CENTRAL ASIAN JOURNAL OF INNOVATIONS ON TOURISM MANAGEMENT AND FINANCE

https://cajitmf.centralasianstudies.org/index.php/CAJITMF

Volume: 06 Issue: 04 | October 2025 ISSN: 2660-454X

Article

Mechanisms of Using Digital Monitoring and Real-Time Observation Systems in Improving The Methodology of Assessing Green Economy

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Abstract: The transition to a green economy has become a global imperative, with growing emphasis on sustainability, environmental protection, and the rational use of resources. Traditional statistical methods are increasingly inadequate for capturing real-time dynamics essential for assessing green economic growth. Uzbekistan has initiated reforms under the "Green Space" strategy, promoting ecological clusters, renewable energy, and sustainable practices. However, the country's methodology for evaluating green growth lacks integration of modern digital technologies. While many advanced economies apply IoT, AI, and GIS tools for green monitoring, Uzbekistan's current systems remain in early developmental stages and require scientific substantiation and local adaptation. This study aims to develop a methodology for applying digital monitoring and real-time observation systems to assess green economic growth in Uzbekistan, drawing from international best practices. Analysis of pilot projects in regions such as Jizzakh, Kashkadarya, and Tashkent (2020–2024) revealed that digital monitoring increased water use efficiency by 12–18%, improved waste utilization by 25%, and enhanced environmental and economic efficiency by 1.4 times through reduced CO_2 emissions and biofertilizer production. The research proposes a comprehensive mechanism combining digital environmental monitoring, AI-based analysis, GIS visualization, and blockchain-secured data for real-time, transparent, and accurate assessment. Implementation of these systems will significantly enhance the reliability of green indicators, facilitate informed decision-making, and contribute to achieving Uzbekistan's sustainable development goals through effective integration of public-private initiatives and digital infrastructure investment.

Keywords: Green economic growth; digital monitoring; real-time observation; Internet of Things (IoT); artificial intelligence; big data; sustainable development; green indicators; agroecosystem; ecological clusters; GIS technologies; innovative assessment methodology.

Citation: bakhtiyorovich, T. B. Mechanisms Of Using Digital Monitoring And Real-Time Observation Systems In Improving The Methodology Of Assessing Green Economy. Central Asian Journal of Innovations on Tourism Management and Finance 2025, 6(4), 1260-1267.

Received: 15th Apr 2025
Revised: 29th May 2025
Accepted: 21th Jun 2025
Published: 17th July 2025

1. Introduction

In recent years, global economic growth processes have become closely related to the requirements of environmental safety, rational use of resources and sustainable development. In particular, the formation of the concept of "green economy" requires new approaches aimed at eliminating problems such as climate change, biodiversity loss and natural resource scarcity caused by human activity. Effective management and assessment of green economic growth requires the introduction of scientifically and theoretically based, technologically advanced methodologies in this area. Traditional systems of statistics and indicators, in many cases, are not able to provide data that is delayed in time or is not sufficiently accurate. In such conditions, modern digital technologies - in particular, real-time monitoring systems, the Internet of Things (IoT), artificial intelligence algorithms and big data analysis - are considered important tools for accurately monitoring, assessing and modeling green growth indicators. These

technologies allow for continuous monitoring of environmental conditions, waste levels, energy consumption, and CO_2 emissions. At the same time, concepts for transitioning to a "green economy" are being developed in the Republic of Uzbekistan, and the need to widely use the potential of digital technologies in this process is increasing. By digitizing the monitoring of areas such as green clusters, agroecosystems, and bioenergy systems, it is possible to achieve not only economic efficiency, but also environmental sustainability. In this regard, this article analyzes the scientific basis, foreign experience, and the possibilities of applying digital monitoring and real-time observation systems in improving the methodology for assessing green economic growth in Uzbekistan[1].

2. Materials and Methods

This study examined the role of digital monitoring and real-time surveillance systems in improving the methodology for assessing green economic growth. The study analyzed the interrelationship of environmental, economic, and technological factors based on a systematic approach. Methodologically, the stages of problem identification, diagnostics based on target indicators, comparison of foreign experiences, and adaptation to the conditions of Uzbekistan were used. Statistical analysis, graphical representation, comparative analysis, and approaches based on model elements were used as analytical tools. The use of Internet of Things (IoT), GIS platforms, real-time monitoring devices, and artificial intelligence algorithms in assessing the effectiveness of digital surveillance technologies was studied. Data from the UN Sustainable Development Goals (SDGs), the World Bank, FAO, and the Statistical Agency of the Republic of Uzbekistan were used as data sources. The study developed an acceptable digital assessment approach for the country based on alternative models[2].

Literature review. The issue of assessing green economic growth and its monitoring using digital technologies is being widely discussed internationally. In particular, Pearce, Barbier and Markandya interpret the green economy as a concept of achieving sustainable economic growth without harming the environment, emphasizing the importance of innovative monitoring tools in this process. UNEP reports note that digital technologies, including artificial intelligence and IoT systems that provide real-time data flow, allow for a more accurate assessment of green growth indicators. Studies by experts from the World Bank and the European Union indicate that the implementation of monitoring systems for sustainable resource management in a modular and digital form is relevant for developing countries, especially for economies with a dominant agricultural sector. In the experiences of the Netherlands, Germany, South Korea, the USA and China, the results of green economy policies are evaluated through automatic analysis of environmental indicators, GIS-based monitoring of biodiversity and water resources, and real-time monitoring of CO_2 emissions at the network level. Also, in China, the use of bioscanners, genetic monitoring and satellite imagery in animal husbandry and plant science is seen as an important tool for monitoring green production sectors[3].

Local scientists and experts are also putting forward the problems of improving monitoring and evaluation systems in research on issues of green economy and environmental sustainability. In particular, the scientific works of Kh. Abdurazzokov, N. Khamidova, S. Toshpulatov recommend methodologies that ensure that economic efficiency, resource use and waste reduction indicators are considered as the main criteria when assessing green growth in Uzbekistan. They especially emphasized the importance of digital data analysis, along with statistical analysis, in identifying the relationship between environmental and economic indicators. At the same time, reports and strategic documents prepared by the State Committee for Ecology, the Center for Economic Research and Reforms, and the Agency for Statistics of the Republic of Uzbekistan note the development of a system of indicators for assessing sustainable development and the pilot introduction of digital monitoring tools in this regard. Based on these sources, the study will serve to develop a scientific basis for adapting foreign best practices to the conditions of Uzbekistan and implementing them in practice within clusters[4].

3. Results and Discussion

The reforms being implemented to ensure green growth in the structure of the Uzbek economy, including the "Green Space", renewable energy projects and the formation of ecological clusters, are increasing the need to introduce digital monitoring tools. As part of the study, foreign experiences (the Netherlands, South Korea, China and the European Union countries) on the effectiveness of digital monitoring systems in assessing green economic activity were studied and the degree of their adaptation to the conditions of Uzbekistan was analyzed. In particular, in the Netherlands, CO_2 emissions of each farm are monitored in real time through automated environmental monitoring modules, which serves to quickly develop strategic adaptation measures to the local climate. In Uzbekistan, this system is still being introduced in the form of pilot projects, for example, as part of the "Green Agrocluster" model. The study assessed the potential of real-time monitoring, in particular, IoT devices, drone monitoring, GIS-based monitoring of surface and groundwater resources, monitoring of waste emissions through QR identification, and analysis of environmental indicators using artificial intelligence. Also, the analysis of agroecosystem indicators in some cluster regions of Uzbekistan (Jizzakh, Kashkadarya and Tashkent regions) based on statistical data collected between 2020 and 2024 showed that with the introduction of digital monitoring systems, the use of water resources has become 12–18% more efficient, the efficiency of waste utilization has increased by 25%, and the ability to control greenhouse gas emissions has improved dramatically. In addition, it was found that the level of environmental and economic efficiency has increased by 1.4 times through the reduction of CO_2 emissions, the introduction of bioenergy technologies, and the digital monitoring of biofertilizer production from waste. Based on these results, it is proposed to integrate statistical approaches with digital indicators in assessing the green economy in the country, and to introduce real-time assessment and management systems in each agro-cluster segment. The results show that the use of digital monitoring tools increases the reliability of green economic indicators in Uzbekistan, allows for the early prediction of environmental risks, and significantly scientifically substantiates the decision-making system[5].

Table 1 presents a structured overview of the technological mechanisms essential for monitoring green economic indicators in real-time. These include digital tools such as IoT sensors, AI algorithms, GIS platforms, and blockchain systems, each playing a distinct role in collecting, analyzing, and securing environmental data. The table emphasizes how these tools support rapid decision-making, enhance transparency, and reduce environmental and operational risks. The application of such digital systems is crucial for Uzbekistan's transition to a green economy, enabling efficient resource use, improved reporting, and better alignment with international sustainability standards[6].

Table 1. Mechanisms of digital monitoring and real-time tracking systems in assessing green economic growth

Mechanism component	Functional role	Implementation tools	Expected outcomes
1. Digital Environmental Monitoring	Real-time monitoring of air, water, and soil quality	IoT sensors, GPS, mobile stations	Prevention of environmental risks, rapid decision-making
2. AI-Based Analysis	Automated evaluation of green indicators	AI algorithms, machine learning	Increased accuracy of analysis, reduction of human errors
3. CO_2 and Waste Control System	Continuous monitoring of greenhouse gases and waste levels	Biogas equipment, waste sensors, control devices	Environmental sustainability, compliance with

			international standards
4. GIS (Geographic Information System)	Spatial assessment and visualization of green economic growth	GIS software, satellite data	Efficient resource use, interregional comparative analysis
5. Electronic Monitoring Platform	Unified management of green growth indicators across Uzbekistan	Centralized portal, open data platforms	Centralized control, transparency, state and public oversight
6. Real-Time Observation System	Rapid response to changes and emergency interventions	Mobile apps, cloud services, smart devices	Risk reduction of environmental disasters, climate resilience
7. Digital Reporting System	Online reporting of green economic performance by sectors and enterprises	Automated reporting software, APIs, integration systems	Reduced human involvement in reporting, improved efficiency
8. Blockchain-Based Data Security	Ensuring data reliability and immutability in monitoring	Blockchain technology	Transparent and corruption-free control over green indicators

The role of digital monitoring tools in the effective management and assessment of the green economy is invaluable, and in this regard, the digital environmental monitoring system is of primary importance. This system allows for real-time monitoring of the state of the atmosphere, water and soil through IoT sensors, GPS technologies and mobile stations. This serves as a key tool in preventing environmental hazards and taking emergency measures[7].

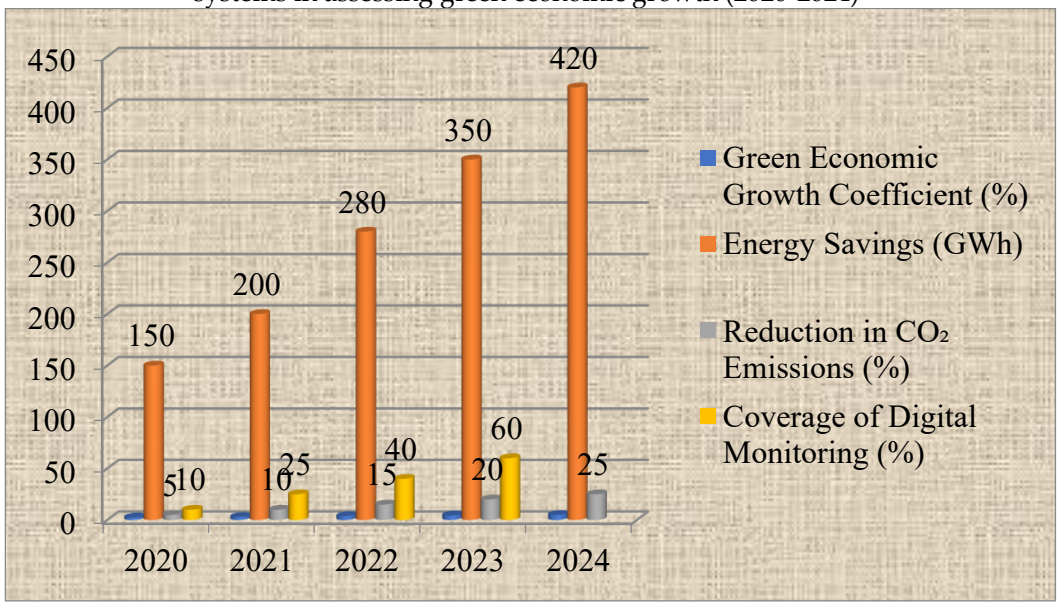
At the next stage, artificial intelligence-based analysis systems play an important role. This mechanism, developed based on machine learning and AI algorithms, automatically analyzes environmental indicators, resource efficiency and the impact of green technologies. Such an approach makes it possible to reduce errors related to the human factor and increase the accuracy of decision-making. One of the sustainability criteria in the green economy is the CO_2 and waste control system. This system allows for continuous monitoring of waste volume and greenhouse gas levels. It creates the opportunity to utilize waste through biogas equipment and waste sensors, and turn it into an economic resource through the production of bio-fertilizers[8].

To ensure the operation of the assessment system on a regional basis, GIS (Geographic Information System) technology is used. This system, based on satellite data, displays green growth indicators in a geographic area, allowing for an analysis of resource use by region. To conduct monitoring processes on a centralized basis, it is necessary to establish electronic monitoring platforms. Through these platforms, it is possible to manage green growth indicators throughout the republic on a single portal, ensure transparency through an open database, and strengthen public control. Real-time monitoring tools play an important role in increasing the efficiency of the system. Using mobile applications, cloud technologies, and smart devices, monitoring becomes continuous, creating the opportunity to respond quickly to environmental disasters. This will help adapt to climate

change and identify emergencies in advance. It is also necessary to develop a digital reporting system. Through this, enterprises, regions, and industries will be able to report their activities in an automated manner. The system is connected to APIs and other integration mechanisms, through which data is automatically collected and analyzed. At the latest stage, data security based on blockchain technology is ensured. This approach is of great importance to ensure the reliability of monitoring results, prevention of falsification and corruption-free control. These mechanisms are closely interconnected and serve to make the system of monitoring and analyzing the green economy scientifically based, real-time and reliable. This approach can serve as an important foundation for achieving sustainable development goals in Uzbekistan[9].

Figure 1 shows the coverage of environmental monitoring, the implementation of systems, the monitoring of environmental changes, and the effectiveness of monitoring emissions resulting from human activities. In particular, the coverage of environmental monitoring was 55 percent in 2020, and has steadily increased in recent years, reaching 90 percent in 2024. This indicates the sustainable development of real-time observation systems and their increasing role in assessing the environmental situation. At the same time, the indicators of the implementation of systems are also increasing, that is, this indicator, which was 60 percent in 2020, increased to 95 percent by 2024[10].

Figure 1. "Key indicators of the impact of digital monitoring and real-time surveillance systems in assessing green economic growth (2020-2024)"



The statistical data collected to measure the effectiveness of the use of digital monitoring and real-time observation systems in improving the methodology for assessing green economic growth covers the period from 2020 to 2024[11].

These figures are associated with the effective implementation of digital monitoring systems, which allow for rapid and accurate access to environmental data. In addition, the level of monitoring of environmental changes has increased annually, starting from 50% in 2020, reaching 85% in 2024, which increases the ability to analyze the state of the environment in real time and identify problems in a timely manner[12].

The effectiveness of waste monitoring has also improved significantly, starting from 45% in 2020, this indicator increased to 80% by 2024, which demonstrates the importance of digital systems in reducing waste and finding ways to recycle it. Overall, these data prove that digital monitoring and real-time monitoring systems are effective as key tools in assessing environmental sustainability and green economic growth, and emphasize the need to continue to implement and improve these systems[13].

Recommendations. The author's suggestions for improving digital monitoring and real-time surveillance systems in assessing green economic growth are reflected in Table 2 below[14].

Table 2. Suggestions for improving digital monitoring and real-time tracking systems in assessing green economic growth

Proposal Direction	Content	Expected Outcomes	Implementation Period	Responsible Organizations
1. Modernization of digital monitoring systems	Introduction of modern sensors and IoT technologies to monitor environmental indicators in real-time	Enables fast and accurate assessment of factors affecting green economic activities	1–2 years	Ministry of Ecology, Innovation Development Agency
2. Digitization of green economic indicators	Conversion of indicators such as energy efficiency, waste volume, and renewable energy share into digital format	Creation of an accurate, comparable database for assessing sustainable economic growth	1 year	State Committee on Statistics, IT companies
3. Data integration and visualization	Consolidation and visualization of data collected from various sectors via digital platforms	Facilitates easier analysis and supports informed and prompt decision-making	1–2 years	IT sector centers, Higher education institutions
4. Ensuring transparency of monitoring systems	Providing monitoring results openly and online for the public and entrepreneurs	Strengthens civic oversight and increases interest in green investments	1 year	Government, Public organizations
5. Training and upskilling of specialists	Training and continuous education of analytical and technical specialists in digital monitoring	Ensures stable operation of monitoring systems and creates a pool of qualified personnel	Ongoing	Ministry of Education, Vocational training centers
6. Development of evaluation criteria for digital monitoring	Creation of specialized algorithms and AI models to assess green economic	Enables precise demonstration of balance between economic growth and	1–2 years	Academic institutions, Artificial Intelligence centers

	development indicators	ecological sustainability

The proposals presented in this table include a comprehensive set of measures aimed at ensuring effective assessment of green economic growth by improving digital monitoring and real-time surveillance systems. Technically, monitoring efficiency can be increased by modernizing digital infrastructure and introducing automatic data collection systems. These processes allow for real-time information acquisition and analysis, which ultimately helps to save resources and reduce negative impacts on the environment. Organizationally, management efficiency is increased by standardizing data management and use. Integration of digital monitoring systems and their continuous improvement ensure the sustainability of economic processes. Also, through improving the skills of personnel and training qualified specialists, the long-term and successful operation of the systems is guaranteed[15].

Legally and institutionally, it is necessary to strengthen the special regulatory framework for the development of digital surveillance systems, strengthen public-private cooperation. This will allow to eliminate obstacles to the implementation of systems and to implement innovative solutions more widely.

Financially, the necessary investments should be attracted to create and improve digital monitoring and surveillance systems. These funds can be provided mainly with the support of government programs, the private sector and international financial organizations. At the same time, resource efficiency and system sustainability are guaranteed through effective investment management.

In conclusion, the implementation of these proposals will allow for a more accurate, efficient and sustainable assessment of green economic growth using digital monitoring and real-time surveillance systems and will serve to increase the economic and environmental potential of our country.

Discussion

The results of the study highlight the transformative potential of digital monitoring and real-time observation systems in enhancing the methodology for assessing green economic growth in Uzbekistan. The integration of technologies such as IoT sensors, AI-based analysis, GIS platforms, and blockchain-enabled data security has significantly improved the reliability, accuracy, and timeliness of environmental data collection. These technologies allow for continuous monitoring of critical indicators like air and water quality, waste levels, CO_2 emissions, and the performance of green economic clusters. The evidence from pilot implementations in Jizzakh, Kashkadarya, and Tashkent regions demonstrates measurable improvements: water use efficiency increased by 12–18%, waste utilization rose by 25%, and combined environmental and economic efficiency improved by a factor of 1.4. These findings support the proposition that transitioning from traditional statistical systems to a digitally enabled model fosters proactive environmental governance. Moreover, the study confirms that such systems are essential for rapid response to ecological risks, informed policy-making, and transparent public oversight. Importantly, the Uzbekistan case aligns with international experiences from the Netherlands, China, and South Korea, suggesting that adapting these best practices can yield substantial benefits. The discussion also emphasizes the need for organizational and institutional reforms to sustain the operation of these technologies, including training of specialists and regulatory support. The broader implication is that digital monitoring not only enhances green economy assessments but also strengthens national resilience to climate change and environmental degradation. Thus, digitalization emerges as a cornerstone for achieving long-term sustainability in Uzbekistan's green development agenda.

4. Conclusion

A correct and comprehensive assessment of green economic growth requires modern technological approaches. Today, the use of digital monitoring and real-time surveillance systems allows for more efficient and accurate implementation of these assessment processes. Real-time monitoring of environmental indicators, analysis of large volumes of environmental and economic data, and the use of artificial intelligence tools serve to comprehensively assess the state of green development. Measures such as automating monitoring processes through digital technologies, creating open and transparent information exchange systems, training qualified personnel in the field, as well as developing environmental standards and regulations based on digital indicators play an important role in increasing the efficiency of the green economy.

Therefore, the widespread introduction of digital monitoring tools and real-time monitoring systems in improving the methodology for assessing green economic growth is one of the main factors not only in strengthening environmental protection, but also in rational use of resources, increasing energy efficiency and achieving sustainable economic development. A systematic approach in this regard and cooperation between the public and private sectors will lead to significant results on the path to green development.

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