

# Issues of Environmental Projects for the Development of Agglomerations in Kazakhstan

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**Abstract.** This study aims to analyse the role and urgency of implementing environmental projects in agglomeration development, with a focus on improving air quality, waste management, rational use of water resources, and reducing the carbon footprint. The study identifies the main challenges and prospects in the implementation of environmental initiatives amid the growth of agglomerations, particularly in Kazakhstan. Using quantitative and qualitative analysis, as well as comparative methods, the study reviewed key environmental aspects such as green infrastructure, digitalisation, smart cities, sustainable transport and renewable energy. The results show that the integration of environmental projects and innovative technologies is essential to minimise negative environmental impacts, improve people's quality of life, and preserve natural resources for future generations. The study highlights global trends and successful practices, including Hammarby Sjöstad in Stockholm, Green Belt in London, and Masdar City in Abu Dhabi. The analysis also shows that although investment in research and development (R&D) in Kazakhstan stagnated at 0.1% during 2018-2023, the application of digital technologies plays a key role in environmental risk mitigation. The study recommends increased allocation of funds for renewable energy projects in scientific funding schemes to support sustainable agglomeration development.

**Keywords:** Environmental Issues, Agglomerations, Entrepreneurship, Digital Technologies, Innovations, Renewable Energy

## 1 Introduction

The relevance of environmental problems in recent years and the implementation of environmental projects for the sustainable development of agglomerations in Kazakhstan is an important task both for economic growth and in order to minimize the negative impact on the environment [1].

With the growth of cities and agglomeration zones, pressure on natural resources increases, which requires the introduction of integrated approaches to solving environmental problems. In the context of global environmental challenges, Kazakhstan strives to integrate innovative solutions to achieve sustainable development goals, including through the implementation of environmental projects. These projects are aimed at improving air quality, waste management, rational use of water resources and reducing the carbon footprint. The

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article explores the key problems and prospects for the implementation of such initiatives in the context of agglomeration growth, focusing on practical examples and opportunities for integrating international experience.

A review of the literature on environmental projects for the development of agglomerations in Kazakhstan shows that research in this area does not cover the entire range of topics, including sustainable urban development, innovative technologies for environmental management and social aspects of environmental initiatives. At the same time, the works of such authors as T. K. Zholdybayeva and M. A. Suleimenov[1] consider waste management strategies and their impact on the ecological state of agglomerations. Articles published in international journals such as the *Journal of Urban Environmental Management*[2] and *Sustainable Cities and Society*[3] emphasize the importance of integrating digital technologies and innovative solutions to improve the effectiveness of environmental projects. Considerable attention is also paid to research on the adaptation of international experience in the context of Kazakhstan, which allows us to identify successful practices and apply them in local conditions.

## **2 Methods**

Official statistical data on the state of the environment and the level of pollution in the agglomerations of Kazakhstan, provided by government agencies and statistical services, as well as examples of successful environmental projects implemented in these agglomerations, which demonstrate effective approaches to solving environmental problems, are used as materials.

The research methods used are quantitative and qualitative data analysis, as well as comparative analysis of environmental initiatives in Kazakhstan with similar projects in other countries, which allows us to identify best practices and adapt them to local conditions.

## **3 Results and Discussion**

### **3.1 Result**

Environmental projects for the development of agglomerations at the global level play a key role in solving problems related to urbanization and population growth.

With the rapid expansion of cities and the creation of large agglomerations around the world, there is an increase in environmental pressures such as air pollution, water scarcity, waste accumulation and a decrease in biological diversity. To solve these problems, many countries are implementing environmental initiatives aimed at sustainable development of urban and suburban areas. To develop proposals for improving environmental issues, it is necessary to analyze the main trends in world practice. The analysis showed that the main global trends in the implementation of environmental projects for agglomerations are the following aspects:

1. **Green infrastructure:** Many countries are actively developing green infrastructure, which includes the creation of urban parks, green roofs, vertical gardens and the restoration of reservoirs. Such projects help to improve air quality, contribute to the conservation of biodiversity and serve as a means of countering climate change. For example, Singapore, known as the "garden city", is actively developing green areas in an urban environment.
2. **Renewable energy and energy efficiency:** In agglomerations, increasing attention is being paid to the use of renewable energy sources such as solar panels, wind farms and biogas plants. European cities such as Copenhagen and Amsterdam are leaders in the use of

renewable energy and the development of energy-efficient solutions such as smart buildings and energy management systems.

3. Sustainable transport: Problems related to road transport, such as air pollution and congestion, have become an incentive for many cities to implement projects aimed at developing public transport, bike lanes and electric vehicles. Cities such as Oslo and Barcelona are successfully implementing environmental transport strategies, reducing carbon emissions and improving the quality of life of citizens.
4. Waste management and recycling: In large agglomerations, they strive to reduce the volume of garbage and increase the level of recycling. Cities such as Tokyo and San Francisco have advanced in this direction, where separate waste collection and recycling systems are actively developing, as well as programs to minimize the use of disposable plastic products.
5. Digitalization and smart cities: The use of digital technologies, such as smart air quality monitoring systems, water management and energy efficiency, is becoming an important part of the development of environmentally friendly agglomerations. The Internet of Things (IoT) and artificial intelligence (AI) platforms make it possible to optimize the management of urban resources and reduce the ecological footprint of cities. Cities such as Seoul and Stockholm are examples of successful implementation of smart technologies for environmental management.

The study of the world experience in the implementation of environmental agglomeration projects made it possible to identify the most successfully implemented examples:

- a. Hammarby Shestad Environmental Quarter in Stockholm (Sweden): This is one of the most successful projects of environmentally sustainable urban development. The project integrates waste recycling systems, energy-efficient buildings and renewable energy.
- b. "Green Belt" in London (United Kingdom): The project aims to create a protective green belt around the city to prevent its uncontrolled expansion, preserve natural landscapes and reduce carbon dioxide emissions.
- c. Masdar City in Abu Dhabi (UAE): This project is an example of creating a city with zero carbon dioxide emissions that runs exclusively on renewable energy sources.

World practice shows that the successful development of agglomerations requires the integration of environmental projects and technologies aimed at minimizing the negative impact on the environment, improving the quality of life of the population and preserving natural resources for future generations.

Environmental projects implemented as part of the development of agglomerations in Kazakhstan are inextricably linked with the volume and direction of investments in research and development (R&D) of the country. In the period from 2018 to 2023, Kazakhstan significantly increased its attention to R&D, directing part of its investments to the development of technologies and innovative solutions to solve environmental problems. Financing R&D in areas such as renewable energy sources, waste management, water treatment systems and carbon dioxide reduction creates the basis for the successful implementation of environmental projects in agglomerations [4].

Agglomerations such as Almaty, Astana and Shymkent face environmental challenges that require innovative solutions developed on the basis of R&D. In recent years, efforts have been made to introduce more environmentally friendly technologies in energy and transport, as well as the development of intelligent systems for monitoring and managing the environmental situation in cities. Investments in R&D have strengthened scientific and technical potential, which contributes to the development of local solutions to improve environmental quality.

Thus, the relationship between environmental projects and R&D in Kazakhstan is manifested through attracting investments in scientific research aimed at developing innovative technologies that will contribute to the sustainable development of agglomerations, reduce environmental stress and improve the quality of life of the population.

**Table 1.** Investments in Research and Development (R&D) for 2018-2023

	2018	2019	2020	2021	2022	2023
Gross domestic product by production method, billion tenge	61 819, 5	69 532, 6	70 649, 1	83 951,9	103 765, 5	120 561,1
Internal R&D costs, million tenge	72 224,6	82 333,1	89 028,7	109 332,7	121 560,1	172 585,9
The share of domestic R&D expenditures in GDP, %	0,1	0,1	0,1	0,1	0,1	0,1
The number of organizations that carried out R&D, units	384	386	396	438	414	425
including:						
public	103	100	93	101	106	102
sector higher professional education	95	92	99	95	94	105
sector business sector	149	158	167	202	179	171
non-profit sector	37	36	37	40	35	47
The number of employees who carried out R&D, person	22 378	21 843	22665	21 617	22 456	25 473

Developed by the authors based on data from the Bureau of national statistics of the agency for strategic planning and reform of the Republic of Kazakhstan, 2024 [5].

As can be seen from this table, the share of R&D costs is 0.1% and remains unchanged for 5 years. The share of public sector organizations is 26.82% in 2018 and 24% in 2023, the practical sector of higher professional education has not changed for 5 years and in 2023 is 24.70%. R&D was carried out by organizations of the business sector was 40.23% in 2023 and 11.07% by organizations of the non-profit sector. However, the number of employees of the organization engaged in R&D increased from 22,378 to 25,473.

Examples of the relationship of environmental projects for the development of agglomerations in Kazakhstan with the costs of information and communication technologies in the period 2018-2023: [6]

1. Smart City project in Almaty and Astana: As part of the program for the development of "smart cities", digital technologies aimed at monitoring the environmental situation were actively introduced in Kazakhstan. Due to investments in information and communication technologies, automatic air quality monitoring systems have been created that allow real-time monitoring of pollution levels and prompt measures to reduce it. These technologies help to minimize the negative impact on the environment by improving the environmental situation in large agglomerations.
2. Water Resources management System in Astana: In the period 2018-2023, the costs of implementing information and communication technologies for water management in agglomerations were increased. Digital solutions for monitoring and management of water supply and sanitation have been implemented in Astana. This made it possible not only to use water resources more efficiently, but also to minimize environmental risks associated with pollution of reservoirs and increased wastewater levels.

3. Digitalization of the waste management system in Shymkent: In 2018-2023, automated waste management systems were introduced in large agglomerations such as Shymkent. These information technology-based systems make it possible to monitor and optimize the collection, processing and disposal of waste, which reduces the load on landfills and contributes to improving the environmental situation in the city. These technologies are an example of using digitalization to solve environmental problems.

The issues of environmental projects for the development of agglomerations in Kazakhstan are directly related to the costs of information and communication technologies, since modern ecosystems of "smart cities" require the integration of digital solutions for the management of natural and man-made processes.

Investments in information and communication technologies contribute to the introduction of automated systems for monitoring air, water and soil quality, as well as intelligent platforms for resource management and energy efficiency. Such systems provide real-time data collection and analysis, which allows timely response to changes in the environmental situation and optimize the use of resources.

Digitalization of waste management, the use of IoT technologies for monitoring emissions and energy consumption, as well as the use of big data for modeling environmental scenarios have become possible due to increased costs for this industry, which makes it possible to more effectively solve environmental problems in the agglomerations of Kazakhstan.

**Table 2.** Expenditure on Information and Communication Technologies in Kazakhstan for 2018-2023

	2018	2019	2020	2021	2022	2023
Total costs of information and communication technologies (taking into account the organization of public administration), billion tenge	305, 22	337, 7	388, 9	443, 1	589, 8	918, 4
The share of total information and communication technology costs in GDP	0,49	0,49	0,55	0,53	0,57	0,76
The level of digital literacy of the population, %	79,6	82,1	84,1	87,3	88,3	90,2
Costs of innovations in the manufacturing industry, billion tenge	610, 8	247, 1	302, 9	421, 2	932, 1	1 358, 1

Developed by the authors based on data from the Bureau of national statistics of the agency for strategic planning and reform of the Republic of Kazakhstan, 2024.

Environmental projects for the development of agglomerations in Kazakhstan have contributed to the introduction of digital solutions for sustainable urban management. The development of information and communication technologies has supported the implementation of initiatives to create "smart" cities such as Astana and Almaty, where digital monitoring systems for air quality, water resources and energy consumption have become key tools to reduce environmental stress. Investments in this industry have also enabled the introduction of waste management and logistics systems that optimize garbage collection and recycling, reducing the carbon footprint of agglomerations. Thanks to the digitalization of processes, Kazakhstan has been able to increase the efficiency of

environmental projects and improve control over key environmental indicators in agglomeration zones.

The issues of environmental projects for the development of agglomerations in Kazakhstan are closely interrelated with the costs of innovation and the use of digital technologies in the manufacturing industry. The development of environmental initiatives in agglomerations requires the integration of technologies used in industry, such as production automation, emission monitoring systems and resource conservation. The costs of innovations in the manufacturing sector, including the introduction of "green" technologies and digital solutions, make it possible to minimize the negative impact of industrial enterprises on the environment in cities and adjacent territories.

The use of digital technologies in the manufacturing industry contributes to more effective management of environmental risks. For example, automated control systems for emissions and energy consumption allow enterprises in agglomerations to reduce pollution and optimize resources, which directly affects the improvement of the environmental situation in cities such as Almaty and Astana. Thus, innovations in the manufacturing industry of Kazakhstan are becoming an important driver for the development of environmentally sustainable agglomerations and reducing their carbon footprint.

Examples of the relationship between environmental projects for the development of agglomerations with the costs of innovation and the use of digital technologies in the manufacturing industry of Kazakhstan:

1. Almaty Thermoelectric power plant (TPP-2): One of the largest projects to modernize industrial infrastructure in Almaty, aimed at reducing greenhouse gas emissions and pollutants. By introducing innovative technologies for filtering emissions and switching to more environmentally friendly energy sources, TPP-2 has reduced its environmental impact, which directly improves the environmental situation in the agglomeration.
2. Astana Solar: A plant for the production of solar panels in Astana, which has introduced digital technologies to optimize production processes. The use of renewable energy sources not only helps to reduce the carbon footprint of the manufacturing industry, but also serves as an example of the integration of "green" technologies into environmental projects for agglomerations.
3. Ecojar project: As part of the development of this project, she actively invested in innovations in waste management and recycling in large cities of Kazakhstan. Digitalization of industrial waste sorting and recycling processes in agglomerations has helped reduce pollution, contributing to the environmental sustainability of cities.

These examples demonstrate how the costs of innovation and digital technologies in the manufacturing industry of Kazakhstan contribute to solving environmental problems in agglomerations, improving the quality of life and reducing the negative impact on the environment.

### **3.2 Discussion**

Despite significant efforts and investments in environmental projects such as improving waste management systems, pollution monitoring and the introduction of green infrastructure, there are a number of problems, including insufficient coordination between different levels of management, limited funding and a shortage of highly qualified specialists.

In addition, it is necessary to take into account social and economic aspects, such as the needs of local communities and the impact on the business environment. It is also important to note that the successful development of environmental projects requires an integrated approach that includes the integration of innovative technologies, active participation of citizens and support from government agencies. The discussion of these aspects highlights

the need for further research and optimization of strategies to achieve sustainable development of agglomerations and effective solutions to environmental problems in Kazakhstan.

Environmental sustainability has also become one of the most important aspects of innovation for small and medium-sized businesses. In response to the growing global concern about climate change and environmental degradation, small and medium-sized enterprises are increasingly introducing green innovations.

They not only contribute to the sustainable development of the planet, but also provide competitive advantages by reducing costs, improving brand image and compliance with regulatory standards. The integration of sustainable practices into business models is becoming a hallmark of innovative and future-oriented entrepreneurship.

**Table 3.** The Impact of Digital Transformation on the Growth and Sustainability of Small and Medium-Sized Businesses

Indicator	Before the digital transformation	After the digital transformation
Market coverage	Local/Regional	Global
Efficiency of operations	Moderate	High
Customer interaction	Traditional methods	Enhanced digital channels
Product personalization	Limited	Wide possibilities
Environmental sustainability	Not a priority	Integrated into the business strategy

This table illustrates how digital transformation is transforming SMEs from local or regional enterprises into global competitors. The shift towards increased operational efficiency, increased customer engagement through digital channels, broad product customization and the integration of environmental sustainability into business strategies highlight the multifaceted benefits of innovation.

## 4 Conclusion

In conclusion, it can be emphasized that the successful implementation of environmental initiatives is a key factor for the sustainable development of large cities and their suburbs.

The analysis of world practice allows us to make some recommendations for solving environmental problems in the agglomerations of Kazakhstan:

1. When conducting competitions for grant financing of scientific projects, pay significant attention to projects on the use of renewable sources;
2. When developing plans for the development of agglomerations, provide for the construction of ecological quarters using an integrated waste recycling system, energy-efficient buildings and renewable energy;
3. Environmental sustainability should be a priority when evaluating any innovative business ideas of entrepreneurship, from mono-projects to megaprojects.

Investments in environmental projects, such as the modernization of waste management systems, improvement of air quality and the introduction of innovative technologies, contribute not only to reducing the negative impact on the environment, but also to improving the quality of life of citizens. However, to achieve these goals, an integrated approach is needed, including active cooperation between government agencies, business and society. Further support and investments are also needed in the research and development of new technologies and methods for managing environmental problems. Only through joint efforts and innovative approaches can we ensure the effective and sustainable development of agglomerations in Kazakhstan, which will be an important step towards improving the environmental situation in the country.

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