Sustainable Development of Civil and Residential Real Estate Based on the Construction Waste Recycling

Irina P. Avilova¹, Alevtina M. Krygina¹[0000-0001-5719-3227], Natalya M. Krygina², Yuri A. Koshlich¹, Marina I. Oberemok¹

¹Belgorod State Technological University n.a. V.G. Shukhov, Belgorod, Russia
²Kursk State University, Kursk, Russia
E-mail: kriginaam@mail.ru

Abstract. The work is devoted to assessing the environmental and economic efficiency of construction waste recycling concerning the sustainable development of civil real estate. The crisis processes in the micro-and macro-level economy has a negative impact on the Russian investment and construction complex, which threatens the national task performance to provide affordable housing within implementation of the investment programs financed by municipal and federal budgets. It is shown that one of the directions of sustainable reproduction of real estate objects in modern socio-economic conditions is the optimal design and selection of materials using innovative recycling technologies. Low rates of retiring areas replacement and a steady trend of growth in the volume of construction industry waste is observed. This approach is focused on solving two global problems: the economic benefits of using resources and the elimination of environmental pollution. Proposed algorithms evaluate the potential effectiveness of the property manager’s activities and the practical implementation of the techniques in management software.

Keywords: sustainable development, real estate, recycling, construction industry waste, green real estate, reproduction.

1 Introduction
The development of civil and residential real estate remains one of the key tasks of the socio-economic country development. In the international ranking of countries with the most unaffordable housing, the Russian Federation ranks fifth [1]. For an average Russian resident the process of accumulating cash funds to buy a house (excluding mortgage and other state investment programs) can last for decades (on the average 20-30 years in the Siberian and far Eastern regions and 35-50 years in the European part of Russia).

The state declares the need for growth rates of housing commissioning up to 1 million square meters per year. The domestic construction industry is not only far from achieving this indicator in terms of the reproduction rate of residential real estate. Most of the introduced square meters of housing space are simply not available to a significant number of Russians by cost indicators [2]. The general micro-and macro-economic situation in the country causes a decrease in the population's ability to pay and provokes a tendency to increase mortgage debt. According to the Russian statistics, the dynamics of real disposable cash income in January 2019 decreased by 1.3% compared to January 2018 [3]. Residential real estate, declared by the developer as social and affordable, is not fine by quality of building materials and structures, as well as the heat-protective properties even at the operation stage [4].
The government implements certain program-oriented approaches to solve this global problem [5]. The Russian Federation has developed a significant number of state housing programs for young families, specialists of certain categories (primarily for rural areas), and other categories of citizens [6]. Over the past decade the development of mortgage lending has been being stimulated by reducing rates by more than 1.5 times (figure 1). But at the same time, the amount of loan debt amounted to 64.7 billion rubles on August 30, 2019 [7]. Delinquency on loans of legal entities in housing construction is 19%.

![Figure 1](image1.png)

**Figure 1.** Dynamics of the weighted average rate on housing loans granted to individuals, rub [2].

![Figure 2](image2.png)

**Figure 2.** Factors hindering the development of low-rise housing construction.
The question is what kind of housing should be built and what resources should be used to determine the sources of cost savings so that residential real estate has become truly affordable [8].

Earlier [9], the efficiency of a low-rise residential real estate was shown [10] in the comparison with a traditional multi-storey one, including such key parameter as energy intensity [11] of the main building structures and materials [12] at all stages of the life cycle [13]. Analysis of domestic and foreign experience [14] shows that one of the promising ways to reduce cost is the use of construction waste recycling technologies [15] in the production of materials and structures [16], including housing construction [17].

The analysis of the main trends hindering the development of a low-rise cluster of residential real estate has revealed their "key pool" (figure 2). It includes the underdevelopment (backwardness, low innovation component) of the industrial base for low-rise construction, including the use of technologies for processing recyclable building materials and structures [18].

According to the researches by Vladimirov S.N., Kravtsova M.V., Lunev G. G., Makarov V.V., Chen Jin, T. Napier, Costanza R. Ruoyu, Qian Lu Weisheng, Chris Webster, and others, construction waste recycling is both an economically [19] feasible and environmentally prospective solution [20] to the problem of utilization [21].

However, despite the obvious problem, a number of key tasks have not yet been solved. They significantly hinder the development of recycling technologies [22] with the subsequent use of secondary products for the purpose of improving the efficiency of reproduction of residential real estate in our country [23], including the lack of legislative regulation [24] and evaluation of the economic efficiency of the use of these technologies [25].

Based on the above, the purpose of this work is to develop criteria for evaluating the effectiveness of construction waste recycling in the development of residential real estate.

2 Materials and methods

Every year the amount of construction waste increases by 25% [26].

In solving environmental problems, recycling of construction industry waste takes a special place, particularly in the issue of the development of housing renovation technologies that have become widespread in major cities of the Russian Federation [27]. This direction of residential real estate reproduction is associated with the formation of significant amounts of construction waste. Ignoring the problems of recycling this type of waste inevitably leads to the negative consequences:

1) the economic losses due to underutilization of secondary resources;
2) the growth of negative technogenic impact on the biosphere in conditions of assimilation potential exhaustion.

In the Russian Federation the priority is given to the disposal of inert construction waste at operating landfills, i.e. burial [28]. Despite the fact that currently free areas of polygons are being reduced daily, and this is happening very rapidly, the development of new areas of polygons inevitably leads to a significant reduction of the biosphere potential (due to the confiscation of arable land, forest land, etc.).

The analysis has made it possible to identify the main negative consequences of the low level of development of waste recycling in the construction industry (WRCI) (figure 3).

Currently, a number of indicators have been proposed to assess the efficiency of recycling. Thus, Abramov A.V. [29] proposes to evaluate this criterion based on the economic efficiency of resource use and prevention of environmental pollution, as well as the availability and volume of a certain class of waste in the territories under consideration (Eq. 1):

\[ I_{er} = f(E, E_{c}, M) \rightarrow 1.0, \]  

where \( I_{er} \) – recycling efficiency index;

\( E \) – indicator of economic efficiency of recycling;

\( E_{c} \) – indicator of environmental significance of recycling;

\( M \) – indicator of the relative volume of expected recycling [29].
Gorin V.A. suggests adjusting the proposed index by including a social component that assesses the health of the population in the territory under consideration [30]. However, the recycled construction products, elements, and structures have a number of specific features that must be taken into account when determining the efficiency of utilization and recycling [31]. Thus, individual structures and elements of buildings that have a small percentage of physical depreciation are suitable for further economic purposes without the use of additional processing technologies. In particular, these are ceramic bricks and individual elements of reinforced concrete structures. Based on this, it is proposed to include in the recycling efficiency index an the percentage of building elements indicator that can be reused without the use of additional recycling technologies. In this case, the recycling efficiency criterion takes the form (Eq. 2):

\[ I_{er} = f(E, E_c, M, V_r), \]  

where \( V_r \) – an indicator that takes into account the percentage of building elements that can be reused without the use of additional recycling technologies.

For the domestic industry, we can identify a group of factors that hinder the development of WRCI processes, including:

1) the undeveloped legal framework in the field of WRCI;
2) the disproportion of the rate of processing and formation of considered wastetypes;
3) the low need for secondary materials in production, except for metal elements;
4) the difficulties in selecting recycling technologies due to the variety of waste types;
5) the significance of the costs of collecting, preparing and processing recyclable materials.

Direct operating costs of recycling, \( C_r \), should be adjusted upward due to labor costs, depreciation costs for buildings, basic and auxiliary equipment, costs for auxiliary materials, housing and utilities expenses (Eq. 3), i.e.:

\[ C_r = C_{lab} + C_{depr} + C_{aux} + C_{ut}, \]  

where \( C_{lab} \) – the cost of labor;  
\( C_{depr} \) – depreciation;  
\( C_{aux} \) – costs for auxiliary materials;  
\( C_{ut} \) – expenses for electricity and other utilities.

3 Results
The analysis made it possible to identify a group of key economic waste risks [32] arising from the construction recycling technologies implementation in the realization of investment and construction [33] projects (Table 1). Potentially, one of the ways to reduce risks can be the use of public-private partnership tools [34].

| Negative consequences of the low level of development of waste recycling in the construction industry (WRCI) |
|---------------------------------------------------------------|
| **Social** | **Ecological** | **Economic** |
| the increase in fees for the export of solid waste | the contamination of the biosphere with hard-to-recycle MSW and their decay products | the confiscation of land plots, including agricultural land from agricultural use when generating polygons |
| the increasing threats to public health | the growth of technogenic load on the ecosystem | the increasing demand for primary resources |
| the worsening of the ecological state of the environment | the exhaustion of the biosphere’s assimilation potential | the increase of energy and resource intensity of production and final product |

Figure 3. Classification of negative consequences of low level of WRCI development.
Table 1. Main economic risks associated with the implementation of recycling.

| Category          | Risks                                                                                      |
|-------------------|-------------------------------------------------------------------------------------------|
| Macroeconomic risks| - currency exchange rate instability that causes the cost of equipment to increase       |
|                   |   - sanctioned restrictions on the use of equipment                                         |
|                   |   - sanctions restrictions on attracting foreign investment in the industry                |
| Microeconomic risks| - lack of program-oriented state regulation of financing process                           |
|                   |   - unavailability of funding                                                              |
|                   |   - price instability (with downward dynamics) for secondary products                      |
|                   |   - the absence of tax and tariff exemptions for recycling companies                        |
|                   |   - lack of developed economic mechanisms of recycling technologies and economic fines for waste disposal on landfills |
| Law risks         | - imperfection of the regulatory framework in the field of recycling                       |
|                   |   - high administrative overregulation                                                     |
| Innovative risk   | - lack of innovative potential                                                             |
|                   | - risk of negative development of the industry                                             |
| Organizational risk| - lack of statistical records of waste and secondary raw materials                         |
|                   |   - lack of competent specialists                                                           |
| Social risk       | - low public awareness of the benefits of the industry                                     |
|                   | - low consumer interest in secondary products                                              |

The Russian waste recycling industry is currently fragmentary. Therefore, the need for developing the criteria that will allow determining the effectiveness of recycling measures is relevant for a long time [35]. Due to this criterion, it will be possible to establish and implement the most popular measures for waste disposal and recycling. Unfortunately, such a general indicator of recycling performance is currently under development.

Efficient recycling technology should be focused on solving two global problems at once: the economic benefit from the use of resources and the elimination of environmental pollution.

Ultimately, the assessment of the project's economic efficiency with the implementation of environmental, resource and energy saving measures can be performed using the “object-environment” system's sustainability model [36].

4 Discussions

Due to the complicated modern socio-economic conditions, sustainable reproduction of residential real estate which helps to solve the main national task in providing the population with affordable and comfortable housing determines the need to take into account the resource and energy efficiency of real estate at all stages of the life cycle. It includes the stage of optimizing the choice of building materials and structures [36]. Given the high energy intensity of traditional materials, as well as the steady growth of waste by type of activity "Construction" against the background of a decrease in the assimilation potential of the environment, the direction of development of the construction industry associated with the recycling of construction waste becomes particularly relevant.

The development of low-rise eco-building technologies based on local building materials, waste recycling and the implementation of such real estate in serial construction will allow:
1) to provide the population with affordable and comfortable housing;
2) to minimize the negative impact of territorial investment and construction complexes by recycling waste;
3) to reduce carbon dioxide emissions (by 40% reduction in heat losses) by minimizing the burning of organic fuel;
4) to reduce energy consumption by 30% by using alternative renewable energy sources;
5) to create a safe and comfortable, developing environment for human activity through direct communication with the surrounding nature (work on the plot, walking in the vicinity of the house, etc.).

When evaluating the efficiency of recycling, it is proposed to take into account the formation and disposal character of construction waste. These actions allow conducting an environmental and economic assessment of recycling activities giving consideration to the reuse of waste without the use of additional recycling technologies.

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