Integrated green construction as a prerequisite for sustainable urban development

Sergey Alexandrovich Baronin[1], *Ekaterina Sergeevna* Guschina[2], *Anna Ilyinichna* Romanova[3]

[1]Penza State University of Architecture and Civil Engineering, Department of Expertise and Real Estate Management, 27, Titova street, Penza, 440027, Russia
[2]Penza State University of Architecture and Civil Engineering, Department of Urban planning, 27, Titova street, Penza, 440027, Russia
[3]Kazan State University of Architecture and Civil Engineering, Department of Municipal Management, 1, Zelenaya st., Kazan, 420043, Russia

Abstract: The article studies problems of sustainable housing construction modeling as part of complex development of the territory projects with consideration of requirements of green, energy-efficient and resource-saving approaches as an obligatory condition of sustainable urban development. The aim of the study is to develop methodical approaches and scientific and practical recommendations in the field of integrated green construction modelling on the basis of assessment and cost management of environmental eco-oriented life cycles of a set of capital construction objects. The object of the study is taken in the form of a portfolio of capital construction projects as part of investment programs for integrated residential development of territories at the stage of prospective construction preparation in the conditions of their competitive selection for financing based on the priority. The article demonstrates the obtained scientific results in the form of: conceptual clarification of the category of integrated green construction; methods of estimation of the environmental-ecological cost oriented life cycles of buildings in the competitive selection of complex residential development projects for its application in the selection procedures for financing; justification of the author's coefficient «infrastructure» in the assessment of the cost of the life cycle of buildings; modeling the effects of reducing the cost of environmentally-oriented life cycles of objects of complex green development.

Keywords: sustainability, complex development, green construction, life cycle, competitive selection.

1. Introduction

The current scientific and practical direction of improving the sustainability of urban territorial development is the problem of ensuring expanded use of mechanisms of integrated green construction.

The triad of economic growth, ecological balance and social equilibrium is at the core of the stable development of an urban area, in the classical paradigm of sustainability [1].

In the basis of the economic foundation of the theory of sustainability in construction, the principles of rationality, optimality and proportionality of costs for the design, construction, operation and liquidation of construction facilities are distinguished, which is consistent with the theory of cumulative assessment of the life cycles of objects [2]. The ecological foundation of the paradigm of sustainability is based on the principles of green, energy-efficient and resource-saving construction, which corresponds to the theory of eco-oriented projects in the sustainable development of the territory [3]. The complexity, which is based on the principles of full provision of capital construction facilities with transport, engineering and social functions, is guaranteed by Chapter 10 of the Urban Planning Code of the Russian Federation [4].

The first element in the triad of sustainability is complexity. Integrated development projects are those development projects that involve its integration into the existing system of spatial functional-planning organization of the city or settlement, as well as the creation of an optimal urban zoning system of the territory along with the creation of an integrated engineering and transport infrastructure, ensuring the full, effective development of the territory and its inclusion in the general communication system. The current trend in the complex development of the territory is the formation and development of multifunctional urban environment as a possible combination of residential, public-business, industrial and recreational functional zones of complex development. The second fundamental stable element is the element of "greenness". The essence of the phenomenon of green construction is the humanization and greening of the construction sector by providing a comfortable and safe standard of living and the living environment of the population with architectural planning, construction, organizational and economic measures in order to minimize the harmful impact on the environment. The following main components can be attributed to "green" technologies – energy efficiency (energy saving), safety, comfort and waste-free (resource saving) [5,6].

A review of foreign experience indicates that there is a very large arsenal of standards in this area. For example, foreign standards adopted in other countries: in Australia – Green Star; Brazil – AQUA; Great Britain – BREEAM; Finland – PromisE; France – HQE; Germany – DGNB; Hong Kong – HK BREAM; India – GRIHA; Italy – Green Building Council Italia; Spain – VERDE; Canada – LEED Canada; China – GBAS; Malaysia - GBI Malaysia; Netherlands – BREEAM Netherlands; USA – LEED; Switzerland – Minergie; South Africa – Green Star SA; Japan – CASBEE [7].

One of the key factors in the evolution of eco-development in Russia was the adoption in 2009 of a new law "on energy conservation and energy efficiency improvement", which was followed by increased market expectations of further tightening of environmental legislation. The first edition of the State standard (GOST) in the field of eco-development GOST R 54964-2012 "Conformity assessment. Environmental requirements for real estate" came into force in 2013. International eco-standards served as the basis for this standard, however, they did not sufficiently take into account the peculiarities of the Russian market, the Russian mentality and the existing modern level of eco-development of our country. The history of the formation of green construction in Russia is presented in more detail in [8]. In 2014, the Green zoom standard was adopted [9], which is a practical tool that provides an integrated approach to the construction and operation of buildings, structures, territories based on sustainable development approaches. At the heart of sustainability, the developers of the standard see water efficiency, saving non-renewable resources, and environmental friendliness, reducing operating costs, maintaining a good physical and psycho-emotional state of a person, energy efficiency, decarbonization, reducing the negative impact on the environment.

The third important element of the sustainability of urban development is the optimization of the cost of residential construction in Russia, which is provided by the "Methodology for calculating the life cycle of a residential building taking into account the cost of total costs" [10]. The main principle on which the methodology is based is to reduce the total cost of ownership of the building by reasonably increasing the initial costs at the design and construction stage, for the use of energy-efficient, environmentally friendly technologies and green construction approaches, as a result of which operating costs are significantly reduced at the stage of operation of the building, amounting to an average of 75% of total costs [10 p.11].

Thus, the relevance of this study lies in the deepening of knowledge in the issues of socio-economic efficiency of reproduction of residential real estate based on the implementation of mechanisms for the integrated development of urban areas, as a particularly priority segment of the national housing market responsible for the sustainable development of urban areas.

Within the framework of this study, it is supposed to introduce and define an innovative term in eco-development - it is «integrated green construction», which unites in its definition of the direction of the triad of sustainable development of urban areas (economy, sociology, ecology) which guarantee the improvement of the quality of life of the population while minimizing the harmful impact on the environment.

Scientific hypothesis of the study - provides the assumption that the solution of the problems of sustainable urban development should be carried out on the basis of the concept of integrated green construction as a set of urban planning, spatial planning, structural, architectural, technical, organizational, economic and social solutions in the field of design, construction and operation of all types of eco–oriented life cycles of capital construction facilities at complex development of territories .

The purpose of the study is to develop methodical approaches and scientific and practical recommendations in the field of integrated green construction modelling on the basis of assessment and cost management of eco-oriented life cycles of a set of residential capital construction projects, taking into account the principles of energy efficiency, resource saving and effective infrastructure.

The object of the study is taken in the form of a portfolio of objects of capital construction as part of investment programs of complex residential development of territories at the stage of perspective preparation of construction under conditions of their competitive selection for financing on the basis of priority Implementation of integrated green building standards.

Practical relevance lies in the further development of sustainable urban development approaches based on the concept of integrated green and energy-efficient construction, which should be implemented in urban sustainable development projects.

A review of individual studies in the field of eco-development and green construction in Russia [11], in the practice of foreign construction and architecture [12,13,14,15] shows that despite some research by the authors, integrated environmental development is an insufficiently developed area of residential real estate development. The direction of integrated development of territories in the Russian urban planning legislation appeared only in 2016 (integrated development of the territory, integrated and sustainable development of the territory) [11]. In this regard, the issues of integrated development of the territory as a condition for sustainable urban development are in the process of their creative formation.

2.Methods

The implementation of the triad of sustainable development of urban areas can be carried out by applying the key criteria of greenness, energy efficiency, complexity (through the infrastructure coefficient) in modeling the cost of integrated housing construction projects with formalization through a staged life cycle system.

Currently, a review of research papers [16, 17] has allowed us to establish that in increasing the sustainability of residential capital construction projects, energy efficiency and greenness coefficients are used as part of the methodology for assessing the total cost of building life cycles.

The calculation formula for capital construction life circle (LCC) cost of an object is the following expression:

$$LCC = Зunit*Ek* R + Зper* Gk *T*C*P$$

(1),

where: 3unit – amount of non recurring engineering cost,construction, commissioning and disposal; 3per - the amount of periodic costs during the planned period of operation for resources, maintenance, current and major repairs, consumables, management and remuneration; Ek - the coefficient of accounting for the energy efficiency class of the building; Gk - the coefficient of "greenness"; T - the number of periods of repairs and replacement of equipment during the planned service life (life cycle) for each calculation element; C - correction factor, taking into account seasonality and/or deviation from standards; R – (pricing) discount factor.

As part of the study, to assess the cost of integrated development of the territory, it was proposed to form an "infrastructural" coefficient (Ic) from indices reflecting the availability of infrastructure in the certification of the Green Zoom standard [9]. In most standards of "green construction" within the framework of the concept of sustainable development, the provision and accessibility of social service facilities, provision of transport and utility services occupies a fundamental position and gives a significant increase to the total number of certification points.

The infrastructural coefficient can be formed from the quantitative indicators presented in Fig. 1

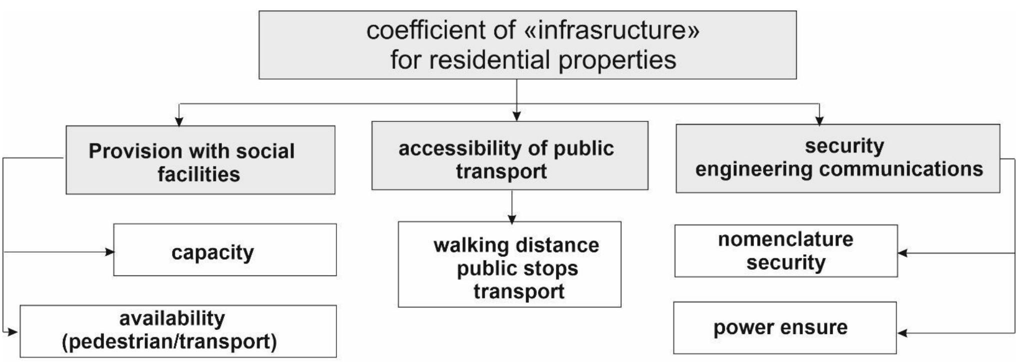


Fig. 1. Components of the "infrastructural" coefficient [Compiled by the authors].

Table 1 shows the affiliation of one or another criterion of the green standard to the components of the "infrastructural" coefficient.

Table 1. List of indicators of the Green zoom standard that meet the criterion of "infrastructural" for the integrated and sustainable development of territories

Indexes	The number of points according to the standard	Social aspect	Transport aspect	Engineering aspect
Assessment of water consumption	1			+
Decentralized water supply	3			+
Decentralized water disposal	3			+
Implementation of an autonomous power supply source	3			+
Integrated energy supply	2			+
Leisure for users	5	+		
Neighborly business	2	+		

Opportunity for small business development	3	+		
Location of the building site	2		+	
Job security	3	+		
Principles of site and building planning	1	+		
Quarter modeling	4	+		
Multifunctionality of the territory	3	+		
Socially significant object	3	+		
Availability of anchor objects	3	+		
Ensuring pedestrian accessibility of various infrastructure facilities	4		+	
Organizing opportunities for small business development/self-employment	1	+		
Organization of the street network	7		+	
Ensuring pedestrian accessibility of public transport stops	3		+	
Organization of parking	7		+	
A network of thoughtful walking, running and cycling paths	1		+	
Ensuring the possibility of using bicycle transport	4		+	
Organization of public space	2	+		
Total	73			

Table 2. The value of the given coefficient of "infrastructuality" in the evaluation of integrated and sustainable development projects

Rating (points)	The number of points scored	Coefficient of infrastruct
Non certified	≤39	1,15
Class D certificate	40-47	1,00
Class C certificate	48-55	0.85
Class B certificate	56-64	0.7
Class A certificate	65-73	0.55

The coefficient of "infrastructure" allows one to assess the convenience, comfort and safety of using residential and public facilities, the availability of functional zones for various purposes as part of a complex development, makes it possible to compare the costs on the part of the developer and the cost of the operational period for end users.

In addition to the introduction of the "infrastructural" coefficient into the LCC evaluation formula, studies have shown that it is necessary to optimize this formula by moving the "greenness" coefficient to the indicator of one-time construction costs, because this indicator primarily affects the change in the cost of designing and building facilities. This is due to the use of more expensive green systems in residential building projects and in the improvement of residential and public areas, the use of engineering systems in the project for the use of unconventional types of energy, etc.

Thus, the author's version of the methodology for estimating the cost of the life cycle of buildings, taking into account the innovative coefficient of infrastructural capacity, will be the following formula:

$$LCC = Зunit *Ek* Gk* Ic *R + Зper* T*C*P \quad (2),$$

where: Ic- the coefficient of "infrastructure", the other components of the formula are taken as in formula (1).

The methodology for estimating the cost of the life cycle of complex residential development objects within the framework of the experiment, in the analysis below, is calculated in relation to low-rise and multi-storey construction as part of integrated development projects of the territory, taking into account the urban component.

Methodically , for projects of complex residential development , the calculation according to the formula will look like this:

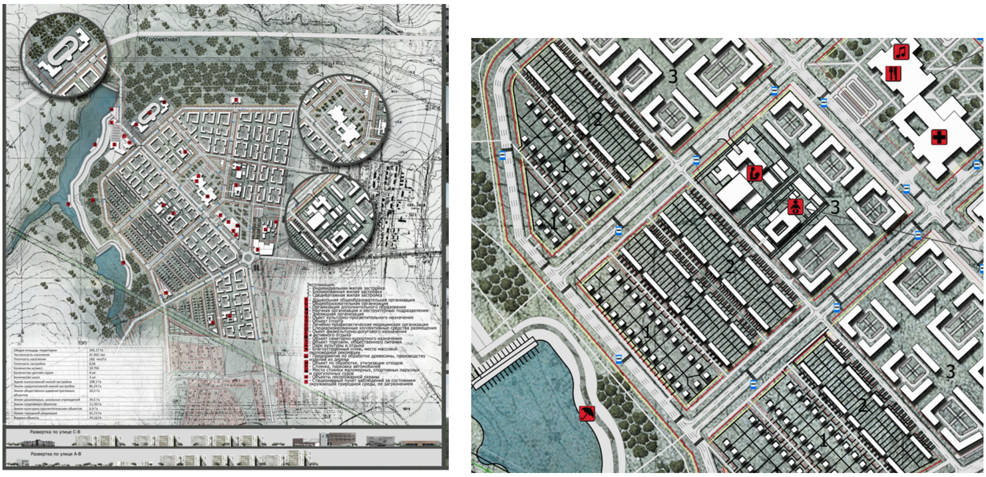
$$LCC\ CRD = LCC\ marb * Nmarb + LCC\ phc * Nphc \quad (3),$$

where LCC CRD is the cost of the life circle of a complex residential development; LCC marb is the cost of the life cycle of a typical multi–apartment residential building; Nmarb is the number of houses of a typical development in a neighborhood unit; LCC phc is the cost of the life cycle of a typical private house; Nphc – number of private housing construction in a residential area.

3. Results

3.1 Initial data for calculation.

The enlarged calculation according to the GREEN ZOOM standard was made for the third stage of construction of the district, which is part of the residential area «Novaya Zarya» in Penza (Figure 2 A). The neighborhood (total area 24.8 hectares) is a mixed residential development area including the school and kindergarten area (figure 2 B) Residential development in the project of complex development of the territory is represented by the houses of the middle floors and individual houses of the blocked and cottage type. Normative accessibility of the network of block transport is organized, the project has formed pedestrian and cycling traffic on the fundamentally important social directions of the residential area, connecting the responsible functional zones of social, cultural and household function in the territory under consideration. The presence of relatively calm terrain and high natural and ecological potential makes it possible to speak of the territory as promising for integrated housing development.



A) B)

Figure 2 A) Project of complex development of the residential area «Nova Zarya» in Penza. B) Scheme of the Master Plan of the 3rd Stage of Construction of Residential District «Novaya Zarya»

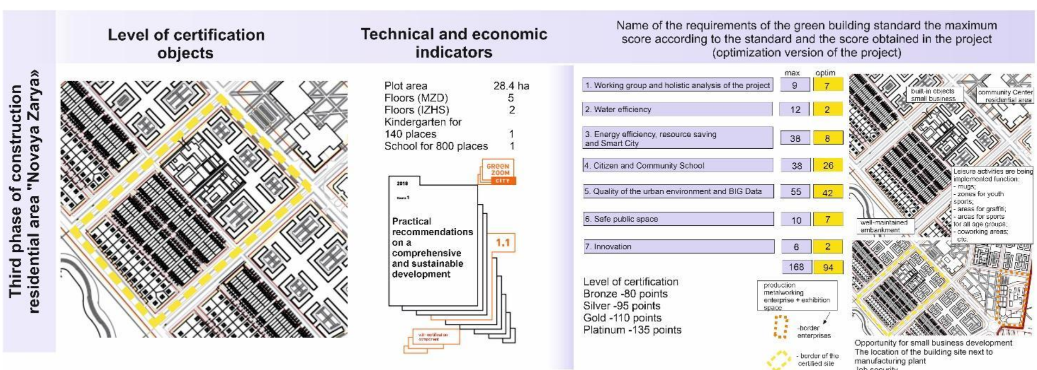


Figure 3. Calculation of the neighbourhood unit according to GREEN ZOOM standard.

According to the GREEN ZOOM CITY standard, the developed basic project receives 67 points, taking into account the application of energy-efficient, green, resource-saving technologies in the project, it was possible to raise the rating of the residential estate to 94 points, which corresponds to the bronze certificate (see figure 3).

3.2 Calculation of the life cycle costs of complex residential development.

The results of the performed research were obtained during the approbation of the author's methods on the example of a microdistrict that is part of the residential area "Novaya Zarya" in Penza, with the calculation of the basic and optimization options of the project. The basic project is represented by the average value of the energy efficiency coefficient Ec = 1.15, certification of the basic project according to «green standard» class C = 0.85. The infrastructure ratio is given as 0.55.

The cost of the life cycle of complex residential development according to the basic version of the project will be: LCC crd (b) = 59 406 051.7 thousand rubles.

The optimization project also takes into account measures to improve energy efficiency, greenness and infrastructure. As a result of these measures it is possible to increase the coefficient of «energy efficiency» to B+ = 0.85 and the coefficient of «greenness» to class B =

0.7. The ratio of «infrastructure» in the optimization project remains unchanged. The cost of the life cycle of complex residential development according to the basic version of the project will be: LCC marb(o) = 32 286 810.2 thousand. rub.

The results of the calculation of the cost of the life cycle of complex housing development on the base and optimization project in % ratio are presented in Figure 4.

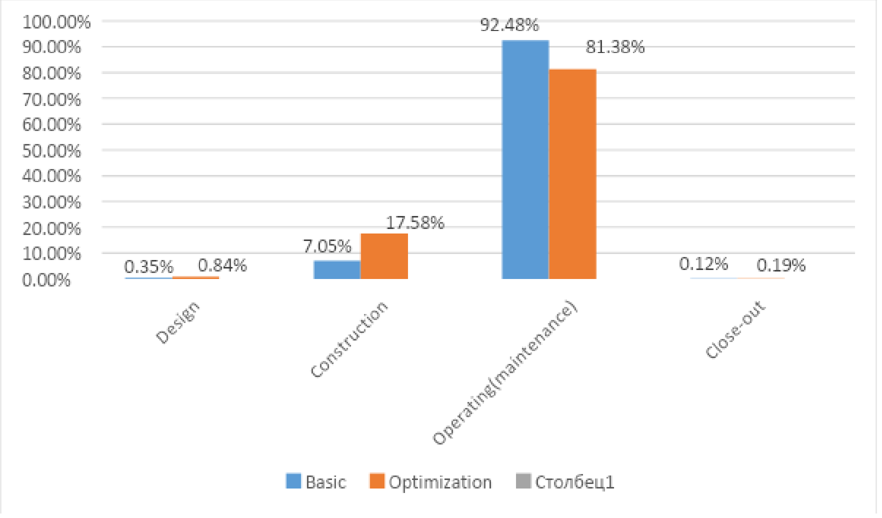


Figure 4. Comparative analysis of the cost of the life cycle of complex residential development according to the basic and optimization options.

Thus, the studies carried out allow us to make a final conclusion that from the compared two project options for financing, it is recommended to choose an optimization option with a minimum life cycle cost of 32,286,810.2 thousand rubles.

3.2 Assessment of the cost of ownership reduction effect

The effect of reducing the cost of ownership of integrated housing will be:

$$Ecro = LCC\ CRD\ (b) - LCC\ marb(o) \quad (4)$$

where Ecro is the effect of cost reducing of ownership; LCC CRD (b)– the cost of the life cycle of complex residential development in the basic version;; LCC CRD the cost of the life cycle complex residential development in the optimization version. Ecro = 59 406 051,7 – 32 286 810,2 = 27 119 241,5 thousand rubles per 50 years

4. Discussion

There is no doubt that the attempt to model the methodological framework of integrated green building is a very necessary and complex issue for the development of sustainable urban development and this direction should be developed by mainstreaming the priority of national and international green standards, as well as by improving the methodology for estimating the total cost of the life cycle of integrated development projects. This determines both the breadth of research areas and the importance of developing many other aspects of theoretical modelling and practical application of the concept of integrated green building.

The analysis shows that the important areas of creative development of the theory of sustainability of urban development from the perspective of integrated green building modelling can include:

1. We believe that it is important to discuss the importance of the theory of life cycles in relation not only to environmental-oriented capital construction objects, but also to elements of urban planning, such as neighbourhood units, residential districts, etc.
2. In the author's studies only the objects of capital construction of residential real estate were taken as the basis for calculation of green complex of residential development. This determines the importance of extending the author's methods to other types of buildings and structures (transport networks, commercial real estate, social objects, etc.).
3. We consider it possible to include among the important issue of the development of integrated green building construction the problem of the formation of national green building standards for the integrated development of residential development areas.
4. The need to improve the valuation of the ecological-oriented life cycles of buildings from the perspective of a combination of portfolios of different types of real estate should be included in the discussion.

Some of the discussion points about the methodology noted above are not so much about shortcomings, but about the prospects for its development.

5. Conclusions

The carried out studies have confirmed the importance of the author's direction of scientific and practical works in the field of development of methodical approaches and practical recommendations in the field of modelling of complex green construction on the basis of assessment and cost management of assessment and cost management of eco-oriented life cycles of a set of capital construction projects, taking into account the principles of energy efficiency, resource conservation and efficient infrastructural.

The realized purpose of the study showed high relevance of the studied problem and prospects of its further scientific and practical development.

General recommendations include the introduction of the concept of integrated green building in urban planning legislation as a separate legal and regulatory definition that defines and guarantees sustainable urban development. In addition, the recommendations include improved knowledge and practical experience in the evaluation of the cost characteristics of integrated development projects and the mainstreaming of green development standards in this area.

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