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Digital platforms for environmental compliance: Adapting to the transition to a green economy

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Abstract

One of the conditions for the sustainable development of countries today is the transition to a green economy. Environmental requirements are increasing and becoming more specific for fulfillment by economic entities. Numerous interconnections and non-linear stages in environmental safety management systems actualize the need to increase the degree of coordination of actions among various actors to prevent accidents and increase productivity. The purpose of the study is to justify the application of digital platforms to optimize the control of environmental compliance for an adaptive transition to a green economy. The application of SWOT analysis and economic and mathematical modeling methods, on the example of the waste management system, revealed the need to develop an integrated digital platform to improve the level of management and process optimization. The results showed that the proposed solution to create a digital platform will increase the manageability of the waste management system by more than two times. The Environmental Monitoring of Waste Management System Performance function will provide 68% more automated measurements, the Waste Volume and Composition Forecasting function will improve by 69%, and the Waste Management Environmental Compliance Verification function will provide 73% more automated control. The proposed solution will ensure compliance with waste management regulations, improve the environmental sustainability of the industry, and accelerate the transition to a green economy.

Keywords: Digital platforms, Ecology, Environmental requirements, Green economy, Stewardship.

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1. Introduction

The effective engine of economic growth is innovative technological development and the optimal utilization of natural resources. Innovations in the sphere of ecology and the green economy create opportunities for further stable development. As a result of disruptions in the international financial and economic system, they become particularly relevant.

"Digital environment" reflects the specifics of modernity: information technologies not only automate existing production and business processes but also change the traditional business model of industrial enterprises. Many countries have developed and implemented regulations that oblige the banking sector to provide investment support to companies to transform management models while utilizing the goals of the sustainable development strategy. Global Sustainable Investment Alliance experts found that the size of financial flows directed towards ESG program implementation amounted to more than $30.3 trillion, with sustainable investment assets under management growing by 20% since 2020 [1].

The basic transformation scenarios with the development of digital platforms should be implemented based on the strategy of transition to a green economy, modernizing the management impacts on production, consumer, distribution, and exchange spheres, according to ESG criteria.

In view of the above, adaptation in the transition to a green economy can be faster and more successful if digital platforms are developed and built to meet environmental requirements. In this regard, case studies in this direction are relevant and in demand in practice.

2. Literature Review

In the current academic literature, studies in the field of the green economy and digitalization are quite widespread. Often, they are independent subjects of research, while digitalization is a rather effective tool used for the transition to a green economy. The latter inherently implies the presence of certain technologies that facilitate its implementation.

The definition of "green economy" was first mentioned in 1989 in a report to the British and Northern Ireland governments, presented by a group of well-known economists [2]. The concept became widespread during the international economic crisis (2008–2009). In 2009, the United Nations Environment Program published a report on the environment [3] which describes the possibility of developing a green economy by introducing goals, elements, incentives, objectives, and domestic policies.

The transition to a green economy is justified economically and socially. Several compelling arguments are emerging [4-6] for increasing public and private sector efforts to drive economic transformation in this direction. It is suggested to level the playing field for green goods [7] provide optimal subsidies for green production [8] reform economic policies to actively encourage green innovation [9] strengthen market infrastructure and create market mechanisms for the adoption of green technologies [10] and move towards green procurement at the state level [11]. The private sector should seize opportunities for green economy transition in leading sectors [12] increase investment in its own green and PPP projects [13] and modernize obsolete technologies [14].

The green economy is sometimes presented as a practical approach to achieve sustainable development through environmentally friendly technologies [15, 16]. According to the Organization for Economic Cooperation and Development classification, the green technology system consists of OECD [17]:

- Environmental management (waste, air quality, water quality, etc.);
- Energy production from renewable resources (solar, wind, biomass, etc.);
- Mitigating the effects of climate change;
- To reduce harmful atmospheric emissions;
- Improving fuel energy efficiency;
- Maximizing the energy efficiency of buildings and lighting.

Sun et al. [18] note that the global mission of the green growth strategy is to increase the efficiency of the utilization of available resources and to develop systems for clean industrial production. In our view, this approach is too narrow. Improving the productivity of resources and the environmental performance of industries are goals set by international organizations and governments during the transition to green standards. But as we can see from the above list of directions of the green technology system, it is applicable not only in the industrial sector but also in the consumption sector.

The essence of digitalization of the green economy, according to our view, is to scale up and deploy resource-efficient, cleaner production and consumption processes, incorporate them into green cities, and in the future, apply them at the national and global levels of economic systems.

Given the widespread introduction of information and communication technologies in various spheres of life, the need to create digital platforms and their integration into large-scale environmental projects becomes evident. Achieving economic and social symbiosis in economic activities is possible with the help of digital platforms that provide sustainable planning and systematic organization of multifaceted processes. As an example, it is possible to exchange waste flows in the region, introducing advanced infrastructure, logistics, and recycling with conversion into a source of low-cost energy (representing a renewable resource).

According to Hu et al. [19] there is an inextricable link between the processes of mechanization, automation, implementation of digital platforms, and technological modernization, improved planning and management, and opportunities to further enhance the productivity of existing resources. Similarly, Khan et al. [20] indicate that the green economy has a strong link with the use of resource-saving technologies, where both economic benefits and environmental effects are realized. We would like to add that an important role is played by information technologies, thanks to which a large amount of data is collected and processed, which makes it possible to qualitatively change the economic activity of integrated organizations during the adaptation period and, in general, to obtain synergetic and multiplier effects.

Innovative projects deploy technologies that support renewable energy, robotics [21] smart communication networks [22] artificial intelligence [23] aimed at reducing the hydrocarbon load based on a regional digital closed-loop ecosystem. The use of digital transformation creates conditions for innovative modernization of business processes.

A digital platform is technologically defined as a dynamically evolving information system operating in real time [24]. In addition to a standard set of components (hardware, mathematical models, system and software, organizational structures, etc.), a platform integrates specialized modules and mechanisms that ensure its constant evolution [25]. The key aspects of this evolution are: inclusion of new objects for analysis and management, expansion of the range of functions performed, integration with other information systems, and creation of new subsystems, as well as adaptation to new technological solutions.

The digital transformation of a specific territory within a particular area requires close interaction among its diverse actors. Meeting the needs and interests of participants is achieved through the development of a digital platform based on the identification of information flows arising within it. Thus, Derave et al. [26] note that the effective functioning of an industry operating in the digital economy requires the creation of a unified digital platform that optimizes communications between stakeholders.

A digital platform is a commercial enterprise, existing online or offline, that creates value for more than one group of actors [27]. The platform is designed to serve the interests of each group of its participants, who are involved in interacting with the platform through the flows that occur within it.

In turn, platformization is a process of change where systemic modular digital technologies are introduced and applied in the management of the activities of market actors. This makes it possible to bring all stakeholders, devices, and systems involved in the stages of value creation into a common digital space [28]. The main task of platformization in the industry space is to create a unified network of information systems and to unify the bases created by different developers.

As a result of considering the defining characteristics of digital platforms, it can be concluded that the digital platform for environmental compliance should be infrastructure- and industry-specific. The main task of the industry infrastructure platform is to provide IT services and large databases, utilizing end-to-end digital technologies to assist in decision-making in the economic activities of entities.

As noted by Deng et al. [29], the use of digital platforms in the industrial environmental safety sector significantly reduces the costs arising from the interaction of actors by reducing intermediaries, decreasing the loss of secondary raw materials, and lowering transportation costs. The consequence is an increase in the quality of industry services and a decrease in prices. Additionally, the creation of such platforms enhances cooperation among stakeholders of the production cluster, improves the relevance of information about its activities, and helps identify sectoral priority areas for greening.

In general, the idea of building a digital platform is popular, but researchers [30-32] have noted the high cost of development as well as other inherent risks of platformization. Table 1 presents a SWOT analysis of the adoption of digital platforms for environmental compliance.

Table 1.
SWOT analysis of the implementation of digital platforms for environmental compliance

Strengths	**Weaknesses**
• The consequences of the adverse effects of environmental factors are reduced; • The quality of life of the population is improved; • A favorable ecological environment is preserved; • Improves data quality; • Speeds up the acquisition of information; • The quality of environmental monitoring is improving; • A continuous statistical and dynamic study of the industry is achieved; • Administrative controls are being increased; • Small and medium-sized businesses in the industry are developing; • The tax base is expanding; • The investment attractiveness of the industry/region increases; • Sustainability of regional development and national economy is achieved; • Social responsibility of the population and business is being formed; • The infrastructural quality of service of the industry's suppliers is improving; • Intermediaries are eliminated and direct channels of interaction are created; • Marketing costs are reduced; • Data quality is improved; • Market volumes are increasing; • New stakeholders are emerging;	• Underdeveloped legislation in the field of digital platforms at the national and international level; • There are no effective regulatory tools. • The complexity of combining existing information systems, databases of different developers in a single network; • Bureaucratic expansion of environmental requirements; • High level of costs; • High investment risks; • Duration of filling information bases; • Costs of commissions for paid use of the digital platform; • Low level of digital competence of industry employees.

• The time to innovate is reduced; • New jobs are created; • Anytime, anywhere access to data; • Versatility; • Prompt feedback.	
Opportunities	**Threats**
• Incentivize innovation; • Get the network effect: increasing the value of the platform while increasing the number of users; • To expand into new markets; • Expand information resources.	• The likelihood of monopolization of digital infrastructure; • New competitors; • The probability of losing control over the industry's distribution channels; • Insufficient provision of personal data protection; • Insufficient quality control of services; • Unstable operation, probability of technical failures.

Source: Compiled by the author of the article based on Zhang et al. [30], Feld [31] and Pisani [32] others.

A review of foreign experience in the creation of digital platforms for environmental compliance, reflected in various studies Acs et al. [33], Wibisono [34] and Yang et al. [35] showed that in most countries, the state approves all the basic rules for interaction on the platform and determines the platform operators who ensure the development of the system, form the technology of entry to the platform, and control the participants to meet the requirements. Some countries delegate to the operator the rights to establish the rules of the platform, but provide mechanisms for control and antitrust regulation (Netherlands, Belgium, Australia, etc.). Developed countries rely on public–private partnerships, whereby the right to own and operate platforms is shared between the public and private sectors.

Thus, a digital platform for environmental compliance is a set of infrastructure and industry-specific digital technologies that unite a large number of users and ensure their mutually beneficial cooperation in ensuring environmental safety. Currently, the digital platform is the best tool for algorithmic configuration and organization of basic processes of interaction that arise in the industry on issues of environmental compliance; the advantage of using it is a high level of manageability of the activities of industry participants. In this regard, the purpose of this study is to justify the use of digital platforms to optimize environmental compliance control for an adaptive transition to a green economy. The hypothesis of the study is the assumption that the application of a digital platform to optimize environmental compliance control will increase the manageability of system processes in an enterprise that performs functions important for building a green economy.

3. Methods

To achieve the goal, we set the tasks of determining the structure of the system of control over compliance with environmental requirements for its digital platformization and forecasting changes in the level of its controllability (on the example of a specific direction of the green economy). The object of the study is such a direction of the green economy as environmental waste management (in the industrial and municipal sphere). Extensive experience accumulated in the field of waste management allows us to formulate the basis of the digital platform, which will ensure the unification of technological equipment, standardization of monitoring and management methods, as well as increase the manageability and safety of waste management processes.

An assessment of the manageability of the waste management system in terms of environmental compliance at present and with the help of the proposed digital platform was carried out. Astana, the capital city of the Republic of Kazakhstan with a developing economy, was taken as a case study. In this city, the concept of sustainable development of the capital, “Smart Astana,” is realized. The source data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, the Ministry of Ecology and Natural Resources of the country, and the organization for waste collection, transportation, processing, and disposal, “Zhasyl Damu,” as well as the local government body, the Akimat of Astana city, were used.

To assess the manageability of the waste management system, the entire life cycle was divided into separate functions, and the R indicator was calculated for each of them. For each function, the importance coefficient σ_i was established, reflecting its contribution to the achievement of the final result, and the optimal value of the degree of manageability $\alpha_{i.opt}$, which allows minimizing risks, was determined. For this purpose, the method of expert evaluations was used.

Next, the mean value of the controllability of the functions is calculated, thus obtaining the parameter R.

$$R = \frac{\sum_{i=1}^{n} \alpha_i \sigma_i}{\sum_{i=1}^{n} \sigma_i} , \qquad (1)$$

where α_i – the result of assessing the level of controllability.

The formula for determining the conformity index of the i-th function to the degree of controllability φ_i is as follows:

$$\varphi_i = \frac{\alpha_i}{\alpha_{i,opt}} * 100\% , \quad (2)$$

When passing to the general case, the function will take the form:

$$\varphi = \frac{\sum_{i=1}^{n} \varphi_i \sigma_i}{\sum_{i=1}^{n} \sigma_i} , \quad (3)$$

In other words, the following data is required to calculate the value of the R-value:

- List of system functions;
- Certain importance measures for these functions σi (based on the results of expert evaluations);
- Controllability level data αi, as well as optimal values of αi.opt (based on technical documentation and expert opinion).

4. Results

The digital platform is expected to be deployed in cloud infrastructure, which will ensure high availability, scalability, and remote access. The platform will interact with various systems, devices, and users through standard network protocols, enabling integration into the existing IT infrastructure of the enterprise.

Ensuring environmental compliance is a priority for the digital platform, and the control system plays a key role in this.

The study enabled the development of a model for the waste management system, including the following components.

1. Input data: information on the quality and quantity of waste obtained from measuring instruments, laboratory analyses and expert judgment.

2. Controlling influences: regulatory requirements, economic indicators (cost of resources), technical characteristics of equipment.

3. Technological processes: a set of operations performed by technological equipment for waste treatment.

4. Output parameters: indicators of system safety in terms of environment and resource intensity.

The analysis of the waste management system has shown that it is a complex hierarchical structure subject to the influence of many factors. For successful management of such a system, it is necessary to use computer technologies that allow modeling various scenarios, optimizing processes, and responding promptly to changes in external conditions.

This is especially important in cases of emergency risks, when it is necessary to make quick decisions and coordinate the work of various technological units. The proposed structure of the environmental compliance control system for waste management, proposed for the digital platform, is presented in Figure 1.

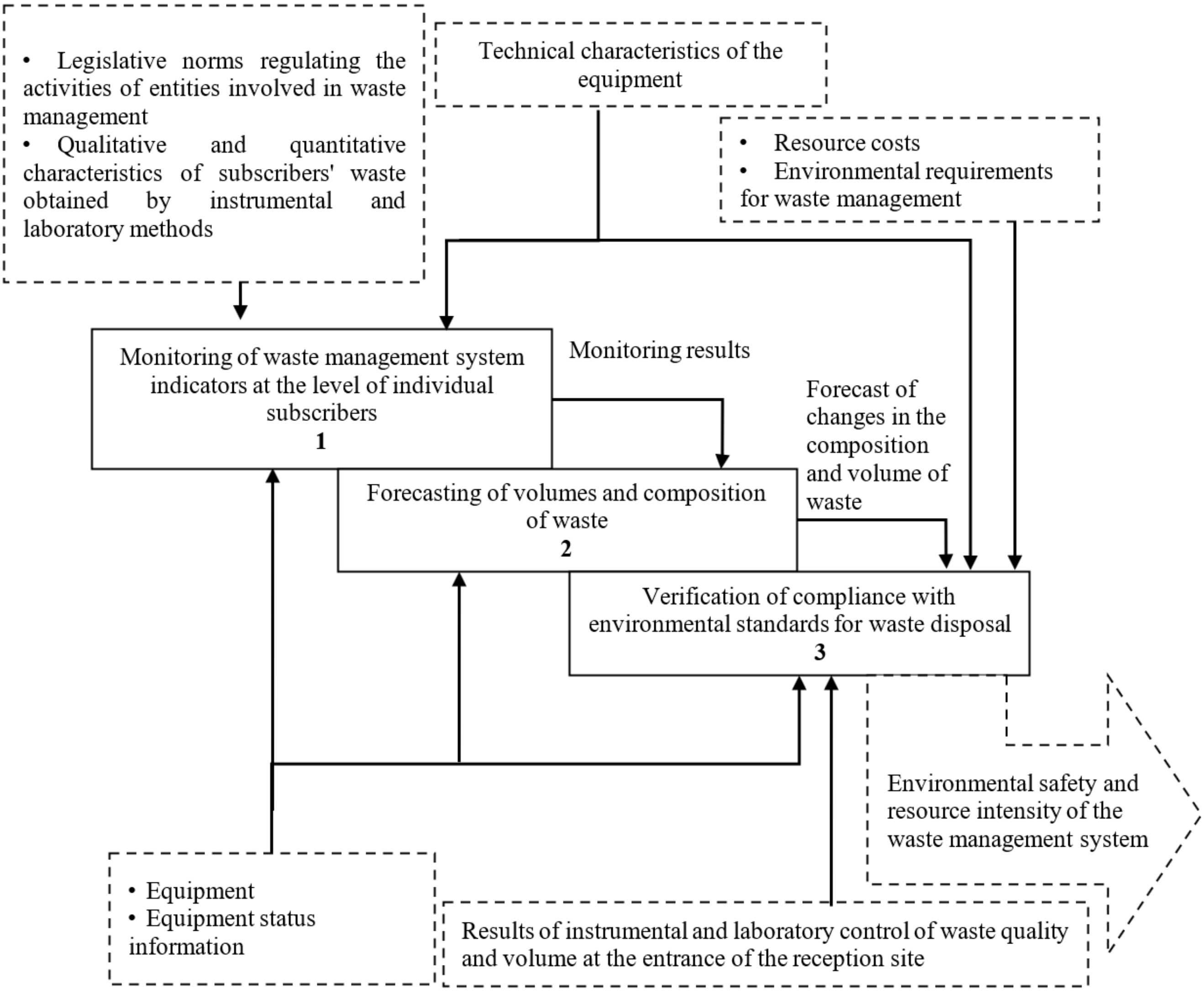

Figure 1.
Graphical representation of the structure of the system of control over compliance with environmental requirements in the sphere of waste management
Source: Compiled by the author of the article (Proposed model).

Next, an estimation of the level of controllability for the functions was performed:

- Environmental monitoring of waste management system indicators at the level of individual subscribers;
- Predicting the volume and composition of waste;
- Verification of compliance with environmental standards for waste disposal.

In order to visualize and further analyze the obtained data, it is proposed to present it in the form of a table (Table 2).

Table 2.
Input data for calculating the manageability of the waste management system.

Stage	σ_i	Number of sub-functions	Formula	$\alpha_{i.opt}$
Environmental monitoring of waste management system indicators at the level of individual subscribers.	1	2	$\alpha_1 = \frac{n_{1.\sigma}}{n_{1.3}}$	0.49
Forecasting waste volumes and composition	0.94	2	$\alpha_2 = \sum_{\sigma=1} \frac{\alpha_{2.\sigma} n_{2.\sigma}}{n_{2.3}}$	0.81
Verification of compliance with environmental standards for waste disposal	1	3	$\alpha_3 = \sum_{\sigma=1}^{3} \frac{\alpha_{3.\sigma} n_{3.\sigma}}{n_{3.3}}$	0.57

n – number of parameters total and measured in a certain automated way (σ)

Source: Compiled by the author of the article based on the results of an expert survey.

The key limitation for the successful operation of the function "Environmental monitoring of waste management system indicators at the level of individual subscribers" is currently a critical lack of measurement tools, which does not allow operational control over changes in the environmental situation and hinders effective management decisions (not exceeding 32% of the need). However, mathematical modeling makes it possible to improve the accuracy of estimates, compensating for the lack of direct measurements [36].

A logical continuation is the development of a waste management platform that will enable not only monitoring of the current situation but also forecasting future changes by integrating data from various sources. Such a platform will serve as the foundation for creating a digital ecosystem that encompasses all aspects of waste management and covers the vast majority of processes.

The “Waste volume and composition forecasting” function currently has no automated tools and relies entirely on expert judgment. A clear methodology for its digitalization will solve a significant part of the problem (based on retrospective analysis and newly added stakeholders), but still requires experts to verify and adjust the results to realities. As a result, the function “Verification of Environmental Compliance in Waste Management” is most quickly controlled due to its localization at the treatment plant. Specialized systems ensure that treatment processes are optimized and data are transmitted to the upper management level.

For example, for the most controllable function “Verification of environmental compliance in waste disposal,” α3 is calculated according to the formula:

$$\alpha_3 = \sum_{\sigma=1}^{3} \frac{\alpha_{3.\sigma} n_{3.\sigma}}{n_{3.3}} = 0.286 , \quad (4)$$

Then, according to the formula for φ:

$$\varphi_3 = \frac{\alpha_3}{\alpha_{3.opt}} * 100\% = 47.3\%, \quad 5)$$

Similarly, controllability parameters were calculated for all other functions of the current waste management system and the planned digital system (Table 3).

Table 3.
Manageability of the waste management system.

Functions	Share of function execution, %	σ_i	α_i	$\alpha_{i.opt}$	φ_i
Environmental monitoring of waste management system indicators:					
Total measurable	100	1.00	0.26	0.49	45.92
Of which manually	68	1.00	0.26	0.49	45.92
After the introduction of digital technology	100	1.00	0.49	0.49	100.00
Forecasting waste volumes and composition	12	0.94	0.12	0.81	14.81
After the introduction of digital technology	81	0.94	0.81	0.81	100.00
Verification of compliance with environmental standards for waste disposal:					
on-site instruments	41	1.00	0.37	0.57	56.58
centralized control system	27	1.00	0.37	0.57	56.58
After the introduction of digital technology	100	1.00	0.57	0.57	1.00

Source: Calculated by the author of the article on the basis of data provided by JSC "Zhasyl Damu" and Akimat of Astana.

Comparative analysis of the functions presented in Tables 1 and 2 allows us to conclude that, in order to achieve the planned level of system controllability, the most significant function is “Environmental monitoring of waste management system performance.” The next most important functions are “Forecasting of waste volumes and composition” and “Verification of compliance with environmental standards in waste management.” Digitalization of the stage “Environmental monitoring of waste management system indicators” requires the creation of new non-volatile measuring devices capable of working in difficult conditions.

Determination of the level of controllability (fact):

$$R = \frac{\sum_{i=1}^{3} \alpha_i \sigma_i}{\sum_{i=1}^{3} \sigma_i} = \frac{1 * 0.28 + 0.94 * 0.11 + 1 * 0.473}{1 + 0.94 + 1} = 0.291 \quad (6)$$

Determining the level of manageability (plan):

$$R_{pl} = \frac{\sum_{i=1}^{3} \alpha_i \sigma_i}{\sum_{i=1}^{3} \sigma_i} = \frac{1 * 0.49 + 0.94 * 0.81 + 1 * 0.57}{1 + 0.94 + 1} = 0.620 \quad (7)$$

Calculations show that with the use of a digital platform, the level of manageability of the waste management system will increase by more than 2 times compared to the present (Figure 2).

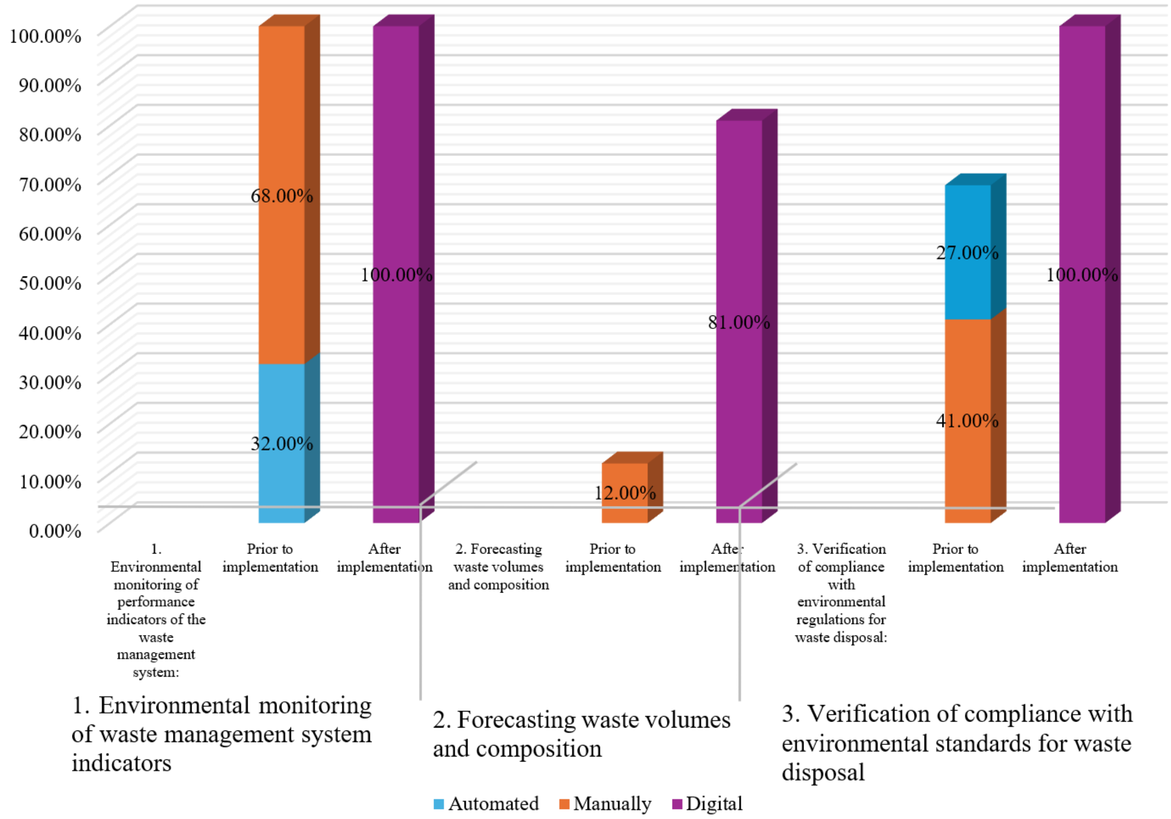

Figure 2.
Graphical representation of changes in the structure of the waste management system due to the introduction of the digital system.
Source: Compiled by the author based on Table 3.

As can be seen in Figure 2, there will be an increase in the manageability of functions when the digital platform is implemented:

- Environmental monitoring of waste management system indicators by 68%;
- Forecasting waste volumes and composition by 69%;
- Checking compliance with environmental standards in waste utilization by 73%.

Thus, the proposal to introduce a digital platform for environmental compliance into the waste management system is constructive and is supported by positive results.

5. Discussion

The main problem at present is the lack of effective infrastructure for waste collection, sorting, and utilization, and there is no unified information resource for these processes. According to Nurpeisova et al. [37] the most productive and least costly way to solve this problem is the introduction of an intelligent system aimed at managing safe waste management.

At the beginning of 2023, the global digital transformation market size in waste management was USD 4.1 billion. The development of information technologies and software applicable to waste collection, sorting, recycling, and transportation is carried out by 58 companies (Waste Management, ZenRobotics, Rubicon Global, Trux, etc.) [38].

Environmental indicators are the predominant components of the proposed digital platform for the waste management system. To make effective business decisions in accordance with the strategy of information industry development, it is necessary to collect digital data, process it, and utilize it at all stages of the waste lifecycle. From the moment of waste generation to its utilization and disposal, many entities from different industries interact with each other, each having their own well-developed waste management processes. Harmonization of the interests of different entities is achievable through the use of modern technological innovations.

The development of the global waste management market is possible through the adoption of digital technologies, including the production and implementation of innovative systems for waste collection, the provision of sensors for specialized vehicles and programs to optimize waste transportation, the development and application of innovative technologies for sorting, recycling, and waste disposal, as well as the development and deployment of information technologies [39].

For example, containers equipped with special sensors control the filling of sorted garbage. Special tags are applied to the containers, which read the vehicle at the moment of pickup and confirm its removal by sending data to a digital platform.

The application of distributed registry technology within the waste management structure, based on a blockchain platform, is recommended. Landfills are equipped with electronic platforms that measure weight and conduct video and photo recordings. The purpose of this process is to collect and process information about the garbage brought into the landfills and the specialized equipment entering the landfills. The latest system prevents unjustified increases in tariffs for the transportation and disposal of solid municipal waste.

With the digitalization of specialized machinery that transports garbage, the amount of waste in the container, in the vehicle, and unloaded at the landfill for disposal or recycling is determined.

The proposed digital platform is designed to provide a significant improvement in the environmental and economic components of the waste management system through the introduction of innovative information technologies such as the Internet of Things, artificial intelligence, and virtual reality. The system will make it possible to optimize technological stages, increase the efficiency of resource use, and reduce the negative impact on the environment.

Table 4 illustrates the main trends in digital technology that can be applied to waste management.

Table 4.
Information technologies in the sphere of waste management.

Information technology	Characterization
Cloud models	Providing remote access via the Internet to digital resources
Blockchain	Electronic databases comprise interconnected blocks of information. The information is located on personal computers. Access to modified data is available to all system participants; thus, transparency is achieved, and loss or falsification of original data is impossible.
Big Data	An effective analysis tool. Includes specialized methods and tools that process and store large amounts of information
Internet of Things	Targeted sensors (e.g., router, smart trash can, meter, etc.) that transmit information to cloud storage. Up-to-date information is available to the user and can be processed promptly

Source: Compiled by the author of the article based on Kaufmann-Ludwig [24], OECD [27] and Suzor and Gillett [25].

A promising area of technological development in waste management is the creation of digital twins of technological processes and objects. Digital twins, based on data obtained from IoT devices and processed using artificial intelligence, allow for modeling real functions, optimizing their operation, and making more informed decisions.

The proposed digital platformization of the waste management system should be carried out in stages, following the classical scheme of planning, calculation, implementation, and maintenance (Figure 3).

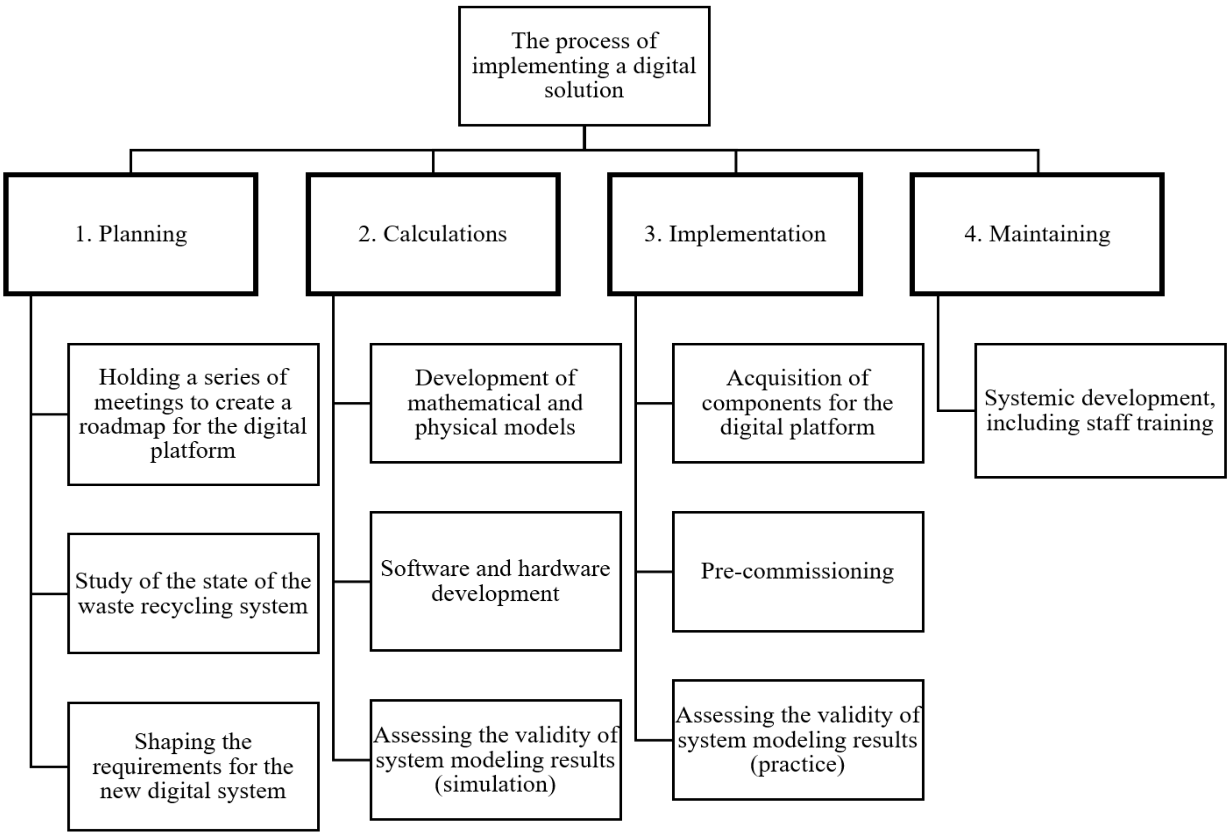

Figure 3.
Sequence of actions for starting the proposed waste management system.
Source: Compiled by the author of the article based on the proposed model.

Expected effects from the implementation of the proposed digital platform:

- Ensuring compliance with environmental standards in waste management.
- Optimization of economic indicators at all stages of the waste life cycle.
- Energy saving and rational use of resources in waste management.
- Accelerating decision-making in waste management.
- Improving the accuracy and timeliness of waste quality monitoring.
- Extension of digital twin technology to other waste management facilities.
- Waste management companies using the digital platform will receive:
- Toolkit for practical implementation, use and scaling;
- Method for creating digital models of waste management equipment;
- Software that ensures the creation and operation of virtual copies of technological lines for waste processing.
- Additional benefits of the proposed digital platform will enable:
- Create an integrated waste life cycle management system;
- Increase the productivity of technological processes while reducing costs;
- Ensure that the environment is reliably protected from pollution;
- Carry out scheduled preventive maintenance and timely repairs;
- To develop a system to prevent accidents and minimize their consequences;
- Implement a system of continuous training for employees.
- Government agencies, project participants and experts will receive:
- Methodological recommendations for evaluating investments in waste treatment enterprises;
- Modern standards and requirements for design, expertise and operation of waste management facilities based on digital technologies;
- A single digital portal for waste quality monitoring;
- Scientific and methodological justification for the development of environmentally friendly technologies within the urban environment.

There are similar studies on the economic feasibility of digital platforms in the environmental sector. In particular, in Yousaf et al. [40] the authors used data on environmental innovation based on digital platforms of the commercial sector in Pakistan. The use of digital platforms is shown to positively influence the relationship between digital orientation and digital eco-innovation. Using correlation and structural modeling, the cost-effectiveness of digital environmental solutions has been established, which correlates with the results of our study. However, it should be noted that the sample of companies used cannot be sufficiently informative and reflect a complete picture because the sampling method used in the work, and the characteristics of the general population, which are unknown, limit the application of the results of this study. The results of the assessment would be more informative if the study were conducted at enterprises whose activities are directly related to environmental safety.

Li et al. [41] We are also able to demonstrate the economic feasibility of adopting digital technologies, including platformization. The analysis of panel data enabled us to consider many economic issues; however, their multidimensionality does not necessarily indicate sufficient informativeness and reliability. Problems associated with the reduction characteristic of panel analysis, such as the natural dropout of a significant portion of study subjects, may lead to potential distortions of the results and a decrease in data set reliability. In this context, we believe that the SWOT analysis and economic-mathematical modeling we employed allowed us to obtain more reliable results.

The perspective of this study is to evaluate the environmental and economic efficiency of the new waste management system operating on the basis of a digital platform, as well as the possibility of its expansion from a “smart city” to a “smart region”.

6. Conclusion

Thus, the goal of justifying the use of digital platforms to optimize environmental compliance monitoring for an adaptive transition to a green economy has been achieved.

The SWOT analysis of the implementation of digital platforms for environmental compliance showed the advantages of their strengths, while the weaknesses are mainly based on the duration of the changes to be introduced and the resulting adaptation of the economic system. The broad opportunities of such platforms indicate significant prospects, while possible threats can be addressed through the development of regulations and the training of qualified personnel, which is characteristic of the adaptation period when introducing any progressive changes in the economy.

The application of functional modeling methodology revealed the high complexity of waste management systems, which requires the use of a digital platform for effective management and accident prevention. The main directions of waste management cluster infrastructure development in conditions of digitalization were identified, due to which a model of an intelligent system regulating waste under industry platformization was created. This solution will make it possible to conduct operational monitoring based on timely obtained relevant data, to increase the manageability of system processes.

Analysis of the controllability data on the selected case study revealed a twofold advantage of the digital platform in relation to the existing waste management system. This discrepancy indicates the need to improve the waste management system and justifies the creation of a digital platform that will enhance forecasting accuracy and optimize functions.

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