

DIGITALIZATION OF ENVIRONMENTAL SAFETY MANAGEMENT AS A TOOL FOR ENSURING SUSTAINABLE DEVELOPMENT

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Abstract. The purpose of the research is digitalization of environmental safety management. It has been proven that the latest information systems and technologies are the driver of digital transformation and the formation of an ecological business model focused on ensuring environmental safety and sustainable development of the enterprise. The tools are identified and the stages of modernization and transfer to the digital space of the environmental safety management system are determined. A reference model has been developed that will allow for a comprehensive solution to the challenges of digitization of environmental safety management, taking into account changes in the business environment and the needs of stakeholders. A model of digitization of the management of the production of ecological products is proposed, which is based on innovative principles and is integrated into the environmental safety management system, which in the complex serves as a guarantee of ensuring the implementation of the goals of sustainable development.

Keywords: digitalization, environmental safety, management, sustainable development, integrated information system, European experience

The priorities of the sustainable development policy are to ensure economic development supported on the basis of a modified market system; natural and ecological sustainability; close international cooperation and cooperation to achieve the goals of sustainable social development based on the principle of justice. The awareness of the scientific and political public of Europe of the need to develop and implement new approaches to the preservation of the natural environment, biotic and landscape diversity as interconnected indispensable components of the human habitat and the guarantee of further development of society led to the formation of a number of new approaches to solving organizational tasks of nature protection and understanding them scientific basis from a new point of view.

The ecological dimension of sustainable development is considered by scientists¹¹² using two indicators: 1) Environmental Sustainability Index ESI (Environmental Sustainability Index), which is formed from 21 environmental indicators calculated based on the use of 76 sets of environmental data on the state of

¹¹² Kashchena N., Nesterenko I., Kovalevska N. (2021). Monitoring of natural capital indicators as tool for achieving sustainable development goals, p. 156-166.

natural resources in the country, the level of environmental pollution, the country's efforts in the field of environmental management, the country's ability improve environmental characteristics, etc.; 2) EPI (Environmental Performance Index), which consists of 16 indicators that convey the country's achievements on its way to sustainable environmental development. These indicators include: child mortality rate (deaths per 1,000 children aged 1-14 years), chemical pollution and dustiness ($\mu\text{g}/\text{m}^3$) of the atmosphere, provision of drinking water and its sufficient purification (%), ozone status, nitrate content in drinking water (mg/l), water consumption, share of natural and protected areas, degree of deforestation (%), level of support for agriculture, depletion of fish stocks, share of alternative energy sources, energy efficiency and level of CO² emissions¹¹³.

The main criteria for evaluating ecological efficiency in order to fulfill the goals of sustainable development are presented in Figure 1.

For each indicator, the country receives points. Their number depends on the state's position within the range set by the worst country for this indicator (relative zero on the one-point scale) and the desired goal (the equivalent of one hundred points). The desired goal can be established on the basis of international treaties and standards.

According to the conducted studies¹¹⁴, in 2021 the best level of development of the ecological component will be in: Malta, France, Estonia, Portugal, Slovenia, Spain, Denmark, Sweden, Finland; the worst level is Cyprus, Belgium, Poland, and the Netherlands (Figure 2). The average level of sustainable development in EU countries is 3.3 units. That is, the following countries have a high level of sustainable development: Belgium, Slovenia, Portugal, the Czech Republic, France, Spain, Estonia, Ireland, and the Netherlands.

The tool for implementing the strategy of sustainable development is program-targeted regulation through the development of long-term, medium-term and short-term development programs of the state, its regions, administrative-territorial units, innovation and investment projects implemented in the state administration system. A necessary element of the process of development and implementation of Ukraine's sustainable development strategy is the formation of their resource and institutional and organizational support¹¹⁵.

The international TEEB project (The Economics of Ecosystems and Biodiversity, TEEB) contributes to the solution of issues in the field of institutional and organizational support of Ukraine's sustainable development strategy. It is focused on environmental safety and is designed to ensure the systematic integration of ecological assessment of biodiversity into the decisions of relevant authorities in the country and into the general system of ecological and economic calculations, which requires, first, the development of methodological principles for accounting for

¹¹³ Kashchena N., Nesterenko I., Kovalevska N. (2021). Monitoring of natural capital indicators as tool for achieving sustainable development goals, p.157.

¹¹⁴ Environmental Sustainability Index (ESI).

¹¹⁵ Zakharchenko O. V. (2014). Assessment and problems of sustainable development in the world, p. 111.

individual elements of natural capital and their disclosure in reporting business entities.

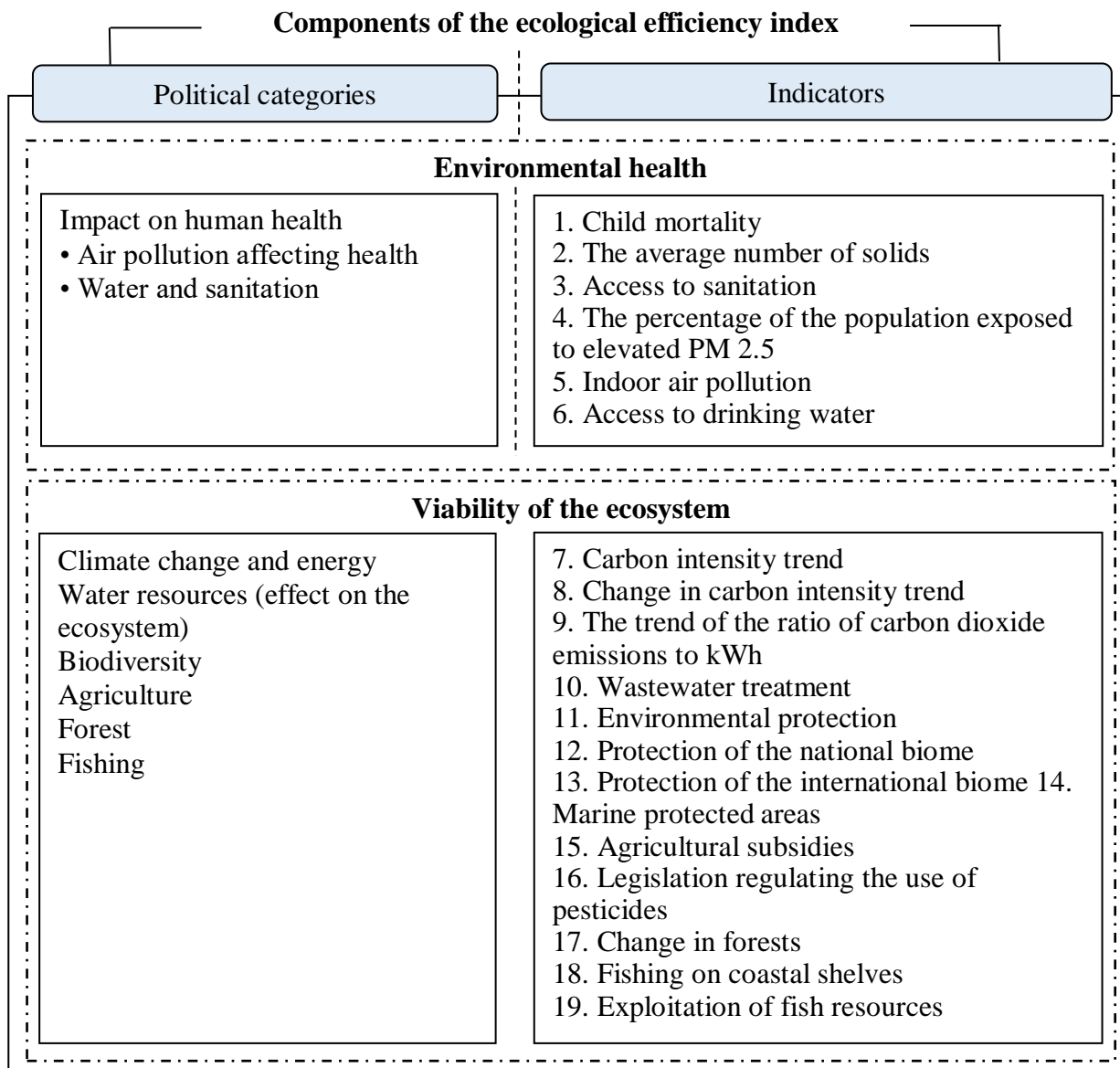


Fig. 1. The main components of the ecological efficiency index

Source: formed on the basis¹¹⁶

The European Union considers environmental security as a part of the national security of each state, as an important component of pan-European stability. That is why environmental protection is defined as a priority area of cooperation between Ukraine and the European Union. In Ukraine, an integrated approach to environmental management has not yet been implemented due to the imperfection of the relevant legislative and regulatory framework.

¹¹⁶ Kashchena N., Nesterenko I., Kovalevska N. (2021). Monitoring of natural capital indicators as tool for achieving sustainable development goals, p.157; Environmental Sustainability Index (ESI); Davydova O. et al. (2020). Sustainable Development of Enterprises with Digitalization of the Economic Management, p.2370-2378

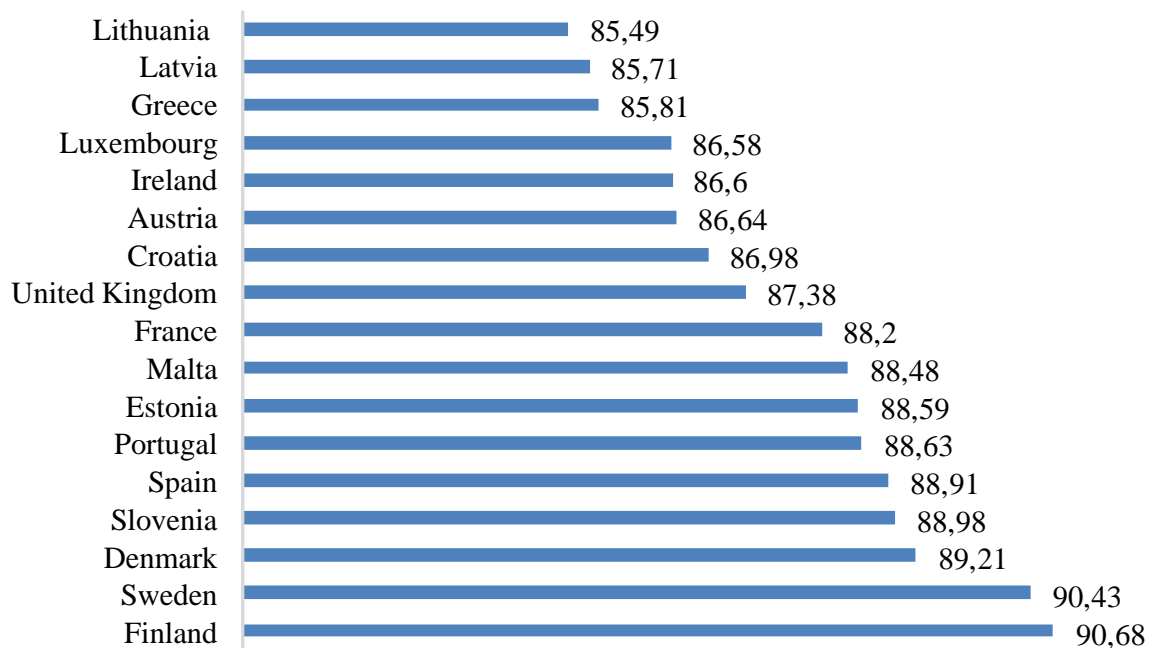


Fig. 2. EPI environmental efficiency indices of EU countries, 2021

*Source*¹¹⁷

Currently, Ukraine is interested in developing further cooperation in the field of environmental protection. The priority directions are global climate changes; management of water resources, in particular the Black Sea; renewable energy and energy efficiency. The application of European experience on the territory of Ukraine is possible in terms of the pace and quality of the implementation of the strategic goals of sustainable development. The list of the main indicators of the strategy (economic development, social development, protection of the natural environment and rational use of natural resources) should be distributed and take into account: the ecological balance of production in the basic branches of industry, agriculture, the production of consumer goods and the provision of services, housing and utilities, transport, military activity; environmental expertise in the field of scientific support, environmental education, civil society, regional policy, international cooperation. The development of a package of normative legal acts in Ukraine on environmental protection and conservation of natural diversity is the basis of sustainable development. As part of the transition to balanced socio-ecological and economic development in Ukraine, a few legal acts were updated to implement the goals and principles of sustainable development.

At the same time, modern state policy requires new approaches to its implementation, which should be based on innovative developments based on the principles of environmental safety.

Environmental safety and innovative development are components not only of state policy, but also the basis of its competitiveness, which is achieved primarily

¹¹⁷Environmental Sustainability Index (ESI). URL: <http://sedac.ciesin.columbia.edu/data/collection/esi>.

through the effective use of regulatory tools and the activation of environmentally oriented business (Table 1).

Table 1 – Tools for regulation and activation of ecologically oriented business

Tools and measures		Subject of development and implementation
Coercive and restrictive	Standardization and rationing, licensing, environmental expertise, environmental payments, financial sanctions for violation of environmental regulations, taxes, fees, fines, etc.	State
Stimulating and compensatory	Tax benefits, targeted subsidies and grants, preferential lending, financing (at least partial) of socially important environmental projects and programs	State, investors
Financial	Formation of specialized investment funds, environmental banks and programs; environmental insurance; environmental audit.	The state, business entities, investors
Informational	Free access of business entities to the environmental legal framework, environmental certification; formation of local environmental information centers; environmental consulting.	The state, business entities, investors
Social and psychological	Environmentally and socially oriented corporate culture and responsibility; activation of environmental education; environmental ethics and consciousness of the entrepreneur and the whole society	Business entities, the state (institutions of education, culture, upbringing, health)
Market (marketing)	Formation of the market for eco-safe products – demand, supply, competition; ecological marketing; creation of ecological brands.	Market entities

Source¹¹⁸¹¹⁹

In domestic practice, such regulatory instruments as certification, licensing, environmental expertise, environmental payments, financial sanctions, taxes, fees, fines, etc. are coercive and restrictive. Currently, disciplinary, administrative, civil, and criminal liability for violation of environmental legislation is common in Ukraine, as specified in Art. 68 of the Law of Ukraine "On Environmental Protection"¹²⁰.

Under modern global challenges, the prerequisite for ensuring environmental safety is effective innovative activity. At the stage of striving for sustainable development and directing entrepreneurship to ecologies economic activity, such types of innovative activities are activated as:

¹¹⁸ Omarov Sh. A. (2014). The concept of sustainable development in the legislation of Ukraine and the countries of the world and the practice of its implementation, p. 85.

¹¹⁹ Svistun L.A., Rozhko A.A. (2016). Strategic principles of ensuring the sustainable development of the economy of Ukraine, p. 866.

¹²⁰ Nazarova H. et al. (2022). Theoretical and methodological aspects of improving the functioning of the accounting system, p. 246.

– instrumental preparation and organization of production. It is at this stage that the ecological component of production is established through changes in the procedures, methods and standards of production and quality control of the production of a new ecological product or the application of a new technological process, the purchase of production equipment, etc.

– start of production and design work. At this stage, new modifications of the ecological product and technological process, which are adjusted in accordance with the norms and standards at the stage of the trial run of production, must meet the norms of environmental safety. An important component of this stage is the retraining of personnel according to the principles of eco-management, as well as the use of new technologies and equipment.

– marketing of new products, which includes preliminary market research, product adaptation to different markets or market preparation for the acceptance of new ecological products, creation of a new market, conducting advertising campaigns, etc.

– acquisition of intangible assets (patents, licenses, know-how, trademarks), services of technological content, machines and equipment, which by their technological content are related to the introduction of product or technological innovations. From the point of view of environmental safety, this component should be thoroughly investigated by the state with the help of regulatory mechanisms and standards to prohibit the introduction of pseudo-innovations on the market, based on secondary technologies that have not justified themselves or are prohibited in other countries.

In the conditions of total digital transformation of economic relations, effective environmentalization of business is possible only on the basis of digitization. The formation of a digital ecosystem of enterprise management requires the identification and rethinking of forms, directions, methods, technologies and tools of digital, innovative policy and the corresponding corporate culture, a high level of which is necessary for reliable communication between all levels of management in order to quickly implement changes and update the existing one or form a new one business models. It is advisable to modernize the enterprise management system and transfer it to the digital space in stages:

– 1st stage – building a system of communications with clients (understanding, analytics, tracking of client experience);

– 2nd stage – formation of modern corporate culture (introduction of new technologies, processes and skills);

– 3rd stage – optimization of business processes and formation of an effective operating model (implementation of new systems, restructuring of infrastructure, modernization of business applications and processes);

– 4th stage – renewal of the existing or formation of a new ecological business model (creation of new ecological products; digitization of production; reorganization of logistics; change of approaches to one's own positioning, etc.).

The basis of the new environmental digital business model and the organization of effective environmental safety management is the use of the latest information systems and technologies, in particular such as applied artificial

intelligence, which is based on big data tools, and allows visualization, end-to-end planning, modeling and adjustment of environmental policy sub business object in real time (Figure 3).

Information systems and technologies, integrating with analytical applications and services for working with intelligent devices, hybrid networks and other components of the digital world, allow optimizing the infrastructure of business process management and provide an opportunity to form digital platforms for the accumulation of information, its processing and transmission for decision-making.

To increase the efficiency of environmental safety management of enterprises, it is advisable to use the reference model of business digitalization (Figure 4), which allows to provide a comprehensive solution to the tasks of digitization of the management process, considering changes in the business environment and the needs of stakeholders.

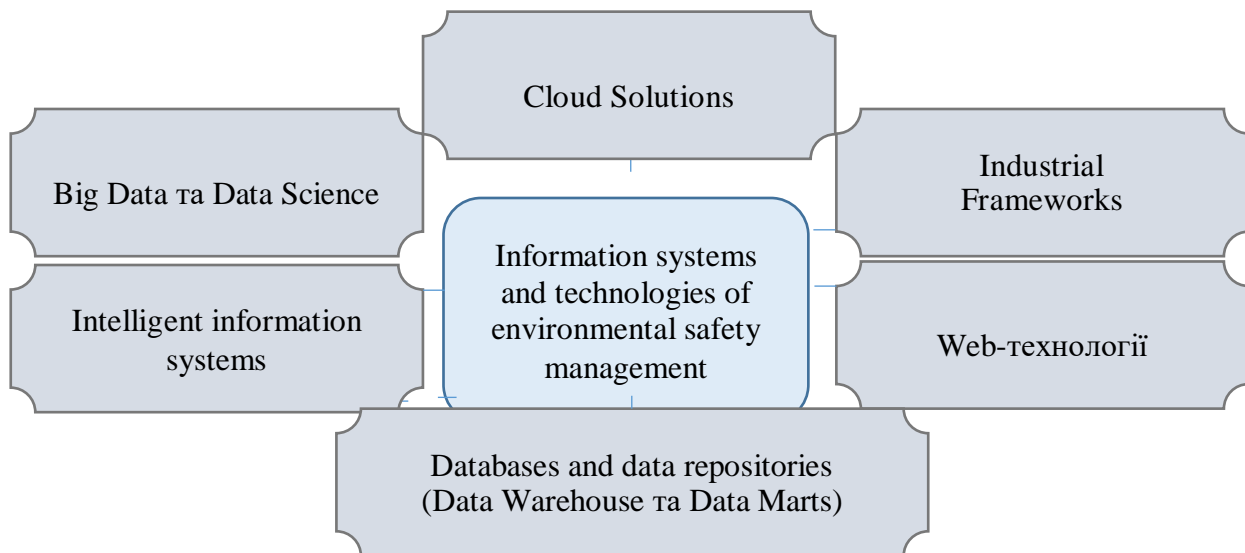


Fig. 3. Information systems and technologies of environmental safety management

Source: own development

The instrumental basis of the reference model of digitalization of business environmental safety management consists of its own databases, freely distributed information content (social networks, Internet resources, market information, etc.), open software of the business process management information system that implements the technology of data integration and digital applications¹²¹.

The current level of information technology development has clearly defined a platform for creating a new solution – a Web environment for consolidation and management of data and processes within the framework of a full set of

¹²¹ Davydova O. et al. (2020). Sustainable Development of Enterprises with Digitalization of the Economic Management, p. 2371.

environmental safety management tasks, the solution of which is necessary for the successful production of ecological products.

For internal data storage, the most effective is a mixed model, in which the XML format is mainly used. However, for attributes that are often used when forming samples, it is advisable to use traditional relational tables. Wide use of web services helps to implement the necessary functionality of a complex distributed solution. To coordinate and synchronize the work of services, you should choose an event mechanism and a link structure of applications and modern methods of creating screen web interfaces.

In the digital space of business entities, an important place should be given to:

- hardware (Devices and Networks) – smart devices, in particular sensors, interfaces and data transfer protocols, cyber security;

- specialized software and algorithms (Industrial Frameworks) – programming tools, promising packages for the development and implementation of control functions (IDE, CAD/CAM, SCADA), software integration of local devices, software gateways and data processing methods, modern algorithms for controlling technological equipment; cloud technologies (Cloud Solutions) (cloud services, cloud environments);

- digital twins (Digital Twins) – components and technologies of digital twins, development, modeling and integration into the production environment, predictive analytics, modern management methods and laws.

Therefore, the implementation of an information system that ensures the concentration of data and their management within the production processes of innovative eco-products is currently an urgent task for a wide range of business entities. The successful organization of innovative production is achieved by ensuring the connection between heterogeneous work processes at the enterprise and the effective use of data created in management corporate software systems¹²².

The concept of digital integrated innovative production of ecological products involves a new approach to the organization and management of production, the novelty of which consists not only in the application of information systems and technologies for the automation of technological processes and operations, but also in the creation of an integrated information environment for managing production on an ecological basis. In the concept of digital production, an integrated computer system plays a special role, the main functions of which are the automation of the design and preparation processes to produce ecological products, as well as functions related to the provision of information integration of technological, production processes and environmental safety management processes. Digital integrated production of ecological products combines the following functions:

- design and production preparation;
- planning and production;
- supply management;
- management of production sites and workshops;

¹²² Koshkalda I. et al. (2020). Motivation Mechanism for Stimulating the Labor Potential. Research in World Economy, p. 54.

- management of transport and warehouse systems;
- quality assurance systems;
- sales systems;
- financial subsystems.

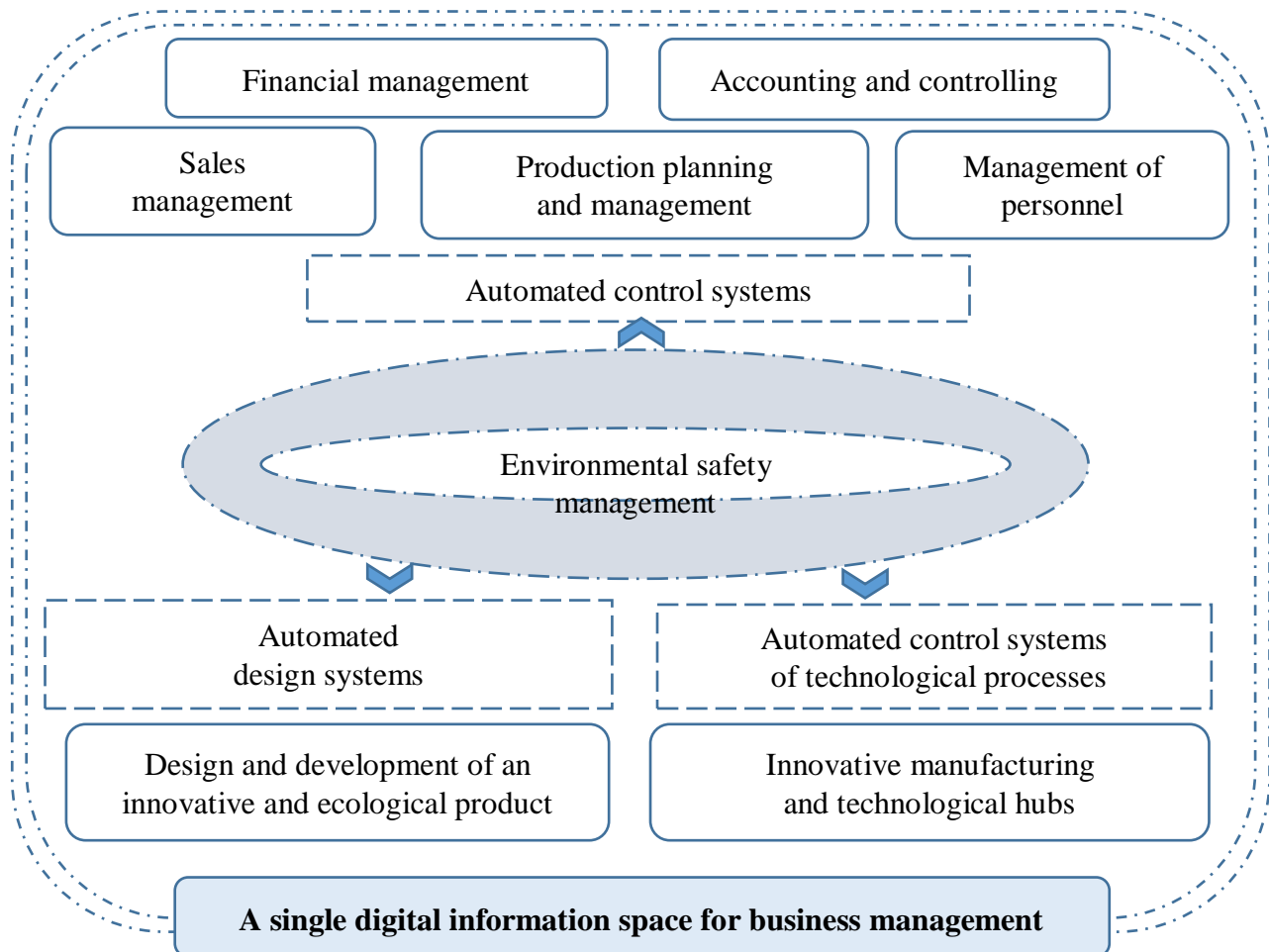


Fig. 4. Reference model of digitalization of environmental safety management of a business entity

Source: own development

All functions are performed using special software modules. Data required for various procedures are freely transferred from one software module to another. In digital production, a common database should be used, which allows, through an interface, to provide user access to all modules of production processes and related business functions that integrate automated segments of activity or production complex. Practice proves that the digital production of ecological products reduces and practically excludes human participation in production. This allows you to speed up the production process and reduce the rate of failures and errors.

Therefore, the modern digital transformation of business processes must be implemented systematically. The digital production system covers the design

processes (beginning with the study of market conditions and ending with logistics issues), manufacturing and sales of ecological products¹²³.

Based on the above, we offer the architecture of the digitalization model for the management of the production of ecological products (Figure 5), which consists of three main, hierarchically interconnected blocks, focused on the implementation of the functions of different levels of management, and in its outline integrates the relevant functional information systems and technologies.

Digital production systems of the strategic and tactical level include systems that perform the task of planning the production of ecological products. The current level is occupied by design systems to produce ecological products. At the operational level are production equipment management systems. The main components of the integrated model of digitalization of management of the production of ecological products are as follows:

1) at the strategic and tactical level (planning level):

- SPMEP (Systems of Planning and Management of Ecological Production) – systems of planning and management of ecological production;
- EPPS (Environmental Policy Planning System) – environmental policy planning system;
- CAP (Computer-Aided Planning) – technological training system;
- CAPP (Computer-Aided Process Planning) – an automated system for designing technological processes and drawing up technological documentation;
- MRPS (Manufacturing Resource Planning Systems) – system of resource needs planning;
- ASMR (Automatic System of Moving Resources) – automatic system of moving resources;
- ASS (Automated Storage System) – automated warehouse system;
- PPMS (Production Process Management System) – production process management system.

2) at the current level (the level of design of ecological products and production):

- PDM (Project Data Management) – data management system for ecological products;
- modification of systems: CAE (Computer-Aided Engineering) – automated environmental engineering system; CAD (Computer-Aided Design) – automated design system; CAM (Computer-aided manufacturing) – automated system of technological preparation of ecological production;
- ETD (Electronic Technical Development) – a system of automated development of operational documentation;
- IETM (Interactive Electronic Technical Manuals) – interactive electronic technical manuals.

¹²³ Kashchena N., Nesterenko I. (2022). Digitalization of the innovative development management information service of the enterprise, p. 255.

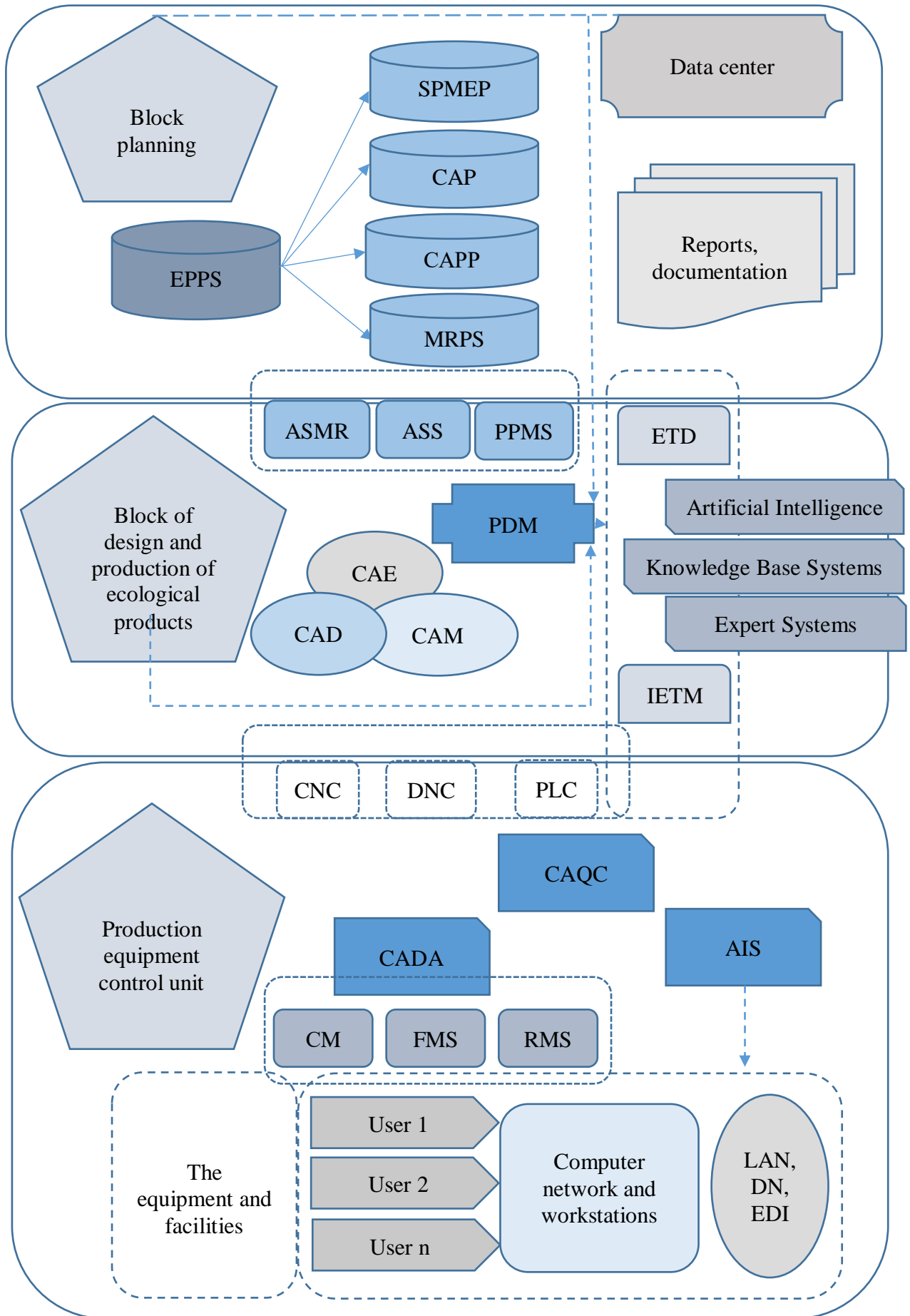


Fig. 5. Integrated model of digitalization of management of production of ecological products (Source: own development)

3) at the operational level (production equipment management level).

- CAQC (Computer Aided Quality Control) – an automated system of environmental product quality management;
- CADA (Control and Data Acquisition) – data management and collection;
- FMS (Flexible Manufacturing System) – flexible manufacturing system;
- RMS (Reconfigurable Manufacturing System) – reconfigurable manufacturing system;
- CM (Cellular Manufacturing) – automated production process management system;
- AIS (Automatic Identification System) – automatic identification system;
- CNC (Computer Numerical Controlled Machine Tools) – numerical software control;
- DNC (Direct Numerical Control Machine Tools) – direct numerical software control;
- PLC (Programmable Logic Controllers) – programmable logic controller;
- LAN (Local Area Network) – local network;
- DN (Distributed Network) – distributed network;
- EDI (Electronic Data Interchange) – electronic data exchange.

The presented integrated model of digitalization of the production of ecological products is a component of the system of digitalization of environmental safety management, which through the applied solutions of the latest information technologies in the field of design, manufacture and sale of ecological products ensures the implementation of the relevant functions of managerial influence, effective information communication interaction and the formation of a single digital information space of business management. The presence of the latter serves as a guarantee of ensuring the implementation of the goals of sustainable development¹²⁴.

The above proposals in a complex form a scientific and applied approach to the digitalization of business environmental safety management, the difference of which is the implementation of the latest achievements in the field of eco-innovations and IT technologies of data collection and processing for all business processes in the management information system of business entities with the aim of obtaining a number of economic, environmental and social benefits¹²⁵. Thus, the economic effect consists in: minimization of costs due to the innovativeness of equipment and technologies; improving the quality of ecological products, reducing energy and material consumption, increasing labor productivity and employee motivation, etc.; increasing profits, strengthening the financial and economic situation; minimization

¹²⁴ Shiyani D.V. et al. (2021). Forecasting the demand for organic products in households with different income levels, p. 16.

¹²⁵ Kashchena N. (2021). Scientific and applied platform of trade enterprises economic activity digital management transformation, p. 17.

of environmental risks by taking measures to prevent environmental fines and sanctions; increasing business reputation; increasing innovative and market attractiveness, additional attraction of investments; development of ecologically oriented markets, etc. Environmental benefits are associated with: image enhancement due to environmental responsibility of business; improving the state of the environment, preserving and restoring the natural resource potential; preservation and improvement of the ecological environment in the locations of enterprises; the development of types of activities in which the growth of production volumes is not accompanied by environmental pollution; conquering a niche in the «environmentally friendly products» market, etc. The social effect is manifested in the realization of personal potential as a socially responsible business entity and the fulfillment of its social mission to society.

In conclusion, we note that digitalization is no longer just a trend, but an integral tool for building economic systems, which through the integration of digital technologies in all spheres of life ensures the transition of business from the real world to the virtual world, its efficiency and further sustainable development on the basis of innovation and environmentalization production taking into account changes in the business environment and the interests of all interested parties. The implementation of the latest achievements in the field of eco-innovations and IT technologies of data collection and processing for all business processes (design, manufacturing, sales, etc.) into the information system of the enterprise's management enables the improvement of the socio-ecological-economic parameters of the enterprise's development and contributes to the strengthening of its environmental safety.

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