Reducing the Negative Impact of Demolition on the Environment

Sampath Kumar Paspunoori

Capital Program Manager, Alexandria City Public Schools, Alexandria City, Virginia, USA

Abstract: ***The topic's relevance is due to the growing scale of urbanization and the need to upgrade urban infrastructure, which leads to an increase in the volume of dismantling works and, as a result, an increase in the burden on the environment. The study aims to develop a comprehensive algorithm to reduce the negative impact of demolition on ecosystems, integrating innovative technological solutions and the principles of circular economy. The analysis revealed significant contradictions between the growing need for environmentally safe dismantling and the fragmentation of existing approaches, which do not take into account the complexity of the interaction of demolition processes with urban ecosystems. In addition, there is a lack of integration of advanced digital developments into dismantling management practices. It was possible to conclude the need to create an adaptive process management system based on the use of Internet of Things technologies, artificial intelligence, and robotics. An innovative algorithm for environmentally safe demolition of buildings is proposed, including stages from preliminary 3D scanning of the object to environmental rehabilitation of the territory. The article is of interest to specialists in the field of environmental management, urban planning, and construction engineering, as well as to decision - makers in the field of urban development, and environmental protection.***

Keywords: dismantling of buildings, "green" construction, Internet of Things, recycling of construction waste, demolition of buildings, construction waste, urbanization, circular economy, environmental safety.

1. Introduction

Urbanization and modernization of city infrastructure inevitably lead to the need for the demolition of outdated or unsafe buildings. However, this process is naturally associated with serious environmental risks that require thorough analysis, along with the development of innovative methods to minimize environmental damage. Therefore, the target goal is to consider the key aspects of the negative impact of demolition work on the ecosystem and to formulate the author's perspective on resolving this pressing issue.

Modern urbanization and the need to update urban infrastructure result in an increase in the volume of demolition work, creating a significant burden on the environment. Despite the growing awareness of the importance of environmentally safe building demolition, existing approaches are often fragmented—they fail to account for the complexity of interactions between demolition processes and the ecosystems of urban environments.

The key problem lies in the absence of a comprehensive, integrated methodology that would combine advanced technological solutions, circular economy principles, and environmental management practices to minimize the negative impact of building demolition on the environment.

2. Methods and Materials

The article applies methods of comparative analysis, systematization, synthesis, and generalization. Upon reviewing materials and sources, it was found that in recent years, interest in reducing the negative impact of construction and demolition on the environment has grown. Researchers are actively studying various aspects of this topic, proposing innovative approaches and solutions.

For instance, C. Balemba and co - authors conducted a review of methods for the disposal of construction waste after demolition in the context of a "green" and circular economy. The authors emphasize the importance of transitioning to more sustainable practices in the construction industry [1]. Similarly, G. Bertino and colleagues explore the fundamentals of building deconstruction as a strategy for reusing materials. Their publication offers a systematic approach to the planning and implementation of processes [3].

The issues of recycling and disposal of construction waste are extensively covered in the work of I. Bejaoui and co - authors. They examine the possibility of using demolition waste as an additive to cement, which opens up new prospects [2]. F. Chang and D. Wang propose an innovative approach to calculating resource utilization and energy consumption based on Internet of Things technologies, allowing for the optimization of waste management processes [4].

M. K. Dixit and P. Pradeep Kumar focus on analyzing the embodied energy and water in building materials to create an environmentally sustainable environment. Their research helps to assess the full life cycle of materials and their impact on the natural environment [5]. X. Li proposes dynamic modeling of the system flow of "green" building complexes, considering the vulnerability of the ecological environment, which optimizes the environmental performance of buildings [7].

Special attention is given to reducing noise pollution during building demolition. Ka. L. K. Leong and co - authors present a case study on the implementation of a noise management structure to achieve "silent" demolition in Hong Kong's urban environment [6]. Their approach demonstrates the potential for significantly reducing acoustic impact during demolition activities.

J. Xiao and his colleagues raise the important issue of the fate of demolition waste, using the example of the earthquake in Turkey in February 2023. Their analysis highlights the need to develop effective waste management strategies in emergencies and large - scale demolition work [10]. D. Maier focuses on the use of wood waste from construction and demolition for the production of sustainable bioenergy, conducting a bibliometric review of the literature [8].

J. De Oliveira and co - authors further develop the concept of circular economy by considering buildings as "banks" of materials to mitigate the environmental impact of demolition waste. Their work describes a comprehensive approach to managing the life cycle of buildings from an ecological sustainability perspective [9].

Thus, scientific publications present a wide range of research directions: from optimizing waste disposal and recycling processes to implementing circular economy principles in the construction industry. The focus is on innovative technological developments and methods that allow for minimizing the environmental footprint of demolition work and maximizing resource efficiency.

3. Results and Discussion

First and foremost, it is essential to focus on the primary environmental risks associated with building demolition. The corresponding differentiation is presented in Figure 1.

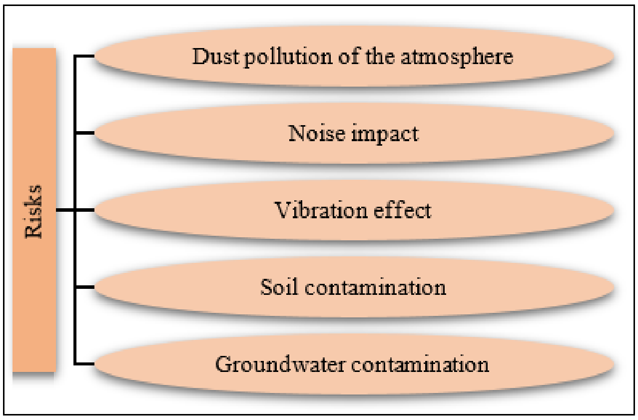

Figure 1: The allocation of environmental risks during the demolition of buildings [2, 4, 7, 10]

During the destruction of building structures, a significant amount of fine dust is generated, containing particles of cement, asbestos, silica, and other potentially hazardous substances. These aerosols can remain suspended in the air for extended periods, dispersing over large distances and negatively affecting air quality in nearby areas. Inhalation of such dust triggers respiratory diseases in the local population and workers involved in the demolition process.

In turn, the use of heavy machinery and explosives during building demolition generates intense noise and vibrations, disrupting the natural behavioral patterns of local fauna. This can lead to the migration of animals from their habitual habitats, disruptions in their reproductive cycles, and an overall reduction in biodiversity within urbanized ecosystems.

Demolition work is often accompanied by fuel and lubricant leaks, as well as the leaching of toxic substances from construction debris. This results in soil contamination and the infiltration of harmful compounds into underground water - bearing layers, which typically has long - term consequences for local ecosystems and public health.

Given the above, it is appropriate to consider innovative methods that significantly reduce environmental damage (Figure 2).

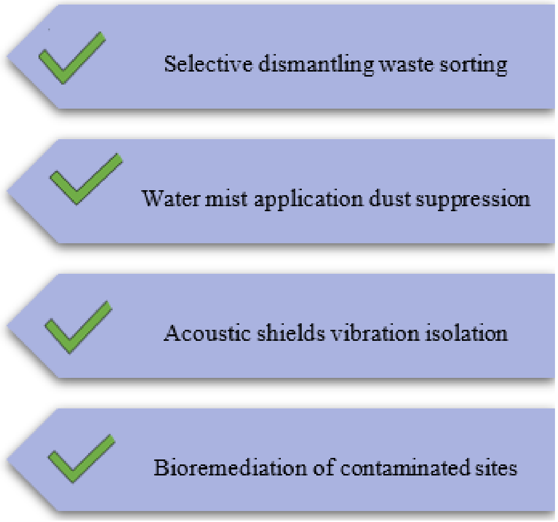

Figure 2: Innovative approaches to reducing environmental damage [1, 6]

The implementation of phased building dismantling with careful sorting of the resulting waste significantly increases the efficiency of subsequent recycling. Within this approach, potentially hazardous materials (such as asbestos - containing insulation panels) are separated in the early stages of demolition, which mitigates the risk of their dispersion into the environment.

The use of specialized spraying systems that create a fine mist of water around the dismantled object effectively binds dust particles, preventing their spread into the atmosphere. This method is particularly relevant when working in densely populated urban areas where traditional dust suppression methods are often insufficient.

The installation of temporary acoustic barriers around the construction site allows for a significant reduction in noise pollution. The use of modern vibration isolation materials and technologies when placing heavy machinery minimizes the transmission of vibrations to adjacent areas, which is especially important when working near historical buildings or critical infrastructure.

After the completion of demolition work, it is advisable to carry out a set of activities aimed at restoring disrupted ecosystems. A promising direction in this regard is the use of phytoremediation methods, which involve planting vegetation capable of accumulating and neutralizing pollutants in the soil. This approach not only aids in cleansing the area but also positively affects its natural greening process.

Digital technologies in environmental management during demolition work are represented by various innovations (Figure 3).

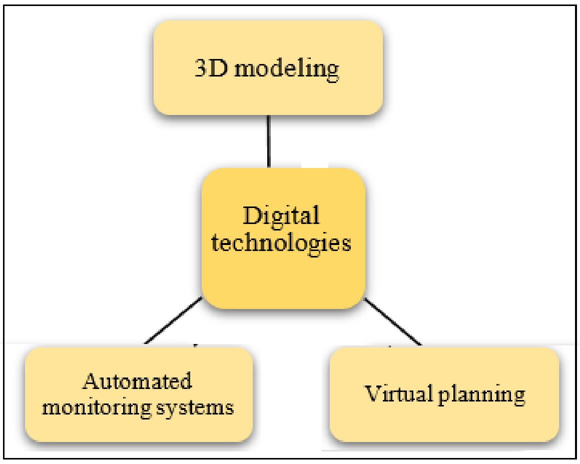

Figure 3: Digital technologies in the arsenal of environmental management during the demolition of buildings [3, 9]

In commenting on the above diagram, it is worth highlighting that the application of three - dimensional scanning and modeling technologies allows for the creation of detailed "digital twins" of demolished objects. This enables the optimization of the demolition process, minimizing the amount of waste generated and significantly reducing the risk of unforeseen situations potentially hazardous to the environment.

The introduction of IoT sensor networks for continuous monitoring of air quality, noise levels, and vibrations allows for prompt responses to exceedances of permissible levels. The integration of such systems with machine learning algorithms enables the prediction of potential environmental risks and the automatic adjustment of demolition parameters.

The study proposes an innovative algorithm aimed at minimizing the negative environmental impact of demolition work. The outlined sequence of actions (Table 1) integrates advanced technologies and methodologies into a unified decision - making system.

Table 1: Recommended algorithm for reducing the negative impact of demolition work on the environment (compiled by the author)

Stage	Content
1. Preliminary 3D scanning of the object	Creation of a detailed digital model of the building using LiDAR technologies. Analysis of structural elements and materials through machine learning algorithms.
2. Assessment of environmental risks	Modeling the dispersion of dust and vibrations based on meteorological data and characteristics of the surrounding construction. Calculation of potential impacts on local ecosystems, taking seasonal factors into account.
3. Development of an adaptive demolition plan	Optimization of the demolition sequence to minimize peak loads on the environment. Integration of dynamic dust suppression systems synchronized with the demolition process.
4. Implementation of a "smart" monitoring system	Deployment of a network of interconnected IoT sensors for real - time monitoring of air quality, noise levels, and vibrations; use of predictive analytics to forecast and prevent critical situations.
5. Selective demolition using robotic equipment	Utilization of autonomous robots for dismantling structures in high - risk areas and automated sorting and separation of materials directly on - site.
6. Closed - loop waste recycling	Introduction of mobile units for on - site processing of construction waste. Application of biotechnologies for accelerated neutralization of hazardous substances in the soil.
7. Environmental rehabilitation of the area	Use of genetically modified microorganisms for intensive soil cleanup. Formation of biodiverse ecosystems considering urban needs.
8. Analysis and optimization	Collection and analysis of data on the effectiveness of implemented measures, and adjustment of the algorithm using deep learning methods for future projects.

Next, it is necessary to substantiate the novelty of the algorithm described above. A comprehensive approach is proposed, synthesizing advanced achievements in the fields of 3D modeling, IoT, robotics, and biotechnology into a unified system for managing the building demolition process. The algorithm emphasizes dynamic planning based on real - time data analysis, allowing for flexible responses to changing environmental conditions. In turn, the implementation of artificial intelligence systems for optimizing demolition processes minimizes the influence of the human factor on environmental safety.

The use of mobile recycling units and bioremediation methods directly at the demolition site significantly reduces the burden on transportation infrastructure and decreases the overall carbon footprint of the operation, which is also accounted for in the recommended algorithm. It lays the foundation for creating a closed - loop system for the use of construction materials, consistent with the principles of the circular economy.

The integration of methods from various scientific fields (ecology, robotics, computer science, biotechnology) creates a synergistic effect unattainable with traditional approaches.

Finally, the modular structure of the algorithm allows for its adaptation to both small - scale projects and large - scale urban renovation initiatives.

4. Conclusions

Reducing the negative environmental impact of building demolition requires a comprehensive approach that combines innovative technological solutions with careful planning and strict adherence to environmental regulations. The implementation of the methods described in the article will significantly minimize the damage to ecosystems during the modernization of urban development and contribute to the formation of a more sustainable and environmentally safe urban environment.

The proposed and characterized algorithm represents a qualitatively new approach to organizing the building demolition process, aimed at maximizing the reduction of environmental impact. Its novelty lies not only in the use of advanced technologies but also in their systematic integration, which will help achieve a fundamentally new level of environmental safety in demolition work within urbanized areas.

References

[1] Balemba C. A review on the utilization of construction and demolition waste (CDW) toward green and circular economy / C. Balemba, B. Mirenge, D. Konde, N. Hossiney, S. L. Kumar, K. Sarath Chandra // Lecture Notes in Civil Engineering. – 2021. – Vol.143. – Pp.215 - 224.

[2] Bejaoui I. Feasibility of the demolition waste incorporation as an additive to cement: comparative study according to current standards / I. Bejaoui, H. Hammi, Kh. M. Hammi, A. H. Hamzaoui, R. Abidi // Chemistry Africa. – 2024. – Vol.7. – No.1. – Pp.291 - 299.

[3] Bertino G. Fundamentals of building deconstruction as a circular economy strategy for the reuse of construction materials / G. Bertino, J. Kisser, J. Zeilinger, G. Langergraber, T. Fischer, D. Österreicher // Applied Sciences (Switzerland). – 2021. – Vol.11. – No.3. – Pp.1 - 31.

[4] Chang F. Construction waste resource utilization and energy consumption calculation based on Internet of things / F. Chang, D. Wang // Soft Computing – A Fusion of Foundations, Methodologies and Applications. – 2023. – Vol.27. – No.11. – Pp.7567 - 7578.

[5] Dixit M. K. Analyzing embodied energy and embodied water of construction materials for an environmentally sustainable built environment / M. K. Dixit, P. Pradeep Kumar // IOP Conference Series: Earth and Environmental Science. – 2022. – Vol.1122. – No.1. – Pp.12 - 45.

[6] Leong Ka. L. K. Implementing construction noise mitigation management framework to achieve quiet building demolition in urban environment of Hong Kong: a case study on demolition of a multi - storey carpark building / Ka. L. K. Leong, M. Ch. Wong, K. T. Ch. Kwok, Ch. K. A. Wong, W. K. J. Wong // INTER - NOISE and NOISE - CON Congress and Conference Proceedings. – 2023. – Vol.268. – No.8. – Pp.986 - 994.

[7] Li X. Dynamic simulation of system flow of green building complexes considering ecological environment vulnerability / X. Li // Fresenius Environmental Bulletin. – 2020. – Vol.29. – No.9. – Pp.7660 - 7667.

[8] Maier D. The use of wood waste from construction and demolition to produce sustainable bioenergy - a bibliometric review of the literature / D. Maier // International Journal of Energy Research. – 2022. – Vol.46. – No.9. – Pp.11640 - 11658.

[9] Oliveira J. De. Circular economy and buildings as material banks in mitigation of environmental impacts from construction and demolition waste / J. De. Oliveira, D. Schreiber, V. D. Jahno // Sustainability. – 2024. – Vol.16. – No.12. – Pp.5022.

[10] Xiao J. Where are demolition wastes going: reflection and analysis of the February 6, 2023 earthquake disaster in Turkey / J. Xiao, Qi. Deng, M. Hou, J. Shen, O. Gencel // Low - Carbon Materials and Green Construction. – 2023. – Vol.1. – No.1. – P.17.