

## ЕКОНОМІКА ПРИРОДОКОРИСТУВАННЯ ТА ОХОРОНИ НАВКОЛИШНЬОГО СЕРЕДОВИЩА

UDC 334.021:352.075

DOI: <https://doi.org/10.32782/2224-6282/187-26>**Niesheva Anastasiia**Assistant of the Oleg Balatsky Department of Management,  
Sumy State University  
ORCID: <https://orcid.org/0000-0003-0399-201X>**Smolennikov Denys**PhD in Economics, Associate Professor,  
Sumy State University  
ORCID: <https://orcid.org/0000-0001-8418-051X>**Kostyuchenko Nadiya**PhD in Economics, Associate Professor,  
Sumy State University  
ORCID: <https://orcid.org/0000-0003-4946-4028>**Нешева А.Д.**асистент кафедри управління імені Олега Балацького,  
Сумський державний університет**Смоленніков Д.О.**кандидат економічних наук, доцент,  
Сумський державний університет**Костюченко Н.М.**кандидат економічних наук, доцент,  
Сумський державний університет

### CITY INFRASTRUCTURE MANAGEMENT BASED ON SUSTAINABLE DEVELOPMENT GOALS AND INDUSTRY 4.0 PRINCIPLES<sup>1</sup>

*This paper delves into the examination of innovative approaches to urban infrastructure management, with a particular focus on the transformative influence of Industry 4.0 and the profound implications for achieving the Sustainable Development Goals (SDGs). By scrutinizing the interaction between Industry 4.0 technologies and urban infrastructure, the paper seeks to unravel how these advancements can be harnessed to create more sustainable, efficient, and resilient cities. The comprehensive assessment combines theoretical analysis with practical insights and case studies to illuminate the potential benefits, challenges, and opportunities associated with the integration of Industry 4.0 technologies into urban infrastructure management. Through this exploration, the paper aims to provide policymakers, urban planners, and stakeholders with valuable insights and recommendations for enhancing urban sustainability and advancing progress toward the SDGs in the era of Industry 4.0.*

**Keywords:** urban infrastructure management, Industry 4.0, Sustainable Development Goals, sustainability, sustainable infrastructure.

**JEL classification:** H54, Q01, O18, O32, Q56

### УПРАВЛІННЯ ІНФРАСТРУКТУРОЮ МІСТА НА ЗАСАДАХ ЦІЛЕЙ СТАЛОГО РОЗВИТКУ ТА ПРИНЦИПІВ ІНДУСТРІЇ 4.0

*У сучасному світі, де темпи технологічного розвитку постійно зростають, управління інфраструктурою міста стає важливим завданням для досягнення Цілей сталого розвитку (ЦСР). У цій статті розглядаються підходи до управління міською інфраструктурою та їх вплив для досягнення ЦСР з особливим акцентом на трансформаційній ролі Індустрії 4.0. Поява Індустрії 4.0, що характеризується інтеграцією цифрових технологій та процесів, керованих даними, призвела до значного прогресу в управлінні та розвитку міської інфраструктури. Дана стаття включає багатогранне дослідження цих інноваційних підходів, що охоплюють такі ключові теми, як розумні енергосистеми та управління енергією, інтелектуальні транспортні системи, зелене будівництво, стале управління водними ресурсами*

<sup>1</sup> The research is supported by the budget of the Ministry of Education and Science of Ukraine, provided for the research topic: «Cognitive model of innovations; commercialization in the conditions of Industry 4.0: intellectual capital protection, marketing and communications» (0122U000780).

та відходами, а також зелені насадження та міське землеробство. Дана стаття поєднує теоретичний аналіз з практичними висновками та тематичними дослідженнями успішних прикладів впровадження сталої інфраструктури у містах по всьому світу. Серед них інноваційні підходи до озеленення в Сінгапурі, інтелектуальні транспортні системи в Бразилії, передові методи управління відходами в Сан-Франциско тощо. Головною метою є висвітлення потенційних переваг, викликів та можливостей, пов'язаних з інтеграцією принципів Індустрії 4.0 в управління міською інфраструктурою. Досліджуючи взаємодію між технологіями Індустрії 4.0 та міською інфраструктурою, автори дослідження з'ясували, як ці досягнення можуть бути використані для створення більш стійких, ефективних та сталих міст. Крім того, в статті наведена оцінка того, якою мірою ці інновації узгоджуються з ЦСР і сприяють їх досягненню. Враховуючи той факт, що ЦСР використовуються як глобальний план для вирішення нагальних соціальних, екологічних та економічних проблем, дана оцінка набуває ще більшої актуальності. Автори цього дослідження мають на меті надати політикам, містобудівникам та зацікавленим сторонам цінну інформацію та рекомендації щодо шляхів та підходів до підвищення сталості міст та отримання прогресу в досягненні ЦСР в епоху Індустрії 4.0.

**Ключові слова:** управління міською інфраструктурою, Індустрія 4.0, Цілі сталого розвитку, сталий розвиток, стала інфраструктура.

**Foreword.** In today's world, where the speed of technological development is constantly increasing, managing the city's infrastructure is becoming an important task to achieve the Sustainable Development Goals (SDGs). Industry 4.0, which includes the use of cutting-edge technologies such as artificial intelligence, the Internet of Things (IoT), and data analytics, opens new opportunities to improve the efficiency and sustainability of urban infrastructure.

The rapid development of technology, coupled with the urgent need for sustainability, has led to the emergence of Industry 4.0 and its potential to revolutionize urban infrastructure. This article explores the intersection of sustainable urban infrastructure, Industry 4.0 and the SDGs. It explores how innovative technologies such as the IoT, Artificial Intelligence and big data analytics, can be used to create smart, efficient, and environmentally friendly urban systems. This article also examines the challenges and opportunities of implementing these innovations, highlighting successful examples and providing recommendations for future progress.

**Analysis of recent research and publications.** In recent years, a considerable number of researchers from around the world [1–4] have previously studied the role of Industry 4.0 in achievement of SDGs and sustainable development highlighting the crucial role of technological innovations, outlining benefits and challenges Industry 4.0 offers for all three dimensions of sustainability. Slightly smaller number of articles have been published in relation to the influence of Industry 4.0 on urban infrastructures [5–8]. However, authors failed to find any articles that explore the intersection of sustainable urban infrastructure, Industry 4.0 and the SDGs in detail, thus leading us to the research in question.

**The aim of the article.** The aim of the article is to analyze the innovative approaches to urban infrastructure management, with a particular focus on the transformative influence of Industry 4.0 and the profound implications for achieving the SDGs.

**Coverage of the primary material.** One of the main reasons why the analysis of innovative approaches to the management of the city's infrastructure is relevant is the need for efficient use of resources. Cities face a number of challenges, such as population growth, pollution, and limited resources. Innovative approaches based on the use of modern technologies can help cities effectively manage infrastructure, reduce negative environmental impacts and ensure sustainable development.

The use of artificial intelligence in the management of urban infrastructure opens up many opportunities.

Machine learning algorithms and data analysis can help in forecasting demand for various services and optimizing vehicle routes. For example, by analyzing traffic data, city management systems can efficiently distribute traffic flows, reducing congestion and improving residents' mobility.

The IoT is another important component of Industry 4.0, which has great potential for urban infrastructure management. With the help of sensors and device-to-device communication, cities can collect large amounts of data on various aspects such as air quality, noise levels, and resource use. This data can be used to make informed decisions about infrastructure management, ensuring efficient use of energy and water, and improving the quality of life of residents [9].

In addition, innovative approaches to the management of the city's infrastructure also contribute to the achievement of the SDGs. The UN has identified 17 Sustainable Development Goals, including those related to sustainable urban development [10]. Innovative technologies and approaches can help cities achieve goals such as providing affordable and clean energy, creating sustainable infrastructure, and improving the quality of life of the population.

Therefore, the analysis of innovative approaches to the management of the city's infrastructure in the context of Industry 4.0 and the achievement of the SDGs is an extremely urgent task. The use of cutting-edge technologies such as artificial intelligence and the IoT, combined with targeted sustainability strategies, can contribute to the effective management of a city's infrastructure and improve the quality of life of residents. Analysis and implementation of innovative approaches is a necessary step for the creation of cities that will be environmentally sustainable, use resources efficiently and provide convenience and comfort to their residents.

The emergence of Industry 4.0, which is characterized by the convergence of digital technologies and industrial processes, opens up an opportunity for transformation to develop sustainable urban infrastructure and contribute to the achievement of the SDGs. Industry 4.0 technologies have the potential to revolutionize urban systems, improve resource efficiency, promote environmental sustainability, and improve the overall well-being of urban communities. Exploring the intersection of Industry 4.0, sustainable urban infrastructure and the SDGs, it is worth highlight key areas where these synergies can contribute to progress towards a sustainable future. Among them (Fig. 1):

1) Smart and Efficient Energy Management (SDG 7):

Industry 4.0 technologies such as the IoT, data analytics, and artificial intelligence enable smart and efficient energy

management in cities. Smart power grids, smart energy monitoring systems, and demand response mechanisms optimize energy distribution, reduce losses, and integrate renewable energy sources. By using Industry 4.0 solutions, cities can accelerate progress towards SDG 7 by increasing access to affordable, reliable, and sustainable energy while reducing greenhouse gas emissions [10].

2) Smart transport and mobility (SDG 11):

Sustainable urban infrastructure based on Industry 4.0 has the potential to revolutionize transportation and mobility systems. Intelligent transportation systems, connected vehicles, and data-driven analytics optimize traffic flow, reduce congestion, and improve public transportation services. Shared mobility platforms, EV charging networks, and real-time information systems contribute to sustainable vehicles, contributing to the achievement of SDG 11 goals on sustainable cities and communities [10].

3) Circular Economy and Waste Management (SDG 12):

Industry 4.0 solutions play a crucial role in promoting the circular economy and optimizing waste management practices. Smart waste monitoring systems, predictive analytics, and robotic sorting technologies enable efficient waste collection, recycling, and resource recovery. By implementing the achievements of Industry 4.0, cities can minimize waste generation, reduce the use of landfills, and create economic opportunities through the reuse and recycling of materials, aligning them with SDG 12 on responsible consumption and production [10].

4) Data-driven urban planning and management (SDG 9 and SDG 16):

Industry 4.0 technologies provide vast amounts of data that can inform evidence-based urban planning and management processes. Data analytics, simulation models, and digital twin technologies enable cities to optimize resource allocation, improve infrastructure design, and improve decision-making. Using data-driven information, cities can achieve SDG 9 targets for sustainable infrastructure and SDG 16 targets on inclusive and accountable institutions, ensuring effective and sustainable urban development [10].

5) Inclusive digital connectivity and digital skills (SDG 5 and SDG 8):

As Industry 4.0 evolves, it is critical to bridge the digital divide and promote inclusive digital connectivity and digital skills. Sustainable urban infrastructure must prioritize equitable access to high-speed internet, digital services, and digital literacy programs. By bridging the digital divide, cities can empower individuals and communities, strengthen social inclusion (SDG 5), and drive economic growth and innovation (SDG 8) through digital entrepreneurship and participation in the digital economy [10].

Industry 4.0 and sustainable urban infrastructure are intertwined in the pursuit of sustainable development and the achievement of the SDGs. By harnessing the power of digital technologies, cities can optimize energy management, transform transport systems, promote a circular economy, enable data-driven urban planning, and promote inclusive digital connectivity. Collaboration between governments, industry stakeholders, communities, and academia is critical to harnessing the potential of

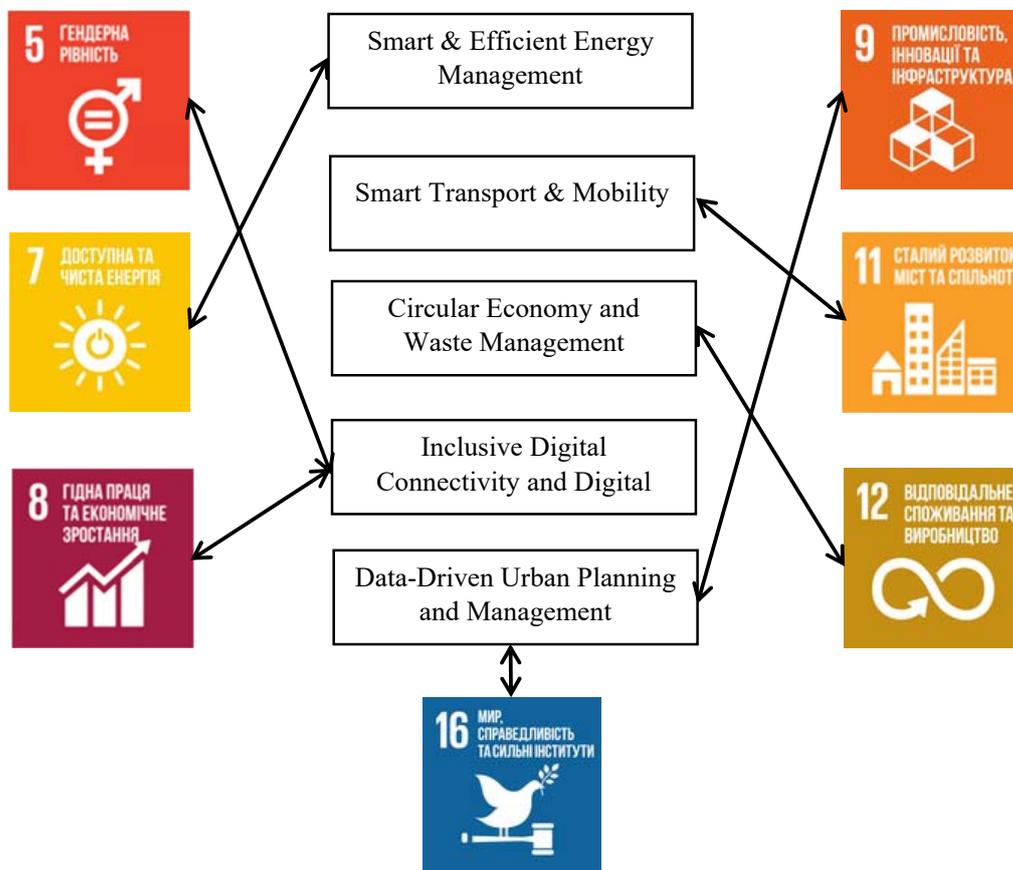


Figure 1. Correlation of key areas of Industry 4.0, sustainable urban infrastructure and SDGs

Industry 4.0 and sustainable urban infrastructure for a sustainable future. By combining these concepts, we can build sustainable, livable, and inclusive cities that will make a significant contribution to the realization of the SDGs and create a better world for all.

Urbanization has become a defining global trend of the 21st century. Today, more than half of the world's population lives in cities, and the UN predicts that this number will reach 68% by 2050 [11]. The rapid growth of cities presents a range of challenges, including increased demand for resources, stress on infrastructure and environmental degradation. Addressing these challenges requires a paradigm shift towards sustainable urban development, with a particular focus on building sustainable and ecological infrastructure.

Sustainable infrastructure of the city is an important component for ensuring sustainable urban development and improving the quality of life of residents. This infrastructure includes physical structures and systems, such as roads, bridges, buildings, water supply, energy, transportation, communications, and other major networks that keep a city functioning.

One of the main aspects of a city's sustainable infrastructure is the efficient use of resources. Ensuring sustainable water supply and sewage systems, energy efficiency of buildings, use of renewable energy sources and rational use of land resources are important aspects for ensuring sustainable development of the city.

A sustainable infrastructure of the city should ensure mobility and accessibility for residents. The development of an efficient transportation system, including urban transport, cycle paths, and pedestrian zones, helps to reduce congestion, air pollution, and improve the quality of life of citizens.

Safety is also an important aspect of a city's sustainable infrastructure. Ensuring the reliability and resilience of buildings, roads, and other engineering structures, as well as proper planning and risk management, are essential to ensure the safety of citizens.

In addition, the city's infrastructure should promote social development and inclusiveness. This includes access to education, healthcare, cultural and sports facilities for all residents of the city, regardless of their social status or place of residence.

Finally, green infrastructure is an important element of a city's sustainable infrastructure. The creation of parks, squares, gardens, the use of green spaces and ecosystem services helps to ensure ecological balance, improve air quality and contributes to the physical and psychological well-being of citizens.

Sustainable urban infrastructure refers to the planning, design, construction, and operation of urban systems that minimize environmental impact, optimize resource use, and improve the quality of life for urban residents. It is based on the principles of sustainability, which include environmental responsibility, social justice, and economic vitality. Sustainable urban infrastructure takes into account the interconnections between different sectors and seeks to create a harmonious balance between human needs and the natural environment.

Industry 4.0 and sustainable urban infrastructure are two concepts that are interconnected and of great relevance in today's world. Industry 4.0 describes a new era of industrial development based on digital technology

and automation, and the city's sustainable infrastructure reflects the need to develop and modernize infrastructure to achieve sustainable development goals.

Industry 4.0 includes concepts such as the IoT, artificial intelligence, machine learning, and process automation. These technologies enable businesses to streamline production processes, increase efficiency, reduce costs, and improve product quality [12]. In the context of the city, these technologies can be applied to the development of "smart cities", where different systems (transport, energy, water supply, waste management) are interconnected and ensure optimal functioning.

The connection between Industry 4.0 and the sustainable infrastructure of the city is that the development of digital technologies and automation can be used to modernize and improve the infrastructure of cities. For example, IoT applications can help track and manage energy consumption in buildings, leading to reduced costs and improved energy efficiency. The implementation of artificial intelligence in the management of the transport system can ensure that traffic flow is optimized and congestion is reduced.

The city's sustainable infrastructure also plays an important role in achieving the SDGs. It helps to ensure the availability, efficiency and safety of the use of various resources. The city's sustainable infrastructure includes the development of energy-efficient buildings, the introduction of renewable energy sources, the improvement of water and wastewater systems, the development of efficient transport networks, and more.

As the world's population continues to grow and urbanize, the need for sustainable urban infrastructure is becoming more acute. Cities are responsible for a significant share of greenhouse gas emissions, energy consumption, and resource depletion. However, innovative solutions and technological advancements are changing the urban landscape, paving the way for sustainable and sustainable cities. Under the influence of Industry 4.0, a number of significant innovations have emerged in the world that have significantly changed the approach to the management of urban infrastructure. Among the innovations in the field of urban management that have arisen under the influence of Industry 4.0 are the following:

1) Smart Grids and Energy Management:

One of the cornerstones of sustainable urban infrastructure is the development of smart grids. These smart energy grids combine renewable energy sources, such as solar and wind, with traditional power generation and distribution systems. Smart grids use advanced sensors, real-time data analytics, and smart meters to optimize energy distribution, reduce losses, and provide effective mechanisms for responding to demand. By balancing energy supply and demand and integrating decentralized energy sources, smart grids are helping cities transition to a cleaner and more sustainable energy future.

Masdar City in Abu Dhabi is a model of sustainable urban development, including the integration of renewable energy, energy-efficient buildings, and a sustainable transportation system [13].

The City of Vancouver, Canada, has set ambitious goals to make Vancouver the greenest city in the world by 2020, with a focus on renewable energy and energy-efficient buildings. Friendly speaking, according to the last "Top 10 greenest cities in the world" ranking, Vancouver is the 7th cleanest city in the world and number one in Canada [14].

In the city of Freiburg (Germany), known for its commitment to sustainable energy practices, solar energy systems, energy-efficient buildings and a decentralized energy supply network are actively used [15].

#### 2) Green Buildings and Eco-Friendly Materials:

Green buildings have revolutionized the construction industry by incorporating eco-design principles. These structures use energy-efficient technologies such as passive cooling and heating, optimized insulation, and smart lighting systems to minimize energy consumption and reduce environmental impact. In addition, eco-friendly materials, including recycled steel, sustainable wood, and low-carbon concrete, are used to build eco-friendly buildings. Green roofs and living walls are also becoming popular, contributing to improved air quality, energy efficiency, and urban biodiversity.

#### 3) Intelligent Transport Systems:

Transportation is a major source of pollution and congestion in cities. Innovations in clean transportation systems are helping cities meet these challenges. Intelligent transportation systems use advanced technologies such as real-time traffic monitoring, smart traffic signals, and adaptive traffic management to optimize traffic flow and reduce congestion. In addition, the popularization of electric vehicles, combined with the development of charging infrastructure, is accelerating the transition to environmentally friendly vehicles. Bike-sharing programs, pedestrian-friendly infrastructure, and improved public transportation further contribute to sustainable mobility and emissions reduction.

Transportation plays a key role in our daily lives, connecting people and goods. As cities face increasing challenges related to congestion, pollution, and limited resources, transportation innovation is critical to achieving sustainable mobility.

Curitiba, Brazil: Curitiba is known for its innovative transportation system, specifically the Bus Rapid Transit (BRT) system. BRT's integrated urban network favors high-capacity buses, dedicated bus lanes, and efficient boarding systems. This initiative has significantly reduced traffic congestion, improved air quality, and expanded accessibility for residents, serving as a model for sustainable urban transportation [16].

#### 4) Waste disposal and recycling:

Effective waste management is crucial for sustainable urban development. Innovative solutions are being implemented to reduce waste generation, increase recycling rates and minimize environmental impact. Integrated waste management systems use intelligent sensors and data analytics to optimize waste collection routes, reduce fuel consumption, and improve operational efficiency. Advanced recycling technologies, such as mechanical-biological treatment and anaerobic digestion, make it possible to convert waste into valuable resources, including energy and compost. In addition, public awareness campaigns and educational initiatives encourage citizens to adopt environmentally friendly waste management practices, leading to a more circular economy.

San Francisco, California, has had tremendous success in waste disposal thanks to its zero-waste initiatives, including mandatory recycling and composting programs [17].

#### 5) Green Spaces and Urban Agriculture:

Green spaces and urban farming initiatives play a vital role in creating sustainable and livable cities. Parks,

gardens and urban forests improve the quality of life of residents, mitigate the effect of an urban heat island and provide opportunities for recreation. Vertical farming, rooftop gardens, and community gardens promote local food production, reduce food miles, and increase urban biodiversity. These innovative approaches to urban agriculture promote food security, improve air quality, and foster a sense of community.

Singapore's commitment to urban greening is underpinned by initiatives such as Gardens by Bay and the Park Connector Network, which bring together parks, gardens, and nature reserves [18].

Barcelona, Spain, has transformed underutilized urban spaces into green spaces, including the innovative concept of Superblocks [19].

Curitiba, Brazil is known for its extensive green spaces, including parks, botanical gardens, and green corridors [16].

Despite numerous examples of the application of Industry 4.0 in improving urban management and transforming them into sustainable urban infrastructures, this process has still not become widespread enough, largely due to the presence of certain challenges and obstacles that hinder the construction of sustainable urban infrastructures, including:

##### a. Financing Sustainable Urban Infrastructure:

One of the important challenges in implementing sustainable urban infrastructure is to ensure adequate funding. The upfront costs of sustainable infrastructure projects can be significant, creating an obstacle to their implementation. To overcome this problem, various funding mechanisms can be used. These include public-private partnerships, green bonds, effective investment, and attracting international sources of financing. Governments can also explore innovative financing models, such as value mechanisms and infrastructure banks, to attract private investment and create revenue streams for sustainable projects.

##### b. Political and Institutional Barriers:

Political and institutional barriers often hinder the creation of sustainable urban infrastructure. Resistance to change, bureaucratic hurdles, and conflicting priorities can hinder progress. To overcome these obstacles, it is crucial to develop political will and involve stakeholders in decision-making processes. Developing awareness and advocating for the long-term benefits of sustainable infrastructure can help overcome resistance. In addition, streamlining administrative processes, establishing clear governance frameworks, and aligning policies and regulations with sustainable development goals can create a conducive environment for the sustainable development of urban infrastructure.

##### c. Technological Advancement and Innovation:

Keeping up with rapid technological advances is another challenge in the development of sustainable urban infrastructure. The application of new technologies, such as renewable energy systems, smart grids, and intelligent transportation systems, requires continuous learning and adaptation. Encouraging research and development, fostering innovation ecosystems, and establishing partnerships with technology providers can help cities stay at the forefront of technological advancements. Collaboration between academic, industry, and government institutions can spur innovation and ensure that sustainable infrastructure projects incorporate the latest technological solutions.

## d. Collaborative Management and Knowledge Sharing:

Effective management and knowledge sharing are essential for the successful implementation of sustainable urban infrastructure. Collaboration between various stakeholders, including government agencies, private sector organizations, community groups, and academia, is essential. Creating multi-stakeholder platforms and partnerships can facilitate information sharing, coordination, and shared decision-making. Knowledge-sharing platforms, such as conferences, workshops, and online forums, can facilitate learning and the sharing of best practices. Encouraging transparency, accountability, and participatory processes can empower communities and ensure that different perspectives are considered when planning and implementing sustainable infrastructure projects.

So, while developing sustainable urban infrastructure is critical to addressing environmental challenges and achieving the SDGs, it is not without its challenges. Overcoming financial barriers, overcoming political and institutional barriers, implementing technological advances, and promoting participatory governance are key steps towards sustainable urban development.

**Conclusions and prospects for further research.**

Innovations in sustainable urban infrastructure are revolutionizing the way cities are designed, built, and operated. From smart grids and green buildings to smart transportation systems and waste management solutions, these innovations are driving transformation towards sustainable and advanced cities.

Industry 4.0 and sustainable urban infrastructure are intertwined in the pursuit of sustainable development and the achievement of the SDGs. By harnessing the power of digital technologies, cities can optimize energy management, transform transport systems, promote a circular economy, enable data-driven urban planning, and promote inclusive digital connectivity. Collaboration between governments, industry stakeholders, communities, and academia is critical to harnessing the potential of Industry 4.0 and sustainable urban infrastructure for a sustainable future. By combining these concepts, we can build sustainable, livable, and inclusive cities that will make a significant contribution to the realization of the SDGs and create a better world for all.

**References:**

- Berawi M. A. (2019) The role of industry 4.0 in achieving Sustainable Development Goals. *International Journal of Technology*, 10(4), pp. 644–647. DOI: <https://doi.org/10.14716/ijtech.v10i4.3341>
- Gajdzik B. 1, Grabowska S., Saniuk S. and Wiczorek T. (2020) Sustainable Development and Industry 4.0: A Bibliometric Analysis Identifying Key Scientific Problems of the Sustainable Industry 4.0. *Energies*, 13(16), p. 4254. DOI: <https://doi.org/10.3390/en13164254>
- Khan I. S., Ahmad M. O., Majava J. (2021) Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives. *Journal of Cleaner Production*, Vol. 297. DOI: <https://doi.org/10.1016/j.jclepro.2021.126655>
- Beier, G., Niehoff, S. & Hoffmann, M. (2021) Industry 4.0: a step towards achieving the SDGs? A critical literature review. *Discover Sustainability*, 2, 22. DOI: <https://doi.org/10.1007/s43621-021-00030-1>
- Ostbo N. P., Voitko S., Skorobogatova N. (2022) Implementation of industry 4.0 technologies for building smart cities: global experience. URL: <http://confmanagement.kpi.ua/proc/article/view/272092> (accessed 1 October 2023).
- Muller B., Herzog O. (2015) Advanced Manufacturing, Industry 4.0 and Urban Development – Discussion Paper. GIZ: Eschborn. URL: [https://www.researchgate.net/publication/284730451\\_Advanced\\_Manufacturing\\_Industry\\_40\\_and\\_Urban\\_Development\\_-\\_Discussion\\_Paper](https://www.researchgate.net/publication/284730451_Advanced_Manufacturing_Industry_40_and_Urban_Development_-_Discussion_Paper) (accessed 1 October 2023).
- Lom M., Pribyl O., Svitek M. (2016) Industry 4.0 as a Part of Smart Cities. SCSP2016 – Smart City Symposium Prague 2016. DOI: <http://dx.doi.org/10.1109/SCSP.2016.7501015>
- Becic A. (2020) Industry 4.0 and Smart cities: State of the art. *Defense and Security Studies*, Vol. 1, pp. 34–43. DOI: <https://doi.org/10.37868/dss.v1.id148>
- Bibri, S.E. (2018) The IoT for Smart Sustainable Cities of the Future: An Analytical Framework for Sensor-Based Big Data Applications for Environmental Sustainability. *Sustainable Cities and Society*, 38, 230–253.
- United Nations. (2018) Sustainable Development Goals. Retrieved from URL: <https://sdgs.un.org/goals> (accessed 1 October 2023).
- United Nations. (2015) Transforming our world: The 2030 Agenda for Sustainable Development. URL: <https://sdgs.un.org/2030agenda> (accessed 1 October 2023).
- Schwab, K. (2016) The Fourth Industrial Revolution. *World Economic Forum*. URL: <https://www.weforum.org/pages/the-fourth-industrial-revolution-by-klaus-schwab> (accessed 1 October 2023).
- Hollands, R.G. (2008) Will the Real Smart City Please Stand Up? Intelligent, Progressive or Entrepreneurial? *City*, 12(3), 303–320. DOI: <https://doi.org/10.1080/13604810802479126>
- World Excellence (2023) Top 10 greenest cities in the world URL: <https://www.worldexcellence.com/top-10-greenest-cities-world/> (accessed 3 October 2023).
- Fastenrath, S., & Braun, B. (2018) Sustainability transition pathways in the building sector: Energy-efficient building in Freiburg (Germany). *Applied Geography*, 90, 339–349.
- The City Fix (2022) Curitiba Is Evolving But Remains a Model for Urban Sustainability URL: <https://thecityfix.com/blog/curitiba-is-evolving-but-remains-a-model-for-urban-sustainability/> (accessed 3 October 2023).
- McClellan, J. (2017) How San Francisco's mandatory composting laws turn food waste into profit. *Azcentral*. URL: [https://moftarchive.net/wp-content/uploads/2022/04/20170810-How-San-Francisco\\_s-Mandatory-Composting-Laws-Turn-Food-Waste-into-Profit.pdf](https://moftarchive.net/wp-content/uploads/2022/04/20170810-How-San-Francisco_s-Mandatory-Composting-Laws-Turn-Food-Waste-into-Profit.pdf) (accessed 3 October 2023).
- Henderson, J. C. (2013) Urban parks and green spaces in Singapore. *Managing Leisure*, 18(3), 213–225.
- Caragliu, A., Del Bo, C., & Nijkamp, P. (2011) Smart Cities in Europe. *Journal of Urban Technology*, 18(2), 65–82. DOI: <https://doi.org/10.1080/10630732.2011.601117>