

Environmental Aspects of the Housing Renovation Program in Moscow under Sharing and Circular Economy Conditions

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Abstract. Since 2017, a housing renovation program has been implemented in Moscow, which is a unique program aimed at settling and demolishing shabby low-rise housing stock and new construction on the vacated territory. The renovation program raises a fundamental issue of construction waste disposal. Many current technologies of building mass demolition imply dusting of adjacent territories, have low efficiency in transporting construction waste generated in this process and lead to environmental problems resulting from its disposal, so the rational use of construction waste becomes one of the environmental protection's main points. In this research, we address the question: how the principle "Green Digital Technologies," reflected in the Moscow development concept "Smart City," which is a part of the housing renovation program in Moscow, is currently implemented. Three implementation ways of this principle have been revealed: contraction of "smart houses" under the renovation program according to smart 1.0 standard; use of BIM-technologies in the program; use of "smart demolition" technology. It is proposed to consider the process of recycling construction waste after demolishing old houses under the renovation program according to the principles of sharing and circular economy to increase the program's environmental friendliness and reduce environmental risks for the Moscow population.

1 Introduction

In February 2018, the ROMIR research holding company conducted a survey of Moscow citizens on how much they consider their city comfortable for living and what problems they have. Based on the survey data, we will create a rating of Moscow citizens' problems (Fig. 1). It is undeniable that Moscow citizens are mostly concerned about transport, migrants, ecology, and the cost of living.

Since 2017, Moscow has been implementing a housing renovation program, which is a unique program of the Moscow government, aimed at settling and demolition of dilapidated low-rise buildings built in 1957-1968, as well as new construction on the vacated territory. The program is designed for 15 years, according to Moscow citizens' votes, it will include

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more than 5 thousand houses. Since the voting on this program, there have been many disputes on its main provisions, its implementation, and the impact on Moscow citizens' quality of life [2-6]. However, one thing is indisputable - this program may become a real tool to create a new image of entire residential districts of the city. It is an opportunity to engage in the comprehensive development and renovation of residential areas. The program covers not only the districts of direct construction and reconstruction but also neighboring districts and the city as a whole (Fig. 2).

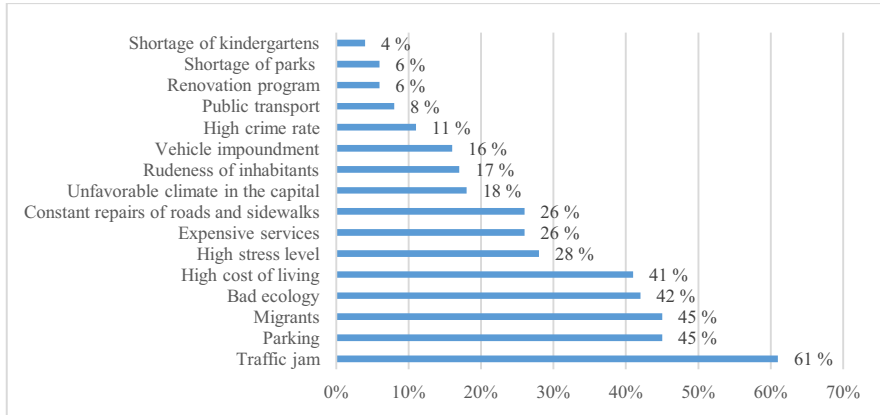


Fig. 1. Rating of Moscow citizens' problems [1].



Fig. 2. Number of houses included in the Moscow Administrative Districts (AD) Renovation Program [8].

Let us take a look at the primary current data on the Renovation Program: August 1, 2017, Moscow Mayor Sergey Sobyenin approved the Renovation Program. On September 26, 2017, the list of the first construction sites appeared. March 3, 2018, the first moves under the program began. By June 3, 2020, 17.1 thousand Moscow citizens (130 residents of five-story buildings) have already moved into new apartments, about 5.5 thousand more were about to move. In the period from 2018 to 2020, the Moscow budget allocated 400 billion rubles for the program. Currently, the program provides more than 350 thousand apartments for the resettlement, including 5174 houses [7].

The Renovation Program should be aimed at improving Moscow citizens' quality of life and should comply with the main provisions of the Russian Digital Economy program. In this regard, we recall that according to the Order of the Russian Government of 07.28.2017 No. 1632-p "On approval of the Russian Digital Economy program," the federal course' direction was the establishment of the country's digital economy. For Moscow, this means striving to implement the concept of Smart City, namely, a comprehensive program for the introduction of the digital environment, which would cover all life aspects [9]. The

concept's context presents Smart city's main principles [10]: The concept's context presents Smart City's main principles: "Smart City for a Human" – focus on humans, providing conditions for a full, high-quality, happy life for all categories of citizens; "Participation of Residents in the City Management" - creating conditions for active participation of citizens in decision-making on urban issues, open digital government; "Artificial Intelligence Solving Urban Problems" - one of the main driving forces of the economy and society digital transformation; "Digital Technologies to Create a Barrier-free Environment" - provision of equal opportunities for all Moscow citizens to improve the safety and comfort of movement, as well as the development of digital public services; "Mutual City Development with Businesses and the Scientific Community" - full participation of business, academic institutions, and research organizations in urban projects on mutually beneficial terms; "Digital Documents' Domination over Their Paper Analogues" - improvement of public services rendering transparency, optimization of administrative procedures, increase of resources use efficiency; "End-to-end Technologies in All Spheres of City Life" - use of perspective digital technologies in all spheres of city life: big data, virtual and augmented reality, 5G technologies, Internet of things, blockchain, etc.; "Domestic Solutions for Digital Technologies" - reasonable approach to import substitution, use of best practices, targeted support of domestic solutions to address the challenges of the city development; "Green Digital Technologies" - use of technologies that reduce waste and emissions, achieve maximum reuse of resources, and conduct environmental activities.

The renovation program raises an important issue of construction waste disposal, which is discussed both in Russian and foreign publications [11-14]. Many currently used technologies of building mass demolition imply dusting of adjacent territories, have low efficiency in transportation of construction waste generated and lead to environmental problems resulting from its disposal, so rational use of construction waste becomes one of the main priorities for environmental protection [15-19].

In this article, we answer the question: how the "Green Digital Technologies" principle, reflected in the "Smart City" concept of Moscow development under the housing renovation program in Moscow, is currently implemented. We also propose to consider the possibility of recycling the construction waste after the demolition of old housing under this program based on the principles of sharing and circular economy in order to improve the program's environmental friendliness and reduce environmental risks for the Moscow population.

The sharing economy implies a "shared consumption economy" or "joint economy." This concept is widely used when discussing the digital economy prospects, but its meaning is far from clear. Russians have slowly but surely adopted the concept of "sharing economy," while in European countries sharing in the field of construction (and not only) has developed to the circular economy concept. It is noteworthy that the first publications devoted to the critique of the established linear economy focused on the unlimited use of resources, which subsequently turn into waste (Fig. 3), gained popularity back in the 1970s. Due to the rapid consumption growth, resource scarcity, and volatility in commodity markets, a shift from the "from the cradle to the grave" economy to the "from the cradle to the cradle" closed-cycle economy [20], a circular economy aimed at preserving the value of products and resources as long as possible and at minimizing waste, is gaining momentum.

The classic concept of production symbiosis involves "physical exchange of materials, energy, water, and by-products" between different production structures (e.g., when one production's waste is used as raw material by others). At present, such cooperation is usually justified by the economic benefits of resource sharing: it provides an income increase (cost reduction); guarantees the stability of the raw material flow in the long term; contributes to meeting the regulatory requirements of authorities regarding the efficient use

of natural resources (energy). The transition from a classic linear economy to a closed-cycle economy is of great importance for Moscow under a large-scale housing renovation program. The demolition of buildings has a clear strategic orientation because the dismantling of buildings is only the first link in a chain of construction work on a particular site. In 2019, there were about 8 million tons of construction and demolition waste of IV-V classes of danger in Moscow, which is comparable to the total amount of solid municipal waste (8.1 million tons per year), the reform of which was introduced in January 2019. Taking into account the Renovation Program, the amount of construction waste in Moscow in 2020 will increase by 500 thousand tons per year, up to 8.5 million tons. Currently, 70% of the total amount of construction waste is generated by the facility construction at the expense of the Moscow budget and the renovation program, and the remaining 30% - from commercial projects.

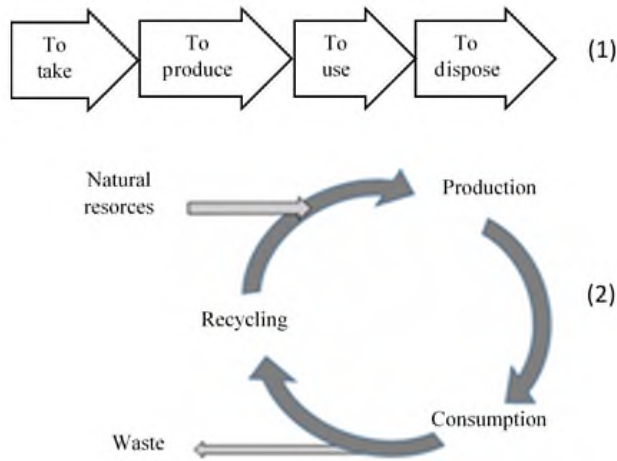


Fig. 3. Linear economy (1); Economy of closed cycle (2).

2 Materials and methods

Systematization, structural, comparative analysis, a theoretical generalization of data obtained from a detailed analysis of literary and statistical sources were used.

3 Results

We have identified three implementation directions of the "Green Digital Technologies" principle of the "Smart City" concept in the Moscow housing renovation program.

3.1 Direction one. Construction based on the smart 1.0 standard for the renovation of "smart houses."

According to the information provided to the public, the renovation program will include the construction of "smart houses" according to the smart 1.0 standard, which has been developed by Stroykompleks' specialists, the Department of Information Technology, Department of Housing and Public Utilities, and Improvement. According to S. Levkin, Head of the Moscow City Planning Policy Department: "These houses are planned to be equipped with the latest communal life support systems. For example, engineering equipment and energy supply systems for new buildings will be integrated with information

systems of the city's resource supply organizations". According to the press service of the Moscow Housing Renovation Fund, the renovation program houses will be designed with due consideration for the possibility to integrate the built housing into the space of a "smart city." Such technical requirements for construction were included in the second edition of the "smart standard." It will allow installing modern intercoms in the houses with a call for emergency services and utilities and a special button for people with low mobility, security systems - video surveillance cameras in the yard and at the entrance, and a smart panel in the entrance lobby. The renovation houses project also takes into account the possibility of installing base cellular stations 5G on the floors. In those houses built from scratch, the smart standard is provided by the specification. The first "smart house" is planned to be put into operation in 2020. Before the renovation program, smart houses were only in the elite housing in Moscow. For example, the residential complexes "Loftec," "Cloud Nine," "Faces," clubhouse "Malaya Bronnaya 15". Since the technical requirements for the house's design under the renovation program have already taken into account the "smart standard" solutions; this will allow integrating the built housing in the space of "smart city" in the future. The next step should be the development of smart 2.0 and 3.0 standards for houses, where "smart meters" will transmit data on the amount of sewage discharge for each apartment and the amount of heat energy consumed.

3.2 Direction two: Using BIM technologies in the program

More and more often, we hear the term information modeling technology alongside the word "renovation." The term "BIM" (Building Information Model or Modeling) means an information model (or modeling) of buildings and structures, which means any infrastructure facilities, such as engineering networks (water, gas, electrical, sewage, communications), roads, railroads, bridges, ports, and tunnels. Information modeling of a building is a way to build, equip, operate, and repair (as well as demolish) a building (facility life cycle management). It implies collection and complex processing during the designing of all architectural, technological, economic, and other information about a building with all its interconnections and dependencies when a building and everything related to it are considered as a single object. By order of the Moscow mayor on BIM-technologies introduction in the city projects, a pilot facility will be erected in the east of Moscow (Metrogorodok, Vladenie 30, Otkrytoe Shosse, Plot 1), where it is planned to test-drive the entire technological cycle using BIM - from design to commissioning of a residential facility. According to Moskomekspertiza, two П-shaped residential buildings with two underground floors will be built. Each house will have five entrances and 924 apartments. In 2017, Moskomekspertiza became the coordinator of the action plan for the information modeling technology implementation. At the end of June 2019, Moskomekspertiza approved the drafted documents related to BIM-modelling, which regulate not only the creation of digital information models but also their submission for projects examination, i.e., a regional database of rules and regulations for BIM has started being established. The information model allows tracking all stages of the facility's life cycle, provides information on the construction's economic feasibility, design, construction, operation, and demolition periods. According to the Moscow Department of Urban Policy, the world experience of information technology in urban planning shows that they can improve control over costs and increase the calculations' accuracy at the design and pre-project stages. At the same time, the construction cost may decrease by 23%, i.e., by almost a quarter of the planned costs. Besides, the transition to digital technologies allows reducing the number of errors in projects by 41% on average.

3.3 Direction three: Using "houses smart demolition" in the program

On August 23, 2018, the "smart demolition" technology was applied for dismantling a five-story building, located near Severnoe Izmailovo (5, Konstantina Fedina Street, building area 3.5 thousand sq. m, height 15 m, four entrances) for the first time. As we noted earlier, the renovation program involves the demolition of more than 5 thousand houses (mostly five-storied); the demolition of one five-storied house generates about 5 thousand tons of various waste. "Smart demolition" has several stages (Fig. 4). At the first stage, individual elements are dismantled inside the building with waste divided into groups (e.g., faience and ceramics, glass, carpentry). Then, the garbage is taken to specialized landfills to recycling for reuse. At the second stage, the building's remaining untouched frame is dismantled with an excavator so that the construction waste accumulates inside the building, not outside. The remnants of structures are taken to landfills, where they are crushed and processed. Remains of a framework (scrap metal) are separated and sent for remelting. The bulk of construction debris after dismantling the building is reinforced concrete, concrete, and brick. Waste is sorted by special equipment. Large bricks are crushed and then recycled in crushers. The recycling product is crushed stone, which is widely used for dumping technological roads, filling pits, drainage devices in the swampy areas. The "building smart demolition" technology is planned to become a standard in Moscow. This mechanized demolition method is very productive and allows to destroy any building without damaging the surrounding facilities and territory, using the equipment that can most effectively solve the demolition problem. This method's main disadvantage is enormous amounts of construction waste, which is difficult to reuse in construction or to recycle due to the high labor intensity of sorting. Therefore, construction waste should be taken to landfills. Taking into account the world trends in the rational use of construction waste, we can say that the mechanized method of building demolition is outdated.

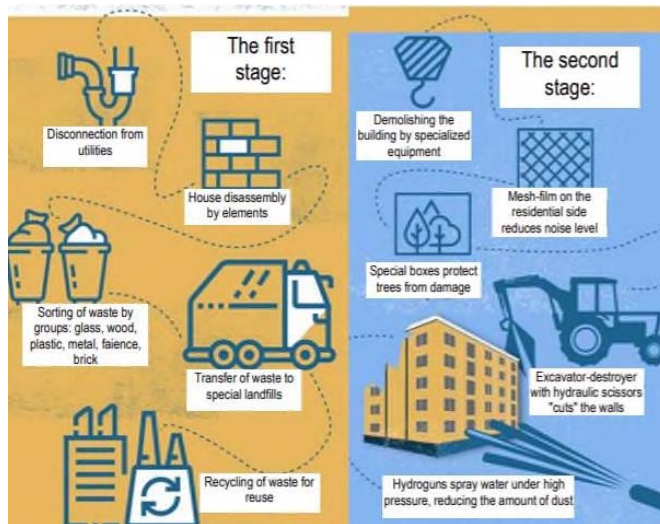


Fig. 4. "House smart demolition's" stages in the renovation program.

Smart demolition technology requires a significant transformation in order to reduce the renovation program's environmental risks and increase economic efficiency from the reuse of construction materials. The legal acts regulating the process of handling construction and demolition waste in Moscow include: Federal Law of 06.24.1998 No. 89-FZ "On production and consumption wastes"; Federal Law of 05.04.2011 No. 99-FZ "On licensing certain activities"; Decree of the Russian Government of 08.16. 2013 No. 712 "On the

certification order of waste I - IV classes of danger"; Order of the Russian Ministry of Natural Resources and Environment of 09.30.2011 No. 792 "On approval of the procedure for maintaining a state register of waste"; Order of the Federal Supervisory Natural Resources Management Service of 05.22.2017 No. 242 "On approval of the federal classification register of waste"; law of Moscow of 11.30.2005 No. 68 "On production and consumption waste in Moscow"; Decree of the Moscow Government of 11.09.1999 No. 1018 "On approval of the sanitary rules of territories, organization of cleaning and ensuring cleanliness and order in Moscow"; Decree of the Moscow Government of 01.25.2000 No. 49 "On approval of the rules and regulations for the design of planning and development of Moscow MGSN 1.01-99". These normative documents were not enough for active control over the construction wastes; that is why on October 1, 2020, the Decree of the Moscow Government of 08.26.2020 No. 1386-III "On approval of the Procedure for handling construction and demolition wastes in Moscow" came into force. According to this decree, the main principles of CDW handling (construction and demolition wastes) will be the maximum CDW direction for recycling in order to reduce the amount of buried waste; segregation of CDW in their accumulation and preparation for recycling; priority CDW recycling before their disposal; preventing the organization of unauthorized CDW landfills; development of the secondary material resources market and their involvement in the economic turnover as secondary raw materials; availability of information on the CDW management; participation in interregional cooperation of the CDW management [21]. Besides, according to the document, there are suggested ways to control construction waste turnover. Method 1 - Construction contractors and companies that take out garbage, as well as construction waste processing complexes, will have to install equipment for such control at their own expense; we are talking about the mobile photo- and video recording, as well as about complexes and equipment for weight control at construction sites and landfills. Method 2 - Carriers of construction waste will have to put GLONASS or GPS sensors on the vehicles. All information from telemetry facilities will be stored in a single automatic information system for the storage and disposal of demolition, construction, and soil waste.

All these measures are aimed against illegal construction waste dumps in Moscow, along roads and in the forests. The authorities are forced to eliminate them at their expense, as well as environmental damage. Unscrupulous market participants rent land plots, formalize them as landfills based on construction waste management licenses, but do not organize processing there and dump the garbage. For illegal transportation and disposal of construction waste without a proper permit or in the wrong place in Moscow, there are fines only up to 200 thousand rubles for legal entities (according to the administrative code). The new resolution of the Moscow Government does not contain any new fines, but landfills and carriers of such waste must obtain permits to handle them, and in case of violations, they will be deprived of this right. After the Moscow authorities introduce the new rules, such landfills shall cease to exist or be modernized by processing and storage of wastes according to all rules of the environmental legislation. Good-faith investors will be able to recoup their costs and not to lose a one-day competition for the cost of services.

This resolution should significantly improve the environmental friendliness of the renovation program in Moscow, but there is an issue that, in our opinion, requires significant adjustment. The "smart demolition" used in the renovation program is based on the mechanized demolition method. "Smart demolition" results in heterogeneous low-quality stone materials with no guaranteed durability. At the same time, numerous inspections of the bearing capacity of building materials, products, and structures carried out by the Building Structures Departments of various Russian higher educational institutions have established that the materials resulting from the phased demolition have sufficient capacity for the construction of low-rise buildings. Phased dismantling of buildings by modern equipment allows reusing the obtained construction materials for low-

rise buildings construction, at the same time reducing their market value by 2-3 times. This method has proved to be effective, for example, in the Voronezh Russian Region. Phased dismantling of buildings with subsequent reuse of building materials was applied in Voronezh already in the postwar period for the reconstruction of the city destroyed during the war and showed high reliability of reused building materials, products, and structures. It is noteworthy that today a quarter of new housing in New Moscow is low-rise and individual housing construction. It should be reminded that New Moscow is the territories that were annexed to Moscow during the most large-scale project of Moscow territory expansion in the history of administrative and territorial division of the city. Moscow's administrative boundary lines were officially expanded by incorporating the Moscow Region's territory on July 1, 2012; after that, the city area increased approximately 2.4 times. As a result, Moscow rose from the 11th to the 6th place in the world in terms of area and became the largest city in Europe. In this case, the city has retained the seventh place in terms of population, as the incorporated territories included less than 250 000 people. New Moscow's area is 1480 sq. km.

The demand for low-rise buildings and individual houses increases thanks to the development of sites far from the Moscow Ring Road. This is due to the active construction of roads, new metro stations, and the development of road and transport infrastructure. Since the beginning of the incorporated territories development, transport accessibility has been growing both within the TiNAD and with the Moscow historical center. The construction of social facilities (schools, kindergartens, polyclinics, hospitals) is another reason for the growing demand for low-rise buildings. By 2021, about 100 such objects are to be built in New Moscow, which is almost twice as high as the commissioning of social facilities in the history of the territories annexed to the capital.

With these positive dynamics of the New Moscow territory development, one can observe another trend. There are about 100 abandoned villages in the country market of the Moscow Region's suburbs. One-third of the settlements have been suspended for more than five years, and the chances of their revival are low due to the physical obsolescence of unfinished houses or legal problems. Among them, there are just plots of bare land, where construction has not started, as well as complexes with varying degrees of construction completeness. Other reasons for such abandoned projects include bankruptcy or the developer's financial difficulties, an unsuccessful concept. All in all, analysts point to low development activity at the country market of the Moscow Region: in addition to entirely hopeless cases, almost half of the settlements are in a semi-deserted state. Abandoned settlements can be seen in the Moscow Region's different parts and at a distance from the capital, but more often than 50 km from the Moscow Ring Road. It is worth pointing out another trend in the construction market. For the first time in the last three years, the steady growth of new housing construction in most regions was recorded. One of the housing construction development drivers in the last few years is the growth of individual housing construction. In 2018, the residential housing commissioning accounted for 42%, this year - 46% of the new construction total volume, and compared to the results of 2016; the share growth exceeded 5.5 pp. (Table 1).

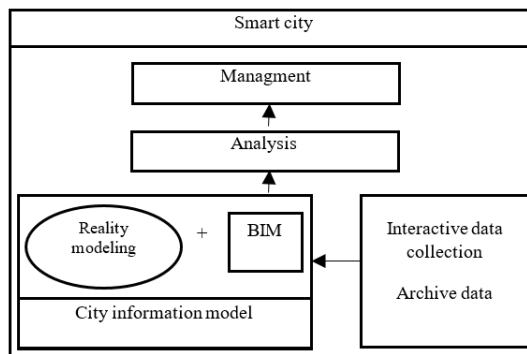
In this sense, Moscow and the Moscow Region are quite far from leading positions in the country, including the fact that the cost of land plots for individual construction is several times higher than the Russian average. The possibility of saving on the cost of construction materials, which are "outputs" of the houses phased analysis in the renovation program, would be an effective way to motivate the process of individual construction of residential real estate in the Moscow region and New Moscow.

Table 1. Dynamics of the share of residential housing commissioning by the population as the share of the nationwide housing construction indicators in the 2010s.

Year	Commissioning of housing, mln. sq. m.	Commissioning of housing by population
2010	58.4	43.5%
2011	62.2	42.8%
2012	65.7	43.1%
2013	70.5	43.3%
2014	84.2	42.9%
2015	85.3	41.0%
2016	80.2	39.6%
2017	78.5	41.4%
2018	75.1	43.1%
2019	80.1	45.1%

4 Discussion

So, let us sum up what "green digital technologies" are used today in a large-scale program of housing renovation in Moscow. Initially, Moscow residents could use the service "Active Citizen" in the voting of apartment owners for entry or not in the renovation program. As experience has shown, it was a useful interactive tool for owners' rights realization. At present, this site provides information on Moscow districts about concrete houses (with their image on the city map), included in the program, or voted against it. A new group of houses on the map appeared relatively recently, the so-called "saved five-story buildings," is of interest. The site notes that the saved five-story buildings will be resettled, while the houses will be restored and used for urban needs. So far, there are few such houses, but most likely, their number will grow during the program, and of course, users of the site have questions about what urban needs we are talking about. The application of the "smart house" standard in the construction of new houses in the renovation program is dictated by specific time requirements from the standpoint of digital tools in human life and management of apartment buildings. The term BIM-technology for an ordinary Moscow citizen probably does not mean anything; it is rather a technology of professionals. However, there is an interesting fact: it may be appropriate to apply information modeling not only in the construction of new houses and even entire neighborhoods during the renovation, but also to pre-describe the existing reality, thus integrating BIM-technology in the "smart city" concept (Fig. 5).

**Fig. 5.** Scheme of embedding BIM-technologies in the Smart City concept in the renovation program [22].

Moscow residents are interested in the quality of life changed thanks to the program, and the connection of stages that we offer: "Preliminary description of the terrain" (with demolition houses and preserved, with the existing infrastructure, environmental and industrial facilities). "Use of BIM-technologies in the demolition and construction of new facilities." "Reducing damage to residents of houses located close to the facilities constructed" and "Information modeling of the use of construction waste produced during the demolition." They can be considered a development course of the capital as a "Smart city," and the use of several technologies for the digitalization of buildings is already possible, even for not brand-new houses [23, 24].

There is a vast potential for cooperation between two segments of the Moscow residential real estate market - the program for renovation of the old stock and construction of new low-rise housing in Moscow suburbs. The proposed change in the "smart demolition" technology from the currently used mechanized method to the phased disassembly is essential in terms of the interrelation of construction waste of the renovation and low-rise construction programs in Moscow and the Moscow Region. The "outputs" of the demolition process will be the "inputs" to the construction process, thus providing for an increase in material efficiency, a considerable cost reduction of the houses built, and a significant environmental effect. Such cooperation on the housing construction market corresponds to the basic principles of both the sharing and circular economies.

5 Conclusion

In the course of the housing renovation program, the capital's residents are concerned not only about increasing the density of construction and population in administrative districts, but also about environmental problems associated with the disposal of construction waste. Therefore, the rational use of construction waste becomes one of the main directions of Moscow's environmental protection. During this study, three directions of applying the principle "Green Digital Technologies" of the concept of developing Moscow as a "smart city" were identified: building "smart houses" according to the smart 1.0 standard renovation program; use of BIM technologies in the program; use of the "smart demolition" technology. It was suggested to consider the process of recycling construction waste after the demolition of old houses under the renovation program in terms of the principles of sharing and circular economy. It is proposed to change the approach in the "smart demolition" technology from the currently used mechanized method to the phased demolition, which will allow the construction waste of renovation to make the "inputs" during low-rise construction in Moscow and Moscow Region, providing an increase in the efficiency of material use, reducing the cost of erected housing, reducing environmental impact.

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References

1. Romir found out what dissatisfied Moscow citizens are and whether they want to leave the city // <https://newizv.ru/news/city/02-02-2018/romir-vvyasnil-chem-nedovolny-moskvichi-i-hotyat-li-oni-uehat-iz-goroda>
2. A. Schmeleva Backgrounds and principles of drafting a standard of life quality in Moscow. Quality Access to Success. **20**. S2. 567-573. (2019)

3. A. Schmeleva, R. Nizhegorodtsev The program of housing renovation in Moscow and the environmental risks of the population. *Quality Access to Success*. **20**. S2. 574-579 (2019)
4. A. Schmeleva, R. Nizhegorodtsev. The life quality in terms of the coordinate system: environmental factors – health saving – property value **19**. № S1. C. 470-474 (2018)
5. A. Schmeleva, R. Nizhegorodtsev. Evaluation of the life quality of Russian population: the development of the environmental aspect. *Quality - Access to Success*. **18**. S2. 388-393.
6. A. Schmeleva, M. Umnova Health and ecology indicators in the quality of life ratings in Russia. **18**. S2. 394-400 (2018)
7. Y.Sudakova Three years of renovation: interim results // <https://www.cian.ru/stati-tri-goda-renovatsii-promezhutochnye-itogi-306560/>
8. "Big Moscow": what is the smart standard of the renovation program // <https://www.m24.ru/infographics/infografika/06122018/6794>
9. Sobyenin instructed to develop the program "Smart city" in Moscow // <https://tass.ru/moskva/5110318>
10. Digital concept of Moscow // <https://ict.moscow/moscowsmartcity/stage/5/page/61/>
11. H. Wu, J. Zuo, Status quo and future directions of construction and demolition waste research: A critical review. *Journal of Cleaner Production*. **240**. (2019) DOI: 10.1016/j.jclepro.2019.118163.
12. L.C.M. Eberhardt Potential of circular economy in sustainable buildings. IOP Conference Series: Materials Science and Engineering. **471**.(2019) DOI: 10.1088/1757-899X/471/9/092051.
13. Yu B., Wang J., Li J., Zhang J., Lai Y., Xu X. Prediction of large-scale demolition waste generation during urban renewal: A hybrid trilogy method. *Waste Management*. **89**. 1–9.(2019) DOI: 10.1016/j.wasman.2019.03.063.
14. F. Aras Monitoring the dynamic properties of a nine-story reinforced concrete building during its demolition. *Structural control & Health Monitoring*. **26**. Issue 11. (2019) DOI: 10.1002/stc.2456.
15. M. R. Munaro Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment. *Journal of Cleaner Production*. **260**, 1 (2020) 121134. <https://doi.org/10.1016/j.jclepro.2020.121134>.
16. C. Joshi, J. Seay Building momentum for sustainable behaviors in developing regions using Locally Managed Decentralized Circular Economy principles, *Chinese Journal of Chemical Engineering*. **27**, Issue 7, (2019) 1566-1571. <https://doi.org/10.1016/j.cjche.2019.01.032>.
17. B. W. Jansen circular economy life cycle costing model (CE-LCC) for building components. *Resources, Conservation and Recycling*. **161**, (2020), 104857. <https://doi.org/10.1016/j.resconrec.2020.104857>.
18. M. Bilal, Khan K. I. A., Thaheem M. J., Nasir A. R. Current state and barriers to the circular economy in the building sector: Towards a mitigation framework. *Journal of Cleaner Production*, **276**, (2020), 123250. <https://doi.org/10.1016/j.jclepro.2020.123250>.
19. G. Foster Circular economy strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts. *Resources, Conservation and Recycling*, **152**, (2020) 104507. <https://doi.org/10.1016/j.resconrec.2019.104507>.

20. M. Braungart, *Cradle to Cradle: Remaking the Way We Make Things*. United States: North Point Press, 208 (2002)
21. T.I. Stavtseva. Sustainable economic development: a closed cycle economy and a shared consumption economy In the edition: Ensuring sustainable regional development in the spatial structure of the Russian economy. National (All-Russian) Scientific and Practical Conference: a collection of scientific papers. Under joint editorship of O. E. Konobeyeva.38-43 (2018)
22. M.R. Chertow Uncovering' Industrial Symbiosis. *Journal of Industrial Ecology*. **11** (1) (2007)
23. S.A. Kolodyazhny Demolition of the buildings and use of the materials produced during the renovation of the urban areas *Vestnik MSCU*. **15**. Edition 2. Pages 271-293. (2020)
24. E. M. Akhmetshin, et al, Institutional analysis of the regulatory and legal framework for financial reporting control in Russia. *European Research Studies Journal* **21(3)**, pp 130-141 (2018)