Improving the quality of low-rise housing construction projects

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Abstract. The main priority of the social and economic policy in Russian Federation is to solve the housing problem. The national project “Affordable and Comfortable Housing for the Citizens of Russia” is an important form of implementation the modern housing policy. The expansion of low-rise buildings is influenced by the housing policy. Existing methods for assessing the quality of low-rise building projects require further development. The issues of improving the quality of low-rise building projects require further system improvement of quality assessment indicators too. Quality assessment takes into account indicators of safety, comfort and resource saving. Mechanism for improving the quality of low-rise building projects is proposed in this paper.

The basis of this mechanism is a system of indicators for assessing the projects quality at the predesign stage. Approbation of the proposed mechanism was made using the example of the construction of Izumrudny cottage complex in Gorny village, Yalta.

Introduction
The sphere of low-rise housing construction is an important and promising direction for the development of an effective and competitive construction industry in the Russian Federation. This industry has a great potential for growth and development, which is due to the fact that the construction of low-rise buildings will allow families that need the better housing conditions to solve the housing problem.

The development of the low-rise construction industry is necessary to solve the problem of providing the population with quality housing in addition, this industry is one of the priorities of the Russian Federation policy.

Providing the population with housing in the regions is two times lower than the permissible norm by world standards. The need for housing construction is about 48 % of the existing housing stock. The quality of the greater part of existing housing stock does not meet modern requirements and standards. The solution of this problem can be achieved by building low-rise buildings. Their advantage over multistory ones is in comfort, environmental friendliness, resource and energy saving.

The issues of development and improvement of the low-rise housing construction quality were discussed in the researches works by A.N. Asaul [1], V.A. Zarenkov [2], S.A. Prigarin [3], M.M. Vorobiev [4], L.M. Datiev, L.E. Khalilov [5], E.K. Ivakin, A.V. Vagin [6], P.P. Kazmina [7], I.V. Faizullina [8], L.I. Tsapu [9], A.M. Moroz [10], E.A. Vodenko [11], T.V. Volobueva [12],
I. I. Anisimov [13], Yu. P. Panibratov [14], A. M. Krygin [15], A. L. Zelentsov [16] and others. Unresolved issues of forming a criteria system for assessing the quality of low-rise housing projects remain.

The low-rise housing concept has now received an extended interpretation. This concept includes a number of traditional types of buildings and their new varieties.

In accordance with official regulatory documents [6], low-rise housing construction is understood as “the construction of the following types of low-rise buildings: individual residential houses are the detached residential buildings with no more than three floors, intended for one family to live in; block houses are the houses with no more than three floors, consisting of several blocks, which number does not exceed ten and each of which is intended for one family, has a common wall (common walls) without openings with a neighboring block or adjacent blocks, located on a separate plot of land and has an access to the common use territory; apartment buildings are the residential buildings with no more than three floors, consisting of one or several block sections, the number of which does not exceed four, each of which contains several apartments and common areas and each has a separate entrance with access to territory of common use.”

Under the low-rise housing construction, it is proposed to understand the investment and construction process of erecting one or more residential houses of no more than three floors, which meet accessibility and quality standards in the allocated residential area equipped with engineering, transport and social infrastructure.

Quality of low-rise housing projects is proposed to be understood as a set of properties and features of organizational, managerial, technological methods of design, construction, commissioning, which characterize the degree of compliance with the customer needs, end-user, legislative, regulatory and other requirements.

Housing quality can be of two types: regulatory and consumer. The first one provides for the requirements fulfillment of the Federal laws and resolutions of the Government of the Russian Federation, construction standards and regulations, state standards, sanitary standards etc. The second includes the fulfillment of regulatory and legal requirements, customer requirements and potential end-user requirements [16].

In order to assess the quality of low-rise housing projects, it is recommended to consider a system that consists of the following criteria: housing comfort; affordability (elite, business, economy class); location; transport accessibility; the absence of adverse factors of natural origin; lack of concern; infrastructure quality; engineering complex availability; residence security (security availability).

Based on the presented criteria, it is possible to form the main indicators reflecting the quality of low-rise housing projects from the point of view of consumers and their attitude to safety, resource saving and comfort (refer with Figure 1).

Proceeding from the indicators presented on figure 1, to optimize the process of assessing the quality of low-rise housing projects, a theoretical model of quality improvement is proposed, which is a systematic set of technological solutions made at all stages of the life cycle (LC):

\[ M = f(Elrh) + \{Ests\} \rightarrow \text{max}, \]

where \( M \) is the model for improving the quality of all construction processes of the low-rise housing;

\( Elrh \) are the life cycle stages of the low-rise housing;

\( Ests \) are the development and implementation stages of improved structural and technological solutions of low-rise housing.

The implementation of this model is possible within the framework of the mechanism for improving the quality of low-rise housing projects.

Under the mechanism for improving the quality of low-rise housing projects, it is proposed to understand the system of the main interrelated subjects, objects, principles, methods, tools, and ways
of their interaction, designers, contractors, owners, lenders and buyers of housing and society in the
process of designing low-rise residential buildings.

The essence of the mechanism that is shown in Figure 2, is as follows:

1) integrated and interrelated activity of all the participants of a construction project in the project
indicators formation of the low-rise housing projects quality in the early design stages;
2) formation of an individual system of quality indicators with reference to a specific object;
3) inclusion of project quality indicators in the design assignment;
4) development of two versions for the design solutions;
5) determining the optimality criteria and choice of the optimal variant of the project.

The main difference of the proposed mechanism from the existing ones is the application of a
broader system of evaluation criteria and project quality indicators, which makes management
decisions more effective. This mechanism allows to evaluate suburban housing, and to compare
several options for projects of low-rise residential buildings in all quality parameters.

The mechanism approbation for improving the quality of low-rise housing projects was carried out
using the example of the construction of the Izumrudny townhouse village in the Gorny village, Yalta.
On the territory of the townhouse village, it is planned to build 7 townhouses and 9 townhouses
ranging in size from 160 square meters to 300 square meters.

Taking into account the system of quality indicators presented in Figure 1 integral indicator of the
project quality for the construction of the Izumrudny townhouse village was $I_1 = 0.721$.

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**Figure 1.** Indicators of quality assessment of low-rise housing construction projects
Figure 2. Mechanism of improving the quality of low-rise housing construction projects

The concept development and feasibility study of the project

Obtaining construction permits

Selection of project quality indicators from the established indicators system for assessing the quality of low-rise residential construction projects

Quantitative assessment of chosen quality indicators

Ranking of quality indicators taking into account their weight for the customer

Value determination of the integral quality indicator of the project

Development of basic criteria for making design solutions

Development of two project options and optimality criteria

Selection of the project variant with the highest quality index

Coordination of the selected project variant with the building owner

Monitoring the achievement of quality indicators at all stages of project implementation

The project quality level for the construction of the Izumrudny townhouse village will be determined in accordance with the scale of change in the integral index presented in Table. 1

Table 1. The quality level of the construction projects for the group of low-rise residential buildings

| Project quality level | The integral quality indicator |
|-----------------------|-------------------------------|
| High                  | 0.75 -1                       |
| Medium                | 0.5 - 0.74                    |
| Satisfactory          | 0.25 - 0.49                   |
Low

Based on the integral quality indicator of the construction project for the Izumrudny townhouse village $I_1 = 0.721$, the main measures to improve the construction project quality should be aimed at:

– reducing the cost of construction and increasing the affordability of buying low-rise residential buildings for all segments of the population with different income levels;
– modern technologies use for the mass construction of low-rise housing, to reduce costs and operating costs;
– increasing heat and energy efficiency, based on the use of modern building technologies and materials.

The effect of improving the construction projects quality is multidimensional.

The economic effect is expressed in the reduction of labor, material or natural resources.

The social effect contributes to the needs satisfaction of the individual and society, and as a rule does not receive a valuation (health improvement, satisfaction of aesthetic needs, etc.).

Scientific and technical effect can be estimated through the expected economic effect. Studies show that 15% of applied research results are characterized by the potential economic effect and 85% are expected.

The technical effect obtained as a result of quality improvement in production and operation can be estimated by the actual economic effect.

The commercial efficiency of improving the quality of low-rise construction projects depends on the choice of construction technology, primarily on the construction of the building framework.

When we calculated the construction cost of 1 square meter of residential houses, which are built according to different technologies, we found that the highest cost for residential houses made of aerated concrete blocks. Cost of 1 square meter is $411.34, brick houses are in the second place with cost of $356.88, then houses erected with use of fixed formwork technology with cost of $329.12. Houses erected from sip panels and lumber differ by significantly lower cost, it is $152 and $330, respectively. The cost of 1 square meter of the house construction as a whole is lower using the Canadian technology than using timber. The construction of the frame made from sandwich panels is cheaper than that of the bar, due to the cost reduction of finishing works.

Practice shows that the cost of fuel and thermal energy is constantly growing and, as a result, there is a need to reduce heat loss through external fencing, not only in the designed, but also operated residential buildings.

Since the annual growth of gas tariffs is 30%, the savings on heating for these fencing structures will increase by 30% annually.

Construction technologies of residential houses using the “Benpan” and “Ecopan” technologies are the most effective in the operation process, since they have a significant economic effect during construction. The cost of 1 square meter of enclosing structures in this case are:

– brick plastered wall 2 bricks thick: $62 for sq.m;
– wall of aerated concrete blocks, lined with brick: $80 for sq.m;
– fencing structures according to the Bengpang wall panels technology: $50 for sq.m;
– 3-layer sip panel using the EcoPan technology: $57 for sq.m.

The economic effect calculated for the whole house with a total area of 260m², depending on the type of enclosing structures is shown in table 2.

Results of the conducted researches give the chance to consumers of construction products depending on income and family preferences to choose the most acceptable option of the house according to constructive, space-planning solutions and comfort degree.

The efficiency of quality improvement of the construction project of low-rise houses can be determined by the availability indicator on the basis of calculation of availability coefficients of the houses built with the use of traditional and energy efficient technologies at the average per capita
income of the population for the Republic of Crimea for 2018 at a rate of 326$/per 1 people (refer with table 3).

**Table 2.** The economic effect of improving the quality of a construction project in terms of structural elements as compared with the construction option of aerated concrete blocks of a residential building with a total area of 260 square meters

| Types of enclosing structures                  | Heating costs, $/m² in a year | Cost of a foundation, $ | Cost of walls, $ | Economic effect on structural elements, $ | % of total cost of walls and foundations |
|-----------------------------------------------|-------------------------------|------------------------|-----------------|-------------------------------------------|------------------------------------------|
| Aerated concrete blocks, brick lined          | 0,32                          | 4776,7                 | 8740            |                                           |                                          |
| Brick wall thickness of 2 bricks              | 1,5                           | 4776,7                 | 6763            | -1978                                     | -1978                                    |
| Bengpangs wall panels                         | 0,35                          | 438                    | 5404            | -384                                      | -3336                                    |
| 3-layer sandwich panel according to the EcoPan technology | 0,39                          | 2265                   | 6156            | -25012                                    | -2583                                    |

**Table 3.** Availability coefficients of the houses built according to the different technologies

| Indicators                                      | unit of measurement | Brick          | Aerated concrete | Houses from a bar | Bengpangs | EcoPan technology |
|------------------------------------------------|---------------------|----------------|------------------|-------------------|-----------|------------------|
| Estimated cost of a residential building        | $                   | 92574,29       | 106700,57        | 85373,9           | 52342,4   | 39424,7          |
| Market value                                    | $                   | 159035,0       | 190842,03        | 119276,2          | 71565,7   | 71565,7          |
| Per capita income                               | $                   | 325,72         | 325,72           | 325,72            | 325,7     | 325,7            |
| Number of people in the family                  | persons             | 3              | 3                | 3                 | 3         | 3                |
| Coefficient of the housing availability         | On estimated cost   | 7,89           | 9,10             | 7,28              | 4,46      | 3,36             |
| Coefficient of the housing availability         | At market value     | 13,56          | 16,28            | 10,17             | 6,10      | 6,10             |

Calculations showed that the requirements for accessibility are met by houses built using new low-rise construction technologies. The housing accessibility ratios, calculated on the basis of the market value, are the lowest for the Bengpangs and EcoPan technologies. From this, it follows that in order to improve the quality of low-rise housing construction projects in terms of accessibility, construction of low-rise residential buildings should be carried out mainly on these technologies.

The prognostic evaluation of the mechanism effectiveness for improving the quality of low-rise housing projects was carried out by determining the social and economic project effect as a result of a comparative analysis of the various construction technologies use (refer with Table 4).
Table 4. Assessment of the social and economic effect of improving the quality of low-rise housing projects

| Effect name       | Description of the projected effect                                                                 | Quantitative effect indicators |
|-------------------|-------------------------------------------------------------------------------------------------------|-------------------------------|
| 1. Economic effect| Economy as a result of the modern construction Bengpang technology use                                | 3719 $                        |
|                   | Decrease in operating costs as a result of decrease in heat losses and economy of funds for heating   | 160 $. per year               |
| 2. Social effect  | Providing population with qualitative, comfortable and affordable housing:                         | 275 $ /sq.m. 6.10            |
|                   | - value of one square metre of housing;                                                            |                               |
|                   | - availability coefficient of housing at market value.                                              |                               |
| 3. Psychological effect | Manifestation possibility of the identity as a result of the individual housing construction;   | quantitative assessment is not |
|                   | Organization of the low housing construction environment according to the personal tendencies and preferences; | envisaged                    |
|                   | Owner feeling development, thrifty attitude to the environment;                                    |                               |
|                   | Formation of psychological interrelation with the dwelling                                          |                               |

Summary
Thus, we can conclude that the use of a mechanism for improving the quality of low-rise housing projects will not only improve the quality of construction projects, but also make them more accessible and economically attractive for both investors and the public.

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