LIFE CYCLE MANAGEMENT OF CONSTRUCTION FACILITIES

УПРАВЛЕНИЕ ЖИЗНЕННЫМ ЦИКЛОМ ОБЪЕКТОВ СТРОИТЕЛЬСТВА

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Sustainable Development Paths for Urban Eco-Architecture

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Abstract

Introduction. Environmental development issues have become acutely relevant of late. Therefore eco-architecture is taking centre stage. By using sustainable design concepts and eco-friendly materials, eco-architecture reduces dependence on natural resources, as well as energy consumption and waste emissions, thus effectively decreasing the burden on the environment. Hence not only is eco-architecture an essential area of sustainable urban development, but also provides one with a practical way of designing a more harmonious and high-quality living environment. The aim of the study is to identify the principles of eco-architecture and assess its impact on the sustainable development of the urban environment. The impact of eco-architecture on the entire construction cycle of buildings and structures from the moment of construction to the demolition of the building is examined, and the ways of sustainable development of urban architecture are identified.

Materials and Methods. Ways of sustainable development of eco-architecture in the modern world are analyzed. Various negative impacts such as air and water pollution, noise, landscape and ecosystem disturbance occur during the construction and opera-tion of buildings. To minimise these impacts, it is necessary to develop environmental protection measures and take environmental aspects into account at all stages of design and construction.

Research Results. The study assessed the sustainability of the development of eco-architecture according on the analysis of the life cycle of the building, accounting for the environmental impact at the stages of design, construction, use and demolition of the construction site.

Discussion and Conclusion. The sustainability assessment of eco-architecture is based on the analysis of the building's life cycle, accounting for the environmental impact at all the stages: from design and construction to use and demolition. A comprehensive analysis of the resource consumption and environmental load of the building at different stages would enable one to assess sustainability more accurately. As digital technologies are evolving, the use of intelligent buildings and the Internet of Things (IoT) will enable data to be monitored and analyzed in real time. This will improve the sustainability management of buildings during the operational phase by providing data support in order to optimize resource efficiency.

Keywords: eco-architecture, sustainable development, ecological energy efficiency, low carbon content, resource recycling, environmental friendliness, building lifecycle, urban development, environment

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Оригинальное эмпирическое исследование

Пути устойчивого развития для городской эко-архитектуры

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Аннотация

Введение. В последнее время вопросы экологического развития стали особенно актуальны, поэтому важность эко-архитектуры выходит на первый план. Используя концепции устойчивого проектирования и экологичные материалы, эко-архитектура снижает зависимость от природных ресурсов, уменьшает потребление энергии и выбросы отходов, тем самым эффективно снижая нагрузку на окружающую среду. В связи с этим эко-архитектура является не только важным направлением устойчивого развития городов, но и предоставляет нам практический путь к созданию более гармоничной и качественной среды обитания. Целью данного исследования является определение принципов эко-архитектуры и оценка его влияния на устойчивое развитие городской среды. Проанализировано влияние эко-архитектуры на весь цикл строительства зданий и сооружений с момента строительства и до сноса здания, и определены пути устойчивого развития городской архитектуры.

Материалы и методы. Проведен анализ путей устойчивого развития эко-архитектуры в современном мире.

Результаты исследования. В ходе исследования выполнена оценка устойчивости развития эко-архитектуры на основе анализа жизненного цикла здания с учетом воздействия на окружающую среду на этапах проектирования, строительства, использования и сноса объекта строительства

Обсуждение и заключение. Оценка устойчивости развития эко-архитектуры основывается на анализе жизненного цикла здания, учитывая воздействие на окружающую среду на всех этапах: от проектирования и строительства до использования и сноса. Всесторонний анализ потребления ресурсов и экологической нагрузки здания на разных этапах позволит получить более точную оценку устойчивости. С развитием цифровых технологий применение интеллектуальных зданий и Интернета вещей (IoT) сделает возможным мониторинг и анализ данных в режиме реального времени. Это позволит улучшить управление устойчивостью развития зданий на этапе эксплуатации, обеспечив поддержку данных для оптимизации эффективности использования ресурсов.

Ключевые слова: эко-архитектура, устойчивое развитие, экологическая энергоэффективность, низкое содержание углерода, переработка ресурсов, экологичность, жизненный цикл здания, городское развитие, окружающая среда

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Introduction. As cities are sprawling, pre-existing natural habitats are being exploited on an unprecedented scale causing a dramatic reduction in biodiversity and puts lots of species under risk of extinction. Intensive urbanization affects the quality of life leading to air and water pollution, increased noise, reduced green space, high density of buildings and population. All of these did not only disrupt the balance of the ecosystem, but also posed a threat to the human environment as well as made it imperative to rethink the existing approaches to architectural and spatial organization of the urban environment [1]. A way to address these challenges is the concept of eco-architecture combining respect for nature and concern for human health and comfort. Ecological architecture dates back to the beginning of the last century to the theory of "renewable resource management" which considered the issues around replacing traditional energy sources with alternative ones. It suggested using solar electricity produced by spherical collectors [2]. Variants of solar installations have been developed that generate steam capable of turning turbines that produce electric current. However, in practice, none of the options has been implemented. In Soviet Russia, in general, environmental attempts were confined to planning landscaping areas of Soviet cities and to an extent to reducing the impact of industrial pollution on the environment. Those were only the first steps in the development of green architecture [3].

In the West, during the 1970s energy crisis and an increase in global fuel prices that followed, there was a surge in interest in renewable energy sources, saving fuel and energy resources used for heating construction structures. During this period, there were a lot of projects for buildings that ran on solar energy [4].

In the 1980s, environmental problems got exacerbated. The negative impact on nature increased as there was more anthropogenic impact and the scientific and technical complex was experiencing an intense growth. Buildings emitted almost half of all carbon dioxide into the atmosphere, so the new imperative was to protect the natural world. Comprehensive environmental reconstruction projects got underway [5]. For instance, the solution of traditional issues facing landscape architecture is intertwined with environmental problems as environmental conditions must be accounted for in order to create a sustainable urban environment. As the situation of the urban landscape is being exarcebated by the oversaturation of technology and the corresponding displacement of natural components, it is becoming critical to maintain harmonious and environmentally friendly areas. Hence considerable efforts have been made in order to rehabilitate and improve the environment [6].

A while later there were new trends in the formation of a green space, "...now nature is being „built“ into the building." The flora is becoming one of the elements in the improvement and development of urban ecosystems. There is a new trend emerging — non-traditional design (greening flat roofs, including elements of the biotic environment in the architecture and interior of buildings: living plants; water; stone; materials imitating the wood texture; fragments of specific natural areas with a maintained microclimate, etc.) [7].

Fig. 1 shows the Quai Branly Museum in Paris completed in 2006, which is a wild, disorganized jumble of colorful boxes. In order to enhance the sense of confusion, the glass wall blurs the boundary between the exterior streetscape and the interior garden. Passers-by cannot tell the reflections of the trees from the blurred images behind the wall. The French architect Jean Nouvel is head of the project. It is designed in line with the principles of ecological architecture.

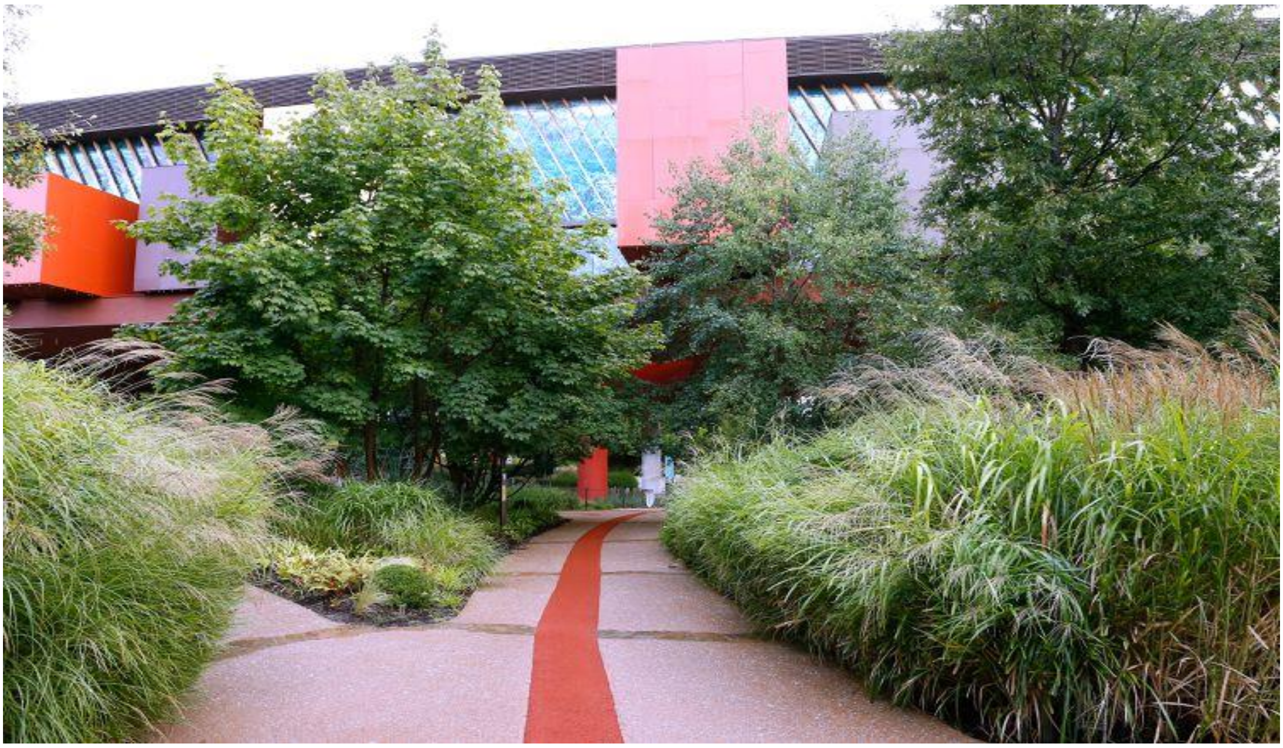

Fig. 1. Quai Branly Museum, Paris[1]

The concept of eco-architecture involves the use of processes that are responsible for the environment, the effective use of resources throughout the life cycle of a building, which is its complete ongoing design, operation and disassembly, including such stages as mining and production of building materials, design, construction of the building, its functioning, including the supply of water, gas, electricity, waste disposal, routine maintenance, possible reconstruction, disassembly following the end of the life cycle and reuse of the resulting materials [8].

Materials and Methods. The analysis of the environmental components of a construction site precedes construction, reconstruction as well as repairs of buildings and structures involving identifying the nature, intensity, and degree of danger this activity poses to the environment and public health. The aim of the analysis is to prevent environmental damage, as well as to ensure environmental safety, protection, sensible use and reproduction of natural resources given national, public and private interests.

[1] *Quai Branly Museum, Paris.* URL: https://www.thoughtco.com/buildings-and-projects-by-jean-nouvel-4065275 (accessed: 16.04.2025)

In order to develop environmental principles for designing construction facilities, it is essential to identify environmental impact factors of construction. The direct negative impact is increased noise, various radiations, and emission of harmful substances. The indirect impact lies in the fact that construction sites, buildings, structures, and roads annually occupy more and more vital space for humans.

The factors affecting the environment at each stage of building construction will be analyzed. During the construction phase, e.g., the most considerable negative impacts on the environment are as follows:

– atmospheric air pollution caused by gas and dust emissions (construction machinery and vehicles, welding and paintwork, etc.);

– contamination of groundwater and wastewater (refueling of machinery and vehicles, spills of concrete mix and various mortars, etc.);

– negative impacts on the acoustic environment (construction machinery, pile work, etc.);

– environmental pollution from construction waste;

– violation of the natural landscape of the area

– removal of soil following excavation which was stored in landfills (alienates territories, transforms the landscape, generates erosion);

– increasing the amount of household waste;

– impact on animals, birds, fish, and their habitats.

At the stage of building operation, there are the following negative impacts:

– disruption of the regime of illumination of the Earth's surface by the sun (insolation);

– disruption of the wind regime;

– violation of the hydrological regime of the area;

– reducing the amount of vegetation;

– soil and water pollution;

– dust, thermal pollution;

– increased traffic flows and thus the effect on the acoustic environment.

In case a building is to undergo reconstruction, a negative impact will come from the air, surface, groundwater, vegetation pollution, waste generation and noise pollution with the impact of the reconstructed facility on adjacent buildings accounted for.

For a more complete assessment of an impact of a project on the environment, its components are typically analyzed: climate and microclimate, airspace, geological layers, reservoirs, soil, flora and fauna, historical and cultural heritage, social and man-made environment.

All of this makes it necessary to come up with special environmental protection measures to ensure an ecological balance between man and nature, as well as sustainable development of construction areas and adjacent areas as well as cities in general. This is what is realized in the designing and constructing the entire life cycle of a building as a single chain. An analysis is crucial as it allows one to address lots of issues occurring at the design, planning, construction and other stages. After all, each stage is made up of lots of elements with incorrectly selected materials or design solutions possibly increasing the costs due to low energy efficiency. It is necessary to account for the environmental aspect in an analysis as legislation is tightening environmental standards and requirements. This is why choosing materials and technologies wisely determines how serious a footprint the project will leave in the environment will be. The use of the principles of eco-architecture is thus particularly poignant.

For instance, the use of a building life cycle analysis methodology, LCA (Life Cycle Assessment), is being widely implemented, which includes multiple steps: from collecting initial data to interpreting it [9, 10].

LCA life cycle analysis is a comprehensive methodology for assessing the full life cycle of a product, equipment, building, or system. It covers all stages (from extraction of raw materials to disposal), revealing the impact on costs, productivity and the environment [11]. This helps determine which of these needs attention: environmental friendliness, costs, productivity, and environmental impact.

The issues of ecological construction and building maintenance are critical in solving a city’s environmental problems. This is being addressed worldwide [12, 13]. As a result, the construction industry is witnessing some changes making it possible to reduce the impact on the environment and use natural resources sensibly.

The quality of life in a city is starting being characterized by the number of buildings certified according to international "green" standards, such as The Leadership in Energy & Environmental Design (LEED) developed back in 1993. It was followed by lots of new certification standards: from the British BREEAM, the American WELL and Fitwel, and others to the Russian "Green Standards" and Green Zoom [14].

Green certification provides an opportunity not only to implement a construction project, accounting for environmental criteria, but also contributes to improving performance at all stages of a building's life cycle: from design and construction to commissioning and subsequent disposal.

In Russia, there are environmental standards NOSTROY 2.35.4–2011 "Green Construction", the Eco Village system for cottage areas, and the GREEN ZOOM standard. Also in 2009, Federal Law No. 261-FZ "On Energy Conservation and Energy Efficiency Improvement" came into force which generated a new system of state regulation in the area [15].

Research Results. A negative impact on ecosystems and saving various resources, particularly non-renewable ones, is reduced by creating conditions for the effective interaction of natural forms and man-made environmental objects. As a result, there is improvement and stabilization of the microclimate parameters inside the facilities being designed with the environment, which reduces energy consumption for the operation of the corresponding energy systems, and also retains and enhances the stability of the ecosystem the facilities being constructed are being implemented [16]. How exactly development and improvement of eco-architecture occur is guided by some principles. They are critical for effective realization of opportunities in developing urban environment.

The key principles of eco-architecture contributing to urban development are as follows:

1. The use of energy-saving technologies and alternative energy sources, which implies that of solar panels, wind turbines, as well as highly efficient heating and cooling systems in buildings [17].

Fig. 2 shows The Edge, a 15-storey office building in the Zuidas financial district in Amsterdam. It was built in 2015, with a total area of 40,000 m^2. The building has almost 30,000 sensors collecting anonymous data on heating and cooling systems, lighting, occupancy, etc. On 14 out of the 15 floors, the walls of the building can be freely moved enabling users to change the workspace as they please. The British rating agency BREEAM awarded the building a record-breaking 98.4% sustainability rating, which is the highest ever in its history.

Fig. 2. Office building in the business district of Zuidas[2]

[2] *Офисное здание The Edge. Dirk Verwoerd.* URL: https://archi.ru/projects/world/9650/ofisnoe-zdanie-the-edge (accessed: 16.04.2025)

2. Buildings should be designed with environmentally friendly materials as well as maintain energy efficiency and provide a longer service life to minimize waste and the need for permanent renovation. In order to create an eco-friendly environment, both previously unused and recycled materials can be used. On top of that, there are lots of alternative materials that are more environmentally friendly. The use of renewable and recyclable construction materials does not only help to reduce resource extraction, but also reduces carbon dioxide emissions through the course of construction [18].

Fig. 3 shows a solar power plant located on the roof of a building in Indonesia in Bontang. Such a solar power plant produces clean energy and reduces carbon emissions into the atmosphere. Its capacities cover up to 30% of the energy needs of office premises. The total area of the power plant is 6,500 m^2, and the capacity is more than 1,000 kW with an output voltage of 380 V.

Fig. 3. Location of a solar power plant on the roof of a building. Indonesia, Bontang, East Kalimantan[3]

a) *b)*

Fig. 4. Energy-efficient buildings using the green design concept: *a* — Chengdu, Southwest China, Minjiang River Valley[4]; *b* — Warsaw University Roof Garden[5]

[3] *Solar power plant on the roof of a building. Indonesia, Bontang.* URL: https://awsimages.detik.net.id/api/wm/2022/08/19/plts-atap-pkt-di-bontang_169.jpeg?wid=54&w=650&v=1&t=jpeg (accessed: 16.04.2025)
[4] *Energy-efficient buildings.* URL: https://ad009cdnb.archdaily.net/wp-content/uploads/2012/10/5078dce228ba0d1640000085_zcb-zero-carbon-building-ronald-lu-and-partners_zcb_01_and_one_planet_living_loop.jpg (accessed: 16.04.2025)
[5] *Warsaw University Roof Garden.* URL: https://i.pinimg.com/originals/bd/cf/77/bdcf77be7986fd3f72fec3c6038f7ede.jpg (accessed: 16.04.2025)

3. Designing a comfortable environment for humans. Green spaces and public parks are a key part of ecological urban planning. They serve to reduce noise and air pollution, improve residents' quality of life and contribute to the conservation of biodiversity. This is where a human can feel one with nature [19].

4. Conservation of biodiversity. The creation of ecological corridors, park areas, and vertical landscaping of buildings as shown in Fig. 5, helps preserve local ecosystems and plant and animal species inhabiting them, which is critical for maintaining the balance of natural processes and biological diversity [20].

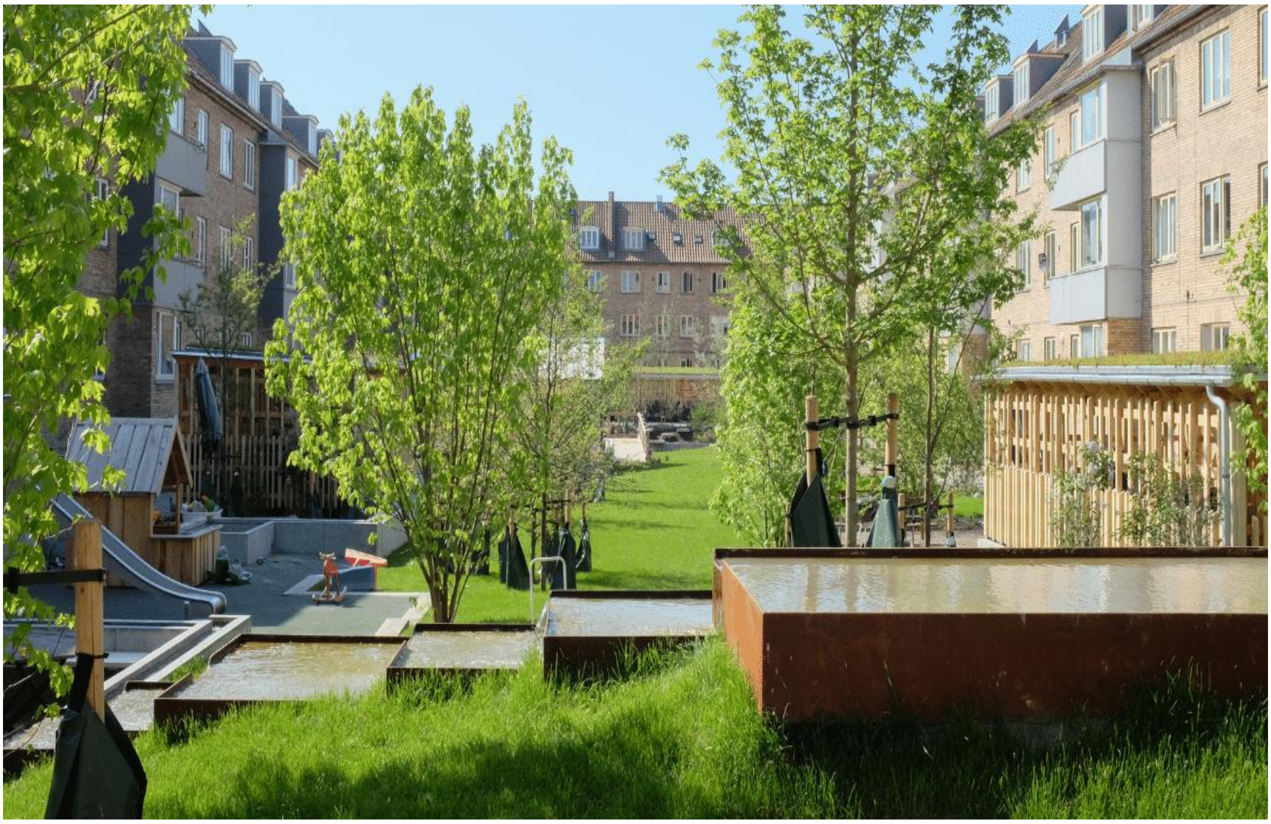

Fig. 5. Modern landscape design[6]

5. Sensible waste management. Urban architectural solutions should come with waste collection and recycling systems in order to minimize a negative impact on the environment. It is also important to encourage waste separation among general public [21].

The Crystal building in London, UK (Fig. 6) is an exhibition center devoted to sustainable development and environmental responsibility. The building is equipped with photovoltaic and solar panels for generating electric energy, and also makes use of a waste disposal system and energy-efficient technologies.

6. Adaptability. Urban architecture should be flexible and able to adapt to changing climatic conditions and environmental issues. This includes the use of artificial intelligence, smart urban systems, and climate change forecasting for effective management of a city [22, 23].

Let us consider the fundamental principles (Table 1) guiding eco-architecture and enabling reduction of negative environmental impacts depending on the stage of the life cycle of a building [24].

[6] *Bæredygtig klimasikring hædret med betonbranchens Oscar*. URL: https://estatemedia.dk/dk/2023/06/02/baeredygtig-klimasikring-haedret-med-betonbranchens-oscar/ (accessed: 16.04.2025)

Fig. 6. The Crystal building, London, UK[7]

Table 1

Major paths of eco-architecture

Design stage	1. Accounting for the environment at all the stages — from design to demolition of a building. 2. Accounting for residents' quality of life at all the stages of construction. 3. A design allowing adaptation to the environment.
Construction stage	1. Use of low-carbon materials and technologies. 2. Effective and sensible use of available resources and renewable energy sources. 3. Restoration of the ecological balance in the surrounding areas. 4. Introduction of a waste management system. 5. Reuse of building resources and structural elements. 6. Use of non-toxic, sustainable materials.
Operation stage	1. Introduction of energy-saving technologies. 2. Introduction of a waste management system. 3. Reuse of building resources and structural elements.

The transition to sustainable urban development plays a key role in solving environmental problems facing cities. Lots of people associate the term "green" architecture with houses whose facades and roofs are completely covered with greenery, which is not the only way to make a building more environmentally friendly [25]. Hence buildings are constructed using natural materials, energy-saving technologies are actively used and the land allocated for building is made the best use of. Of course, there is still no mass demand for green architecture in Russia, but some technologies are

[7] *London: The Crystal is the world's greenest building.* URL: https://ru.baltic-review.com/2012/09/21/london-kristall-the-crystal-samoe-e-kologichnoe-zdanie-v-mire/ (accessed: 16.04.2025)

already in use. For example, reducing energy consumption by regulating heating, using motion sensors and LED lighting in the entrances of apartment buildings. In lots of countries, all of this has become well-known and commonplace, and environmental solutions have been complemented by rainwater treatment systems and roof gardens [26].

On top of that, the future of sustainable urban development depends on a host of factors, including technological innovation, political will, public participation, and global cooperation. The development of smart technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data opens up new avenues for optimizing urban processes, improving residents' quality of life, and reducing environmental impacts.

Residents' and communities' active engagement in planning and decision-making, as well as educational programs for raising awareness of the principles of sustainable development, are fundamental to attaining long-term goals.

Ultimately, the future of sustainable cities will rely on our ability to adapt to change, innovate, and work together for the common good.

Discussion and Conclusion. Eco-architecture naturally helps the planet by making sensible use of local materials and energy. Utilization of its principles enables reduction in environmental pollution, nature conservation and health maintenance.

The use of modern construction technologies and materials enables buildings that are more flexible and efficient in the field of sustainable architecture to be designed. On top of that, the combination of new technological capabilities and the experience gained in traditional architecture will allow for new solutions to ensure maximum functional efficiency, durability and cost-effectiveness at all the stages of the life cycle of a building.

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