](image)

**Figure 1.** Mechanism of creation of digital doubles, object digitization of a housing-and-municipal complex and forming of a virtual system of vital maintenance.

Key select properties [1, 2,8]:

- integrity. It is indisputable what involves changes of one of parameters of a triad, violation of borders of "field" of harmonious functioning from which exit leads to a system imbalance. Given property the effect of a reverse is characteristic: the system status is estimated in a complex when changes of one variable cause change of all other variables. It is necessary to consider a diversity in change manifestation time, i.e. effect of the postponed influence. For example, for JKK, the social
position of residents of the area will not allow to break to please a short-term economic benefit natural integrity by installation of additional buildings, laying is expensive or other, and virtual long-term forecasting of changes with the digital double will allow to find the alternative harmonized option of reconstruction of territories.

- differentialsization. The long-term period of functioning of JKK demands constant perfection, upgrade of outdated objects, use of the innovation technologies of life support. The functional triad of ESE for JKK is represented open system in the direction of a differentialsilation and improvement. For JKK transition to autonomous systems of power supply, collecting garbage, its sorting and in the long term utilization in processing enterprises will allow to gain additional income from functioning of JKK, to socially rally inhabitants and to lower ecoload of nearby territories.

- balance. This property is executable in the long-term period, i.e. in residential quarters change of the owner is always an isolated fact, the period constantly living in residential areas often is measured by several generations that develops a certain stereotype of intra house life. For an ecosystem of JKK which is territorially in borders balance maintenance, consists in cultivation of plantings, their leaving and updating on the entire period of existence of JKK.

- recurrence of events. Objects of JKK have the different level of demand which cycles depend on season, of economic and social requests of inhabitants, in particular, the social demand of adjacent territories of a housing estate depends on season; frequency of garbage removal, maintenance rate of engineering systems of houses, recovery of a paving and other actions of the supporting character on the long-term period of existence of separate JKK is set. Thus, theoretical assessment of harmonious existence of a triad of ESE for JKK allows to provide their effective functioning as on the medium-term, and long-term period.

Selecting in the system of influences key the external environment as the source of factors of production and information defining ability of conversion of these resources is implemented a possibility of object digitization with the subsequent by the personified management of efficiency of system functioning by means of digital doubles.

It is represented that achievement of equilibrium interaction is possible through flexibility property, ability to adapt to external and internal changes, on the long-term period that is also provided with electronic modules of management, for example multiplex, hardware of digital systems.

3. Mathematical modeling
Settlement mathematical the model of component coherence is presented in a dimensionless format that provides control of dynamics of change of indicators through influence infographic for various periods of operation of JKK with a vector of risk forecasts [14-16]. For the purpose of coverage of the maximum quantity of indicators of factorial influence the integrated indicator of complex assessment of a condition of a triad is offered:

\[ I_{hcc} = f(k_{ec.bal.}; k_{soc.bal.}; k_{env.id.}) \]  

where \( k_{ec.bal.} \) - indicators of level of economic balance; 
\( k_{soc.bal.} \) - indicators of level of social balance; 
\( k_{env.id.} \) – indicators of level of ecological identity.

Thus, the problem of quantitative assessment of indicators is solved that allows to create model of the digital double with territorial zoning in borders of influence of a single housing-and-municipal complex.

It is offered to accept basic values of key parameters as reference size. This assumption is proved by the fact that any construction objects before commissioning are estimated on compliance to standards, regarding quality, safety and the term of effective functioning in specific conditions.

The current state of an object, functioning parameters through the system of monitoring is transmitted to the logical module of control of change of a system in general, deviations of values are fixed in
relative values on the module that allows to receive the size of an integrated indicator and to make expected model of its change, both on the medium-term period, and on long-term.

\[ k_{ec.bal.;soc.bal.;env.id.} = \sum_{i=1}^{n} \left| \frac{X_i^f}{X_i^{ref}} - 1 \right] \]

A set of components of the expected models forming an integrated indicator when modeling can be minimized, in case of insignificant influence for the short-term analysis or to enter the maximum quantity to establish risks of the effect of decrease in an indicator postponed in time.

The presented mathematical model complemented with an algorithm of formation of basic indicators and introduction of additional parameters of assessment of sustainable development of objects of JKK allows, in real time to carry out monitoring of "field" of harmonious functioning of a triad of ESE for JKK. To establish limits of system balance, to estimate an economic condition as single and in a complex of objects of functioning, to consider the social inquiries changing in time, to fix ecoloading of territories.

Change of indicators and the description of factors of influence depends on depth of a research of external and internal environment of vital existence of JKK, i.e. the following stage of researches is stability assessment.

It is obvious that it is possible to provide stability of a system by creation of the mechanism of self-control, using basic provisions of the theory of risk and probability theory [14, 15]. Development risk scenarios "a tree of events" with a situational algorithm for the program module of the digital double is required, consistently setting imbalance parameters, receiving reactions of the JKK system components on change of indicators of economic expenses, social contradictions and ecological violations.

The following level of assessment of management efficiency is as a result formed: the expected model of change of parameters considering the speed of reaction to factorial influences, revealing critical and problem situations which model allows to accept the operating influences in reality for the purpose of their prevention, or decrease to a minimum of negative impact, in case of impossibility of full neutralization.

![Diagram](image)

**Figure 2.** Technique of sustainable development of a system triad of ESE with factorial digitalization.

That is developing model of the separate period of functioning for the digital double it is necessary to offer risk scenario "a tree of events", with simulation of result of adaptive adaptation to the changing conditions and assessment of coherence of elements of a triad of ESE.
The mathematical model characterizing structure of the JKK system is represented in a format of matrixes of influence.

Let's assume that JKK is object presented to n of the joint complex structures of zones of inclination. Signs of structural association are the functional demand (ain) and territorial attractiveness (bin), i.e. the sign of a clustering is selected that of the JKK systems it is quite characteristic [8, 13].

Further we make matrixes of incidence [16]:

\[
A_{Fd} = \begin{pmatrix}
    a_{11} & a_{12} & \ldots & a_{1n} \\
    a_{21} & a_{22} & \ldots & a_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & \ldots & a_{nn}
\end{pmatrix}, \quad B_{Te} = \begin{pmatrix}
    b_{11} & b_{12} & \ldots & b_{1n} \\
    b_{21} & b_{22} & \ldots & b_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    b_{n1} & b_{n2} & \ldots & b_{nn}
\end{pmatrix}
\] (3)

For accounting of criteria deviations of size the settlement matrix is given to a rated look by representation of indicators in unit shares.

The sum of the normalized matrix forms the generalized indicator displaying the criteria "force of communication" of parameters.

\[
\begin{pmatrix}
    a_{11} & a_{12} & \ldots & a_{1n} \\
    a_{21} & a_{22} & \ldots & a_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & \ldots & a_{nn}
\end{pmatrix} + \begin{pmatrix}
    b_{11}^U & b_{12}^U & \ldots & b_{1n}^U \\
    b_{21}^U & b_{22}^U & \ldots & b_{2n}^U \\
    \vdots & \vdots & \ddots & \vdots \\
    b_{n1}^U & b_{n2}^U & \ldots & b_{nn}^U
\end{pmatrix} = \begin{pmatrix}
    c_{11} & c_{12} & \ldots & c_{1n} \\
    c_{21} & c_{22} & \ldots & c_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    c_{n1} & c_{n2} & \ldots & c_{nn}
\end{pmatrix}
\] (4)

The most connected are elements \( c_m = c_n \) having greatest values. For JKK objects it indicates harmony of a triad of ESE and is the basis of inclusion in uniform structure. The subsequent calculations will allow to carry out object ranging of the JKK elements and level of harmony of communications of a triad of ESE.

4. Scientific and practical support of the concept
The mechanism of collection of information is in real time presented in the form of the algorithm including the control system consisting of 4 levels (Figure3).

The module of collection of information, value of parameter is in real time provided by installation of monitor sensors, data transmissions in peripheral blocks.

The module of information processing includes a mathematical model with base of reference data on all controlled parameters. Information is compared, on the put algorithms the decision on the level of change of parameter and its influence on the general indicators is made. The control panel by a complex through submission of information on the monitor, its visualization is provided in formats of charts and indication.

All information has several storage locations, both an internal memory, and external resources, up to "Cloudy spaces".

Key result is decision-making by option of harmonious functioning, from standard, to the sentence alternative, in this case at the initial stage of implementation of model of management participation of the person in decision-making is supposed.
Figure 3. Algorithm management mechanism of gathering real-time information on the effective functioning of the triad ESE using hardware digital systems.

The estimated example is given for assessment of object saturation of JKK, the task of assessment of binomial coefficient by means of Pascal’s triangle is set for randomly combined (k) in the JKK [17] system are taken.

\[ C^n_k = \binom{n}{k} \] . As basic data 10 elements (n) are taken.

Design models with any object combination in the JKK system are received:
- for 6 object combinations:
  \[ y = 0.0021x^6 - 0.047x^5 + 0.4527x^4 - 2.1251x^3 + 5.1413x^2 - 5.0803x + 1.6667 \]  \hspace{1cm} (5)
- for 5 object combinations:
  \[ y = 0.0096x^5 - 0.1789x^4 + 1.3365x^3 - 4.4726x^2 + 6.8811x - 3.6667 \]  \hspace{1cm} (6)
- for 4 object combinations:
  \[ y = 0.0427x^4 - 0.6677x^3 + 3.8154x^2 - 8.3378x + 5.4167 \]  \hspace{1cm} (7)
- for 3 object combinations:
  \[ y = 0.1286x^3 - 1.4172x^2 + 4.7269x - 4.1333 \]  \hspace{1cm} (8)

Calculations show that at increase in quantity of the combined objects, and in the same measure it is possible to speak also about parameters of harmonious functioning, extent of influence changes much. It is at first sight possible to reject not meaning components as a little influencing a system in general, but this statement for the long-term period demands check that is implemented only in simulation models with the included settlement algorithm.

Visualization of this situation is presented on graphics (Figure 4).
Figure 4. Assessment of object saturation with any combination in the JKK system.

The mechanism of the solution of a problem of quantitative assessment of indicators, by creation of model of the digital double with territorial zoning in borders of influence of a single housing-and-municipal complex using the modal analysis realizes various completing of objects of influence. Infogram shows value of number of the considered parameters of an object or system objects, the risk of a mistake increases in decision-making with increase in the combined combinations of parameters that once again confirms expediency of the translation of the initial analysis in a digital form with modeling of risk level and the subsequent transition to natural objects and the environment of influence.

5. Results and discussions
Numerous domestic and foreign researches show that to consider problems of sustainable development of the urbanized zones in a foreshortening of one branch component it is already not enough. The available technological and digital reserves move apart a framework of solvable tasks transferring a question to cross-disciplinary, for the guaranteed long-term harmonious functioning of a triad of influence of ESE. The prospects of modernization of the mechanism of management of objects of the construction sphere, in a perspective of development of technological innovations by improvement of the created digital doubles of a virtual system of vital maintenance are obvious [18-22].

6. Conclusion
It is analytically established that improvement of the mechanism of management and organization of process of operation of construction objects on the superlong period the practician demands accounting of the latest technologies and the innovation.

The mechanism of implementation of technological innovations and creation of digital doubles, by object digitization of JKK with forming of a virtual system of vital maintenance is developed.

The definition of the concept "field" of harmonious functioning of a triad of ESE for JKK having characteristic to it borders from which exit leads to a system imbalance is given.

The mathematical model of component coherence is presented in a dimensionless format that provides control of dynamics of change of indicators through influence infogram for the different temporary periods with a vector of risk forecasts.
The mechanism of a solution of a problem of quantitative assessment of indicators allowing to create model of the digital double with territorial zoning in borders of influence of a single housing-and-municipal complex is offered.

The example of calculation with a different object combination of a system for JKK showing complexity of obtaining adequate result without application of simulation models is presented.

It is proved that developing forecast model of the separate period of functioning it is necessary to represent risk scenario "a tree of events", with simulation of result of adaptive adaptation to the changing conditions and assessment of coherence of elements of a triad of ESE.

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