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FORMATION OF THE BALANCED DEVELOPMENT TRAJECTORY OF THE ECOLOGISTIC SYSTEM PROJECT

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Meeting modern requirements for achieving sustainable development goals requires transformational changes in the principles of doing business, in particular the organization of logistics activities. Environmentally oriented management turns the logistics system into an environmentally friendly one, which allows achieving logistics goals with minimal eco-destructive impact on the environment and solving the problem of environmental protection.

The object of this study is the mechanism of forming the trajectory of the ecologistic system project, which makes it possible to take into account the peculiarities of its life cycle and ensure balanced development.

The ecologistics system project is seen as a complex, open, dynamic, stationary system that supports stationary homeostasis through internal and external metabolism. During the life cycle, the ecologistic system project evolves, moving from one stationary state to another, each of which corresponds to certain values of input and output resources. This vision makes it possible to determine the optimal ratio of resources in the resource balance, which ensures the homeostasis of the system and minimizes the eco-destructive impact on the environment. A model of homeostasis of the stationary state of the project and a model of balanced development of the project of the ecologistic system have been developed, the use of which allows creating a trajectory that ensures the maximum value of the ecological and economic value of the project. Experimental calculations confirming the feasibility of using the proposed mechanism and showing an increase in the ecological and economic value of the project as a result of its development in accordance with the formed trajectory are presented. The proposed mechanism should be used when planning the development of logistics system projects in order to achieve a balance of economic and environmental goals of the project

Keywords: ecologistics, ecologistic system, circular economy, balanced development, ecologistics system project

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1. Introduction

Sustainable development as a modern concept aimed at solving problems that have arisen due to the technogenic type of civilizational development, involves maintaining a balance between economic, social, and environmental aspects of human life [1]. The change in the worldview paradigm of humankind has led to the transformation of logistic systems, which respond to the modern linear modem of economics, into closed ecologistic systems (CES). CES makes it possible to implement the principles of circular economics in economic activities and reduce the eco-destructive impact on the environment. Taking into account the environmental component in logistics activities is an urgent request of our time, which allows achieving logistics goals without harming the environment and providing favorable living conditions for both present and future generations.

One of the ways to introduce balanced development is the use of a modern trend in the development of science – convergent management, in which there is a convergence of scientific and methodological foundations of various fields of knowledge to achieve goals [2]. Thanks to the use of convergent management, it becomes possible to consider the process of managing systems of the suprabiological level of the organization, in particular economic systems, through the prism of management mechanisms created by nature. Convergent management of CES projects is based on the convergence of general management and natural science approaches, which allows developing management mechanisms that take into account the specific features of this type of projects, namely their environmental orientation.

One of the main features of CES projects is the transformation of their life cycle by adding environmentally oriented phases, thanks to which it becomes possible to close logistics chains and turn the logistics system into a more environmentally dangerous one [3]. The organization of the functioning of such systems is aimed not only at fulfilling the basic rules of logistics but also takes into account the basic rule of environmental science – the task of minimal ecodestructive impact on the environment.

The environmental orientation of the created systems is reflected in the content and configuration of products formed during the life cycle (LC) of a CES project [4]. The variability of combinations of products from different stages of the project makes it possible to form the trajectory of its development, on which the value of the CES project depends. To form an optimal development trajectory, it is necessary to create a mechanism that will use modern convergent management tools and make it possible to achieve not only economic but also environmental goals of the project. As a result of applying the proposed approach, it becomes possible to achieve a balanced development of the CES project, which corresponds to the principles of sustainable development as a modern concept of civilizational development of humankind. Given the need to balance economic and environmental aspects in all areas of management, the study of specific features of CES projects can be considered relevant. The demand for the results of the presented study is justified by the ever-increasing requirements of society for the environmental friendliness of logistics activities as such, which, currently, causes significant damage to the environment. Changing the ideological paradigm requires immediate fundamental changes in the theory and practice of logistics, which, in turn, requires the development of qualitatively new mechanisms, methods, and management models.

2. Literature review and problem statement

There are numerous developments of scientists, which are the basis for the formation of scientific and methodological foundations of the theory of sustainable development. Fundamental research in this direction is work [5], in which scientists from 19 countries consider theoretical and practical issues of sustainable development.

An important role in the implementation of the principles of sustainable development is played by the circular economy as one of the ways to solve environmental problems to ensure a stable environmental future. Work [6] emphasizes the superficiality and lack of systematic nature of existing research on the circular economy, focuses on the need for scientific research of the content of the concept. Work [7] notes the fragmentation of modern research on the circular economy between different disciplines, which greatly hinders the formation of a common view on the ways of its implementation. The problem is identified and, as a solution, the circular economy is presented as an interdisciplinary direction, applied in a global context, and representing an attempt to integrate economic activity and environmental well-being [8].

Today, the transition to a circular economy is becoming global, and the benefits of implementing this concept are becoming increasingly obvious. According to experts of the Ellen MacArthur Foundation, in 2025 the circular economy can annually provide an increase in the income of the world economy of more than USD 1 trillion. In addition, the transition to a circular economy will create huge opportunities for the modernization of production and the introduction of industrial innovations [9].

The essence of the circular economy, conceived as a continuous positive development cycle that protects and increases natural capital, is presented in [10]. The circular economy keeps resources in the material cycle and reduces waste generation, optimizes resource profitability, and minimizes systemic risk through the management of final stocks and renewable flows. In [11], the possibility of implementing the principle of «closedness» of material and resource cycles at different levels of economic systems is investigated. The above works present the concept and substantiate the feasibility of using the circular economy as a modern economic model that meets the requirements of sustainable development but does not present mechanisms for its implementation in practice.

As a modern direction of logistics, researchers propose to consider environmental studies. Within the framework of the concept of sustainable development in [12], ecologistics is presented as an effective tool for environmentally oriented management of material and related flows in order to preserve the ecosystem. Work [13] emphasizes the importance of the role of logistics in the transition to a circular economy and the need for an integrated approach focused on long-term systemic changes. The features of the formation of the concept of ecology are revealed and the evolution of the development of ecology is investigated in [14, 15]. Ecologistics is considered as a scientific direction, involving the use of modern innovative logistics technologies aimed at minimizing the environmental consequences of logistics activities [16]. The need to change the existing paradigm of logistics systems management and add environmentally oriented to the general principles of logistics is paid attention to in [17]. The general characteristic of the analyzed scientific research is its conceptual nature and the absence of specific mechanisms that will solve the problem of achieving sustainable development goals. More practical direction is reported in work [18], which proved that ecologistics is an important direction of innovation activity of business structures. A scheme of interaction of various factors of macro-and microenvironment in the direction of ensuring the goals of environmentalism in the strategy of enterprise development has been developed.

There are scientific papers that investigate the issue of taking into account the environmental component in assessing the effectiveness of the functioning of CES. Paper [19] proposes a system of indicators for measuring innovations in supply chains implemented for the transition to a circular economy. In [20], it is proposed to apply the relative indicator of ecological and economic assessment in the system of transport logistics of enterprise. This approach allows for a simultaneous analysis of the environmental and economic component of logistics activities, but only at the stage of operation of CES, which is limited.

The methodology that makes it possible to increase the efficiency of the creation and operation of CES is project management. Studies of the features of logistics project management were conducted in [21, 22]. The issues of portfolio management for the implementation of logistics strategies in the networks of supply chain organizations are investigated in [21], resources and products of the logistics system project are identified in [22]. But these studies do not pay attention to the environmental component in logistics system projects, and its impact on the success of this category of projects.

One of the ways to solve such a complex issue as the management of CES projects, taking into account their environmental orientation, is to apply the principles of convergent management. It is proposed to use convergent management by applying the principles of other methodologies to solve the issue or problem under study [23–25]. In [23], it is determined that the main purpose of applying the convergence of methodologies is the synergy of their elements, which are converted in the development of a methodology for managing projects, programs, and portfolios. The convergence of methodologies in project management is proposed to understand as a systematically verified merger, combining methodologies, subject to the conditions of consistency of their elements [24]. The issue of knowledge convergence in project management in work is investigated in [25]. A distinctive feature of these works is the study of the convergence of different project management methodologies, but the possibility of convergence of approaches from different fields of knowledge is not considered.

Recently, scientific research on convergent management in the circular economy and environmental science has appeared. Work [26] identifies the interdisciplinary nature of the circular economy, which forms the prerequisites for the use of convergent management and makes it possible to develop and implement new mechanisms in improving the existing model of production and consumption. The importance of «interlacing» the principles and approaches of various fields of knowledge, in particular natural, social sciences, engineering and management, to solve modern environmental problems, is emphasized in work [27]. Convergence of approaches in supply chain management, ensuring sustainable development, is investigated in [28]. In the presented works, the expediency of introducing environmentally oriented logistics systems and supply chains is substantiated, but the question of efficiency of their creation and functioning is not considered.

The peculiarity of convergent management of CES, which involves convergence of the principles of project, logistics, environmental management with the use of mechanisms of general managerial and natural-scientific approaches, is investigated in [2] but without specifying certain management mechanisms.

Thus, it can be argued that the recognition of convergent management is due to the evolutionary development of the worldview of humankind, awareness of the universality of the laws of nature justifies the use of modern mechanisms for managing CES projects. Currently, scientific works on this topic are generally debatable and conceptual. The lack of tools, through the use of which it is possible to achieve balanced development of CES projects in practice, requires appropriate scientific research.

3. The aim and objectives of the study

The purpose of our study is to develop a mechanism for shaping the trajectory of the CES project as a tool for implementing the principles of the circular economy, which allows for its balanced development.

To accomplish the aim, the following tasks have been set:

– to develop a model of steady-state metabolism of the CES project;

– to provide the definition and calculation formula of the environmental and economic value of the CES project;

– to develop a model of balanced development of the CES project;

– to carry out experimental calculations confirming the adequacy of the proposed mechanism for forming the trajectory of balanced development of the CES project.

4. The study materials and methods

The object of the study is the mechanism of forming the trajectory of the ecologistic system project, which makes it possible to take into account the peculiarities of its life cycle and ensure balanced development.

Research hypothesis: taking into account the transformational changes in the LC of the CES project caused by the environmental orientation of the project, affects its development, and requires the use of a modern mechanism through which it is possible to achieve balanced development.

The methodological basis of the presented research is the convergence of scientific approaches, in particular design, logistics, environmental, systemic, and physical. Convergence (from lat. con – razom, vergere – direction, lust) is the process of convergence, convergence of properties, attributes, arising as a result of evolution in phenomena that are not related to each other, inconsequential. The term is used in different languages, specifically economics, biology, political science, linguistics, etc. The concept of sustainable development is built on the convergence of ideological values of humanity, which reflect various aspects of civilizational development. The change of worldview took place in the direct convergence of these values and raised the urgent issue of developing an appropriate methodology for convergent management, based on the convergence of general management and natural science approaches [2].

The application of the project approach is justified by the fact that the object of research is the mechanism of forming the trajectory of the balanced development of the CES project. The basic concepts of project management are used, such as the project, project life cycle, project products, project value, etc. The logistics approach explains the flow essence of the logistics system, the environmental approach turns the logistics system into an CES.

The convergence of systems and physical approaches is used to develop a mechanism for shaping the trajectory of a balanced development of an CES project. The systematic approach allows taking into account the peculiarities of the CES project as a complex, open, dynamic, stationary system of the suprabiological level of the organization.

A transformed model of the LC of the CES project is applied, which is changed by adding environmentally oriented phases that take into account the principles of ecology and logistics. This makes it possible to determine the stationary states of the system and apply them when creating a system of balance equations using the physical approach. Based on the first and second laws of thermodynamics, a model of the stationary state of the CES design is created. The principle of reducing the eco-destructive impact on the environment from the products of the CES project, which meets the needs of greening economic systems, is described by the problem of multicriteria optimization and is solved by changing restrictions.

When defining the concept and calculating the ecological and economic value, which takes into account not only the economic but also the environmental aspect of the value of the products of the CES project, the provisions of the concept of sustainable development and the achievement of its environmental goals are taken into account.

To determine the trajectory of the balanced development of the CES project, which is carried out by transferring the project from one stationary state to another, the tools of the dynamic programming method are used, which corresponds to the idea of the project as a dynamic stationary system.

In the process of developing a mechanism for forming the trajectory of a balanced development of the CES project, an assumption of determinism of the conditions for project implementation is made. The possibility of uncertainty in the values of cash flows is not taken into account when calculating the ecological and economic value of stationary states of the project.

5. The mechanism of forming the trajectory of balanced development of the ecologistics system project

5. 1. Steady-state metabolism model of the ecologistics system project

The LC of the CES project differs from the LC of the logistics system project in its classical sense, justified by the specific features of this type of project. It is proposed to divide the LC of the project of the ecologistic system into the following phases: pre-investment, investment, operational, regenerative, revitalization [3].

The LC phases of the CES project make up the set of phases of the C^f projects, $(f=\overline{1;F})$. The stages of the project phases are the set S^{fj}, f $(f=\overline{1;F})$ – the project phase, j $(j=\overline{1;J})$ – the phase stage. The stages of the project phases correspond to the time intervals $[t_i;t_{i+1}]$ $(i=\overline{1;I-1})$, where t_i is the beginning, t_{i+1} is the end of the time interval for the duration of the phase stage of the project, which are milestone events. During the LC of the CES project, the following milestone events are distinguished: t_0 – start of the project, pre-investment phase; t_1 – beginning of investment and revitalization phases, end of pre-investment phase; t_2 – beginning of the operational phase, end of the investment phase; t_3 – the beginning of the regenerative phase; t_4 – end of the operational phase; t_5 – end of the regenerative phase; t_6 – completion of the project, revitalization phase.

Thus, the LC includes the set $TI^i, (i=\overline{1;I-1})$ of time intervals $[t_i; t_{i+1}]$ – time periods, the beginning and end of which are milestone events, which correspond to the beginning or end of the phase (stage) of the project.

The LC of the CES project includes phases that differ in the number of stages in their composition: pre-investment phase – $PI^{11}_{[t_0;t_1]}$, investment phase – $I^{21}_{[t_1;t_2]}$, operational phase – $O^{31}_{[t_2;t_3]}$, $O^{32}_{[t_3;t_4]}$, regenerative phase – $RG^{41}_{[t_3;t_4]}$, $RG^{42}_{[t_4;t_5]}$, revitalization phase –$RV^{51}_{[t_1;t_2]}$, $RV^{52}_{[t_2;t_3]}$, $RV^{53}_{[t_3;t_4]}$, $RV^{54}_{[t_4;t_5]}$, $RV^{55}_{[t_5;t_6]}$ (Fig. 1) [3].

The LC stages of the CES project end with the receipt of an intermediate result – the product of the project phase (stage) belonging to the set of project products $R^{fj}_{[t_i;t_{i+1}]}$, $(f=\overline{1;F})$, $(j=\overline{1;J}), (i=\overline{1;I-1})$.

During the time interval $[t_0; t_1]$ there is a pre-investment phase $PI^{11}_{[t_0;t_1]}$, the product of which is a documented CES project – $P^{11}_{[t_0;t_1]}$.

During the time interval $[t_1; t_2]$ the following occurs: the investment phase $I^{21}_{[t_1;t_2]}$, the product of which is CES – $P^{21}_{[t_1;t_2]}$, and the stage of the revitalization phase $RV^{51}_{[t_1;t_2]}$, the product of which is the revitalization of the consequences of the creation of CES – $P^{51}_{[t_1;t_2]}$.

During the time interval $[t_2; t_3]$ the following occurs: the stage of the operational phase $O^{31}_{[t_2;t_3]}$, the product of which is the direct material flow – $P^{31}_{[t_2;t_3]}$, and the stage of the revitalization phase $RV^{52}_{[t_2;t_3]}$, the product of which is the revitalization of the consequences of direct material flow – $P^{52}_{[t_2;t_3]}$.

During the time interval $[t_3; t_4]$ the following occurs: the stage of the operational phase $O^{32}_{[t_3;t_4]}$, the product of which is a direct material flow – $P^{32}_{[t_3;t_4]}$, the stage of the regenerative phase $RG^{41}_{[t_3;t_4]}$, the product of which is the reverse material flow – $P^{41}_{[t_3;t_4]}$. Also, the time interval $[t_3; t_4]$ accounts for the stage of the revitalization phase $RV^{53}_{[t_3;t_4]}$, the product of which is the revitalization of the consequences of the movement of direct and reverse material flows – $P^{53}_{[t_3;t_4]}$.

During the time interval $[t_4; t_5]$ the following occurs: the stage of the regenerative phase $RG^{42}_{[t_4;t_5]}$, the product of which is the reverse material flow – $P^{42}_{[t_4;t_5]}$, and the stage of the revitalization phase $RV^{54}_{[t_4;t_5]}$, the product of which is the revitalization of the consequences of the movement of the reverse material flow – $P^{54}_{[t_4;t_5]}$.

During the time interval $[t_5; t_6]$ the stage of the revitalization phase $RV^{55}_{[t_5;t_6]}$, is underway, the product of which is the revitalization of the consequences of the CES project – $P^{55}_{[t_5;t_6]}$.

The CES project is a complex, open, dynamic, stationary system belonging to the suprabiological level of the organization. As a complex system, a project consists of many elements that form its internal project environment. These elements are in connection with each other and with elements of the external environment, so the project is an open system. As a dynamic system, the project changes its state during LC and, as the stationary system, maintains the dynamic relative constancy of the composition and properties.

The openness of the system means that it carries out material-information-energy exchange with the external environment, as well as individual elements among themselves, that is, metabolism. Metabolism provides the possibility of implementing the CES project by attracting vital substances from the outside and returning to the external environment the results and waste of the system. In addition, matter, energy, and information are also transformed inside the system.

Stable metabolism guarantees the stationarity of the CES project, which reflects the ability to maintain stable dynamic equilibrium or dynamic relative constancy of the composition and properties of the system – homeostasis. The state of homeostasis provides optimal conditions for the implementation of the CES project within the zone of permissible values of its parameters. The CES project as a system metabolizes with the design environment, extracting resources, transforming them, and returning them to the environment, as shown in Fig. 2.

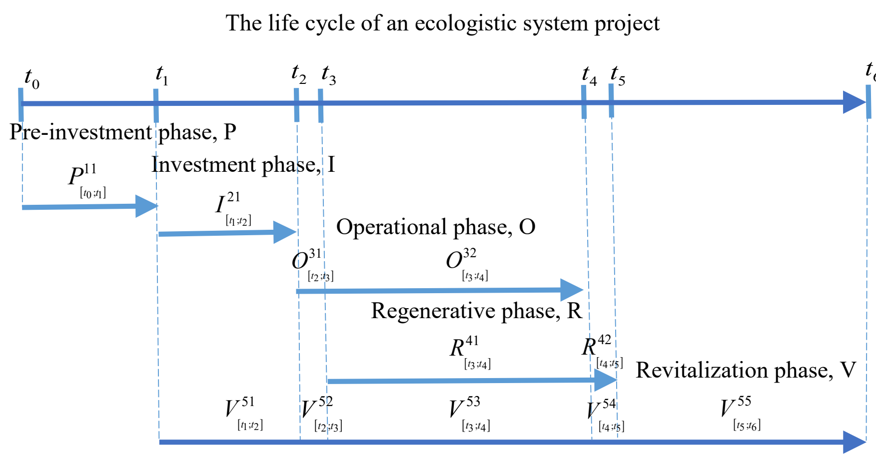

Fig. 1. Graphical model of the life cycle of an ecologistic system project

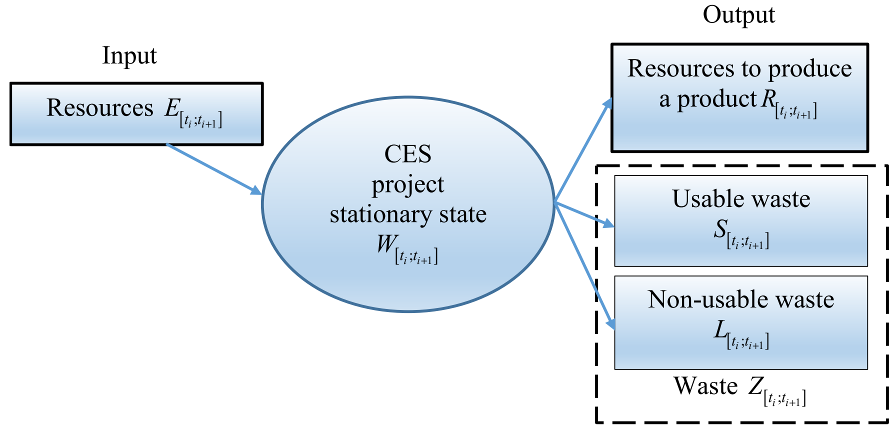

Fig. 2. Metabolism scheme of the ecologistics system project

As a result of metabolism, the project exchanges resources with the environment, thanks to which the project can exist and change its state. Under the stationary state of the system, we understand the set of essential properties that the system has at a given time, or an ordered set of values of internal and external parameters that determine the course of the processes occurring in the system [5]. It is possible to describe the stationary state $W_{[t_i;t_{i+1}]}$ of the CES project with a tuple:

$$W_{[t_i;t_{i+1}]} = \left\langle E_{[t_i;t_{i+1}]}, R_{[t_i;t_{i+1}]}, Z_{[t_i;t_{i+1}]} \right\rangle, \quad (1)$$

where $E_{[t_i;t_{i+1}]}$ is the set of input resources of the stationary state $W_{[t_i;t_{i+1}]}$ of the project; $R_{[t_i;t_{i+1}]}$ – a set of resources used to create stationary state $W_{[t_i;t_{i+1}]}$ products of the project; $Z_{[t_i;t_{i+1}]}$ – a set of waste from the stationary state $W_{[t_i;t_{i+1}]}$ of the project.

The convergence of physical and system approaches allows creating a system of balance equations of the stationary state of the CES project (2) to (5).

The law of energy equivalence (the first law of thermodynamics) and the law of inevitability of losses when performing certain work (the second law of thermodynamics) are the physical laws on which the functioning of CES is based.

According to the law of energy conservation, the amount of resources falling into the CES project in state $W_{[t_i;t_{i+1}]}$, is spent on the creation of products: intermediate or final [4], and the generation of a certain amount of waste:

$$E_{[t_i;t_{i+1}]} = R_{[t_i;t_{i+1}]} + Z_{[t_i;t_{i+1}]}. \quad (2)$$

From the standpoint of the energy balance, equation (2) takes the form:

$$E_{[t_i;t_{i+1}]} - R_{[t_i;t_{i+1}]} - Z_{[t_i;t_{i+1}]} = 0, \quad (3)$$

That is, the material, informational and energy resource potential of the project is spent on obtaining a positive result – a product and a negative one – waste.

To reduce the negative impact on the environment, it is necessary to reduce the amount of waste:

$$Z_{[t_i;t_{i+1}]} = E_{[t_i;t_{i+1}]} - R_{[t_i;t_{i+1}]} \to \min, \quad (4)$$

which is possible by reducing the total amount of input resources $E_{[t_i;t_{i+1}]}$, used to produce the product or by maximizing the use of output resources (ideally without residue, $E_{[t_i;t_{i+1}]} = R_{[t_i;t_{i+1}]}$).

It is possible to reduce the amount of waste not only by reducing the volume of their generation but also by using it as secondary products, raw materials, and materials because:

$$Z_{[t_i;t_{i+1}]} = S_{[t_i;t_{i+1}]} + L_{[t_i;t_{i+1}]}, \quad (5)$$

where $S_{[t_i;t_{i+1}]}$ – the amount of secondary resources generated as a result of the implementation of the stationary state $W_{[t_i;t_{i+1}]}$ of the project; $L_{[t_i;t_{i+1}]}$ – the amount of non-renewable waste generated as a result of the implementation of the stationary state $W_{[t_i;t_{i+1}]}$ of the project.

The proposed system of balance equations substantiates the urgency of the goal – reducing the eco-destructive impact of the CES project on the environment by reducing the waste produced by the project. In this case, $R_{[t_i;t_{i+1}]} \to \max$, $L_{[t_i;t_{i+1}]} \to \min$ provided $Z_{[t_i;t_{i+1}]} \to \min$.

The system of objective functions of the stationary state $W_{[t_i;t_{i+1}]}$ metabolism of the CES project can be written as follows:

$$E_{[t_i;t_{i+1}]} = R_{[t_i;t_{i+1}]} + S_{[t_i;t_{i+1}]} + L_{[t_i;t_{i+1}]} \to \min, \quad (6)$$

$$R_{[t_i;t_{i+1}]} = E_{[t_i;t_{i+1}]} - S_{[t_i;t_{i+1}]} - L_{[t_i;t_{i+1}]} \to \max, \quad (7)$$

$$S_{[t_i;t_{i+1}]} = E_{[t_i;t_{i+1}]} - R_{[t_i;t_{i+1}]} - L_{[t_i;t_{i+1}]} \to \max, \quad (8)$$

$$L_{[t_i;t_{i+1}]} = E_{[t_i;t_{i+1}]} - R_{[t_i;t_{i+1}]} - S_{[t_i;t_{i+1}]} \to \min; \quad (9)$$

– criterion (6) corresponds to the tendency to minimize the use of input resources in the implementation of the stationary state $W_{[t_i;t_{i+1}]}$ of the project;

– criterion (7) reflects the need for the most useful use of input resources in the process of creating a project product that corresponds to the stationary state $W_{[t_i;t_{i+1}]}$ of the project;

– criterion (8) reflects the need to increase the volume of reuse of secondary inventory resulting from the implementation of the stationary state $W_{[t_i;t_{i+1}]}$ of the project;

– criterion (9) reflects the need to minimize the amount of non-renewable waste generated as a result of the implementation of the stationary state $W_{[t_i;t_{i+1}]}$ of the project.

During the LC, the CES project changes its state according to the time intervals $[t_i;t_{i+1}]$ $(i=\overline{1;I-1})$, where t_i is the beginning, t_{i+1} is the end of the time interval corresponding to the duration of the LC phase of the project.

The stationary state $W_{[t_i;t_{i+1}]}$ of the project, corresponding to the time interval $[t_i;t_{i+1}]$, takes into account the intermediate products $P^{fj}_{[t_i;t_{i+1}]}$, of the stage j, $(j=\overline{1;J})$ of phase f, $(i=\overline{1;F})$, formed at this interval. Each time interval corresponds to a set of intermediate products of the phases of the CES project.

According to the stationary state $W_{[t_i;t_{i+1}]}$ model of the project, each of the intermediate products $P^{fj}_{[t_i;t_{i+1}]}$ corresponds to certain values of input resources and waste (Table 1).

Table 1

Characteristics of stationary states of LC stages of the CES project

Time interval	Stationary state of the project	Parameters of the stationary state of the project
$[t_0; t_1]$	$W_{[t_0;t_1]}$	$W^{11}_{[t_0;t_1]} = \left\langle E^{11}_{[t_0;t_1]}, R^{11}_{[t_0;t_1]}, S^{11}_{[t_0;t_1]}, L^{11}_{[t_0;t_1]} \right\rangle$
$[t_1; t_2]$	$W_{[t_1;t_2]} = W^{21}_{[t_1;t_2]} \cup W^{51}_{[t_1;t_2]}$	$W^{21}_{[t_1;t_2]} = \left\langle E^{21}_{[t_1;t_2]}, R^{21}_{[t_1;t_2]}, S^{21}_{[t_1;t_2]}, L^{21}_{[t_1;t_2]} \right\rangle$
		$W^{51}_{[t_1;t_2]} = \left\langle E^{51}_{[t_1;t_2]}, R^{51}_{[t_1;t_2]}, S^{51}_{[t_1;t_2]}, L^{51}_{[t_1;t_2]} \right\rangle$
$[t_2; t_3]$	$W_{[t_2;t_3]} = W^{31}_{[t_2;t_3]} \cup W^{52}_{[t_2;t_3]}$	$W^{31}_{[t_2;t_3]} = \left\langle E^{31}_{[t_2;t_3]}, R^{31}_{[t_2;t_3]}, S^{31}_{[t_2;t_3]}, L^{31}_{[t_2;t_3]} \right\rangle$
		$W^{52}_{[t_2;t_3]} = \left\langle E^{52}_{[t_2;t_3]}, R^{52}_{[t_2;t_3]}, S^{52}_{[t_2;t_3]}, L^{52}_{[t_2;t_3]} \right\rangle$
$[t_3; t_4]$	$W_{[t_3;t_4]} = W^{32}_{[t_3;t_4]} \cup W^{41}_{[t_3;t_4]} \cup W^{53}_{[t_3;t_4]}$	$W^{32}_{[t_3;t_4]} = \left\langle E^{32}_{[t_3;t_4]}, R^{32}_{[t_3;t_4]}, S^{32}_{[t_3;t_4]}, L^{32}_{[t_3;t_4]} \right\rangle$
		$W^{41}_{[t_3;t_4]} = \left\langle E^{41}_{[t_3;t_4]}, R^{41}_{[t_3;t_4]}, S^{41}_{[t_3;t_4]}, L^{41}_{[t_3;t_4]} \right\rangle$
		$W^{53}_{[t_3;t_4]} = \left\langle E^{53}_{[t_3;t_4]}, R^{53}_{[t_3;t_4]}, S^{53}_{[t_3;t_4]}, L^{53}_{[t_3;t_4]} \right\rangle$
$[t_4; t_5]$	$W_{[t_4;t_5]} = W^{42}_{[t_4;t_5]} \cup W^{54}_{[t_4;t_5]}$	$W^{42}_{[t_4;t_5]} = \left\langle E^{42}_{[t_4;t_5]}, R^{42}_{[t_4;t_5]}, S^{42}_{[t_4;t_5]}, L^{42}_{[t_4;t_5]} \right\rangle$
		$W^{54}_{[t_4;t_5]} = \left\langle E^{54}_{[t_4;t_5]}, R^{54}_{[t_4;t_5]}, S^{54}_{[t_4;t_5]}, L^{54}_{[t_4;t_5]} \right\rangle$
$[t_5; t_6]$	$W_{[t_5;t_6]}$	$W^{55}_{[t_5;t_6]} = \left\langle E^{55}_{[t_5;t_6]}, R^{55}_{[t_5;t_6]}, S^{55}_{[t_5;t_6]}, L^{55}_{[t_5;t_6]} \right\rangle$

The principle of reducing the ecodestructive impact on the environment from the products of the CES project, which meets the needs of greening economic systems, is described by the task of multicriteria optimization.

The total resource costs for ensuring homeostasis of the stationary state $W_{[t_i;t_{i+1}]}$ of the CES project are defined as the objective function:

$$E_{[t_i;t_{i+1}]} = \sum_{f=1}^{F}\sum_{j=1}^{J} R^{fj}_{[t_i;t_{i+1}]} + \\ +\sum_{f=1}^{F}\sum_{j=1}^{J} S^{fj}_{[t_i;t_{i+1}]} + \sum_{f=1}^{F}\sum_{j=1}^{J} L^{fj}_{[t_i;t_{i+1}]} \to \min, \quad (10)$$

where $R^{fj}_{[t_i;t_{i+1}]}$ are the material resources used to create the intermediate product of the stage $j, (j=\overline{1;J})$ of phase $f, (i=\overline{1;F})$ at the time interval $[t_i; t_{i+1}]$; $S^{fj}_{[t_i;t_{i+1}]}$ – secondary material resources formed when creating an intermediate product of the stage $j, (j=\overline{1;J})$ of the phase $f, (i=\overline{1;F})$ at the time interval $[t_i;t_{i+1}]$; $L^{fj}_{[t_i;t_{i+1}]}$ – non-renewable waste generated during the creation of an intermediate product of the stage $j, (j=\overline{1;J})$ of the phase $f, (i=\overline{1;F})$ at the time interval $[t_i; t_{i+1}]$.

The amount of material resources $R^{fj}_{[t_i;t_{i+1}]}$, used to create an intermediate product $P^{fj}_{[t_i;t_{i+1}]}$ during the stationary state $W_{[t_i;t_{i+1}]}$ of the CES project, as part of the primary resources withdrawn from the natural environment, should be maximum:

$$R_{[t_i;t_{i+1}]} = \sum_{f=1}^{F}\sum_{j=1}^{J} R^{fj}_{[t_i;t_{i+1}]} = \sum_{f=1}^{F}\sum_{j=1}^{J} E^{fj}_{[t_i;t_{i+1}]} - \\ -\sum_{f=1}^{F}\sum_{j=1}^{J} S^{fj}_{[t_i;t_{i+1}]} - \sum_{f=1}^{F}\sum_{j=1}^{J} L^{fj}_{[t_i;t_{i+1}]} \to \max. \quad (11)$$

The amount of material resources within the total amount of resources used that can be reused as a result of maintaining the homeostasis of the stationary state $W_{[t_i;t_{i+1}]}$ of the CES project should be maximum:

$$S_{[t_i;t_{i+1}]} = \sum_{f=1}^{F}\sum_{j=1}^{J} S^{fj}_{[t_i;t_{i+1}]} = \sum_{f=1}^{F}\sum_{j=1}^{J} E^{fj}_{[t_i;t_{i+1}]} - \\ -\sum_{f=1}^{F}\sum_{j=1}^{J} R^{fj}_{[t_i;t_{i+1}]} - \sum_{f=1}^{F}\sum_{j=1}^{J} L^{fj}_{[t_i;t_{i+1}]} \to \max. \quad (12)$$

The amount of material resources that are not subject to secondary use and as a result of maintaining the homeostasis of the stationary state $W_{[t_i;t_{i+1}]}$ of the CES project fall into the environment should be minimal:

$$L_{[t_i;t_{i+1}]} = \sum_{f=1}^{F}\sum_{j=1}^{J} L^{fj}_{[t_i;t_{i+1}]} = \sum_{f=1}^{F}\sum_{j=1}^{J} E^{fj}_{[t_i;t_{i+1}]} - \\ -\sum_{f=1}^{F}\sum_{j=1}^{J} R^{fj}_{[t_i;t_{i+1}]} - \sum_{f=1}^{F}\sum_{j=1}^{J} S^{fj}_{[t_i;t_{i+1}]} \to \min. \quad (13)$$

The criteria for the efficiency of the use of material resources in the CES project are interdependent – according to the equation of the resource balance of the project, the amount of input resources of the stationary state of the project is equal to the number of output resources.

Solving this type of multicriteria optimization problem is proposed using the method of changing constraints. Therefore, the total resource costs for ensuring homeostasis of the stationary state $W_{[t_i;t_{i+1}]}$ of the CES project are defined as the objective function (10). Resource costs for creating a project product, as well as converted into secondary material resources and resources that are not subject to further use, are defined as control parameters. Their value in the mathematical model has a constraint (14) to (16):

$$R^{fj\min}_{[t_i;t_{i+1}]} \le R^{fj}_{[t_i;t_{i+1}]} \le R^{fj\max}_{[t_i;t_{i+1}]}, \quad (14)$$

$$S^{fj\min}_{[t_i;t_{i+1}]} \le S^{fj}_{[t_i;t_{i+1}]} \le S^{fj\max}_{[t_i;t_{i+1}]}, \quad (15)$$

$$L^{fj}_{[t_i;t_{i+1}]} \le L^{fj\max}_{[t_i;t_{i+1}]}, \quad (16)$$

$$\left(i=\overline{1;F}\right), \left(j=\overline{1;J}\right), \left(i=\overline{1;I-1}\right).$$

The solution to the problem of multicriteria optimization, represented by the proposed mathematical model of stationary state metabolism of the CES project, allows determining the optimal ratio of resources $\{R^{fj}_{[t_i;t_{i+1}]}, S^{fj}_{[t_i;t_{i+1}]}, L^{fj}_{[t_i;t_{i+1}]}\}$ in the resource balance. The optimal ratio $\{R^{fj}_{[t_i;t_{i+1}]}, S^{fj}_{[t_i;t_{i+1}]}, L^{fj}_{[t_i;t_{i+1}]}\}$ not only ensures the homeostasis of the «project» system but also minimizes the ecodestructive impact of its metabolism on the environment.

5. 2. Determination of the ecological and economic value of the ecologistics system project

In general, the development process of an CES project can be defined as a chain of successive stationary states that correspond to intermediate products of the project phases synthesized at time intervals $[t_i; t_{i+1}]$, $(i=\overline{1;I-1})$ of LC of the project. To move from a stationary state $W_{[t_i;t_{i+1}]}$ to a state $W_{[t_{i+1};t_{i+2}]}$, it is necessary that the system reaches a certain level of steady-state homeostasis, which is possible in the case of metabolism in the internal and external environment of the system. There are many alternative options for stationary states of the project, which correspond to certain product parameters that reflect the resource potential of the project.

Taking into account the specific features of the CES, as a criterion of project effectiveness, it is proposed to apply the environmental and economic value of the project, Ecological and Economic Value (EEV), which takes into account both the economic and environmental component of the project efficiency. The economic aspect is determined by the market value of products obtained as a result of the project; the environmental aspect is determined by taking into account the environmental component in the project's cash flows.

For an alternative variant of the stationary state $W_{[t_i;t_{i+1}]}$ of the CES project, which corresponds to the set of intermediate products of stages $j\,(j=\overline{1;J})$ of phases $f\,(f=\overline{1;F})$ of the project, synthesized over the time interval $[t_i; t_{i+1}]$ $(i=\overline{1;I-1})$ of LC of the project, it is possible to assess the environmental and economic value by the formula:

$$EEV\left(W_{[t_i;t_{i+1}]}\right) = EEV\left(\sum_{f=1}^{F}\sum_{j=1}^{J} P^{fj}_{[t_i;t_{i+1}]}\right) = \\ = \sum_{f=1}^{F}\sum_{j=1}^{J}\left(V\left(P^{fj}_{[t_i;t_{i+1}]}\right) + CF\left(P^{fj}_{[t_i;t_{i+1}]}\right)\right)\cdot\left(q^{fj}\right)^{t_{i+1}}, \quad (17)$$

where $V(P^{fj}_{[t_i;t_{i+1}]})$ is the market value of the product $P^{fj}_{[t_i;t_{i+1}]}$ of stage j of phase f of the project flowing over the time interval $[t_i; t_{i+1}]$; $CF(P^{fj}_{[t_i;t_{i+1}]})$ – cash flows corresponding to the product $P^{fj}_{[t_i;t_{i+1}]}$ of stage j of phase f of the project, flowing over the time interval $[t_i; t_{i+1}]$; q^{fj} – discount factor corresponding to the intermediate product formed during stage j of phase f of the project, which takes place over the time interval $[t_i; t_{i+1}]$.

Isolation of discount coefficients q^{fj} for different time intervals $[t_i; t_{i+1}]$ and products of stages j $(j=\overline{1;J})$ of phases f $(f=\overline{1;F})$ of the CES project are due to the different costs of money used to create or produced by certain products at different time intervals of the project.

To achieve the sustainable development goals, it is necessary to maximize the overall ecological and economic value of the project, consisting of individual environmental and economic values of stationary states $W_{[t_i;t_{i+1}]}$:

$$EEV=\sum_{i=0}^{I-1} EEV\left(W_{[t_i;t_{i+1}]}\right)= =\sum_{i=0}^{I-1}\sum_{f=1}^{F}\sum_{j=1}^{J} EEV\left(P^{fj}_{[t_i;t_{i+1}]}\right)\to \max. \quad (18)$$

If we consider the issue of maximizing the ecological and economic value of products from the standpoint of resource balance, it is necessary to determine the following properties of indicators:

– the market value $V(P^{fj}_{[t_i;t_{i+1}]})$ of a product is determined by the real amount of money that can be obtained from the sale of the product $P^{fj}_{[t_i;t_{i+1}]}$;

– cash flows $CF(P^{fj}_{[t_i;t_{i+1}]})$ consist of incoming $IF(P^{fj}_{[t_i;t_{i+1}]})$ and outgoing $OF(P^{fj}_{[t_i;t_{i+1}]})$ cash flows generated by a product $P^{fj}_{[t_i;t_{i+1}]}$;

– incoming cash flows $IF(P^{fj}_{[t_i;t_{i+1}]})$ are generated when using the product and using secondary material resources;

– outgoing cash flows $OF(P^{fj}_{[t_i;t_{i+1}]})$ depend on the cost of acquiring resources spent on product creation and the cost of utilizing material resources that are not recyclable.

The use of material resources is accompanied by the formation of:

1) incoming cash flows of the project:

– $\int_{t_i}^{t_{i+1}} if\left(C_{P^{fj}_{[t_i;t_{i+1}]}}\right)(t)\mathrm{d}t$ – incoming cash flows from product sales $P^{fj}_{[t_i;t_{i+1}]}$;

– $\int_{t_i}^{t_{i+1}} if\left(S_{P^{fj}_{[t_i;t_{i+1}]}}\right)(t)\mathrm{d}t$ – incoming cash flows from the use of secondary material resources generated in the process of creating a product $P^{fj}_{[t_i;t_{i+1}]}$;

2) outgoing cash flows of the project:

– $\int_{t_i}^{t_{i+1}} of\left(R_{P^{fj}_{[t_i;t_{i+1}]}}\right)(t)\mathrm{d}t$ – outgoing cash flows for resource support for product creation $P^{fj}_{[t_i;t_{i+1}]}$;

– $\int_{t_i}^{t_{i+1}} of\left(S_{P^{fj}_{[t_i;t_{i+1}]}}\right)(t)\mathrm{d}t$ – initial cash flows for the use of secondary material resources formed in the process of creating a product $P^{fj}_{[t_i;t_{i+1}]}$;

– $\int_{t_i}^{t_{i+1}} of\left(L_{P^{fj}_{[t_i;t_{i+1}]}}\right)(t)\mathrm{d}t$ – initial cash flows for the utilization of material resources generated in the process of creating a product $P^{fj}_{[t_i;t_{i+1}]}$.

Calculation formulas for determining the ecological and economic value of stationary states $W_{[t_i;t_{i+1}]}$ of the CES project are given in Table 2.

Table 2

CES project cash flows

Stationary project state	Incoming and outgoing cash flows during stationary states of the project
1	2
$W_{[t_0;t_1]}$	$CF_{[t_0;t_1]}=CF\left(P^{11}_{[t_0;t_1]}\right)=\int_0^1 cf_{P^{11}_{[t_0;t_1]}}(t)\mathrm{d}t=\int_0^1 of\left(R_{P^{11}_{[t_0;t_1]}}\right)(t)\mathrm{d}t$ (19)
$W_{[t_1;t_2]}$	$CF_{[t_1;t_2]}=CF\left(P^{21}_{[t_1;t_2]}\right)+CF\left(P^{51}_{[t_1;t_2]}\right)=\int_1^2 cf_{P^{21}_{[t_1;t_2]}}(t)\mathrm{d}t+\int_1^2 cf_{P^{51}_{[t_1;t_2]}}(t)\mathrm{d}t,$ (20) $\int_1^2 cf_{P^{21}_{[t_1;t_2]}}(t)\mathrm{d}t=\int_1^2 if_{P^{21}_{[t_1;t_2]}}(t)\mathrm{d}t+\int_1^2 of_{P^{21}_{[t_1;t_2]}}(t)\mathrm{d}t=\int_1^2 if\left(S_{P^{21}_{[t_1;t_2]}}\right)(t)\mathrm{d}t+\int_1^2 of\left(S_{P^{21}_{[t_1;t_2]}}\right)(t)\mathrm{d}t+\int_1^2 of\left(R_{P^{21}_{[t_1;t_2]}}\right)(t)\mathrm{d}t+\int_1^2 of\left(L_{P^{21}_{[t_1;t_2]}}\right)(t)\mathrm{d}t,$ (21) $\int_1^2 cf_{P^{51}_{[t_1;t_2]}}(t)\mathrm{d}t=\int_1^2 if_{P^{51}_{[t_1;t_2]}}(t)\mathrm{d}t+\int_1^2 of_{P^{51}_{[t_1;t_2]}}(t)\mathrm{d}t=\int_1^2 if\left(S_{P^{51}_{[t_1;t_2]}}\right)(t)\mathrm{d}t+\int_1^2 of\left(S_{P^{51}_{[t_1;t_2]}}\right)(t)\mathrm{d}t+\int_1^2 of\left(R_{P^{51}_{[t_1;t_2]}}\right)(t)\mathrm{d}t+\int_1^2 of\left(L_{P^{51}_{[t_1;t_2]}}\right)(t)\mathrm{d}t$ (22)
$W_{[t_2;t_3]}$	$CF_{[t_2;t_3]}=CF\left(P^{31}_{[t_2;t_3]}\right)+CF\left(P^{52}_{[t_2;t_3]}\right)=\int_2^3 cf_{P^{31}_{[t_2;t_3]}}(t)\mathrm{d}t+\int_2^3 cf_{P^{52}_{[t_2;t_3]}}(t)\mathrm{d}t,$ (23) $\int_2^3 cf_{P^{31}_{[t_2;t_3]}}(t)\mathrm{d}t=\int_2^3 if_{P^{31}_{[t_2;t_3]}}(t)\mathrm{d}t+\int_2^3 of_{P^{31}_{[t_2;t_3]}}(t)\mathrm{d}t=\int_2^3 if\left(C_{P^{31}_{[t_2;t_3]}}\right)(t)\mathrm{d}t+\int_2^3 if\left(S_{P^{31}_{[t_2;t_3]}}\right)(t)\mathrm{d}t+\int_2^3 of\left(R_{P^{31}_{[t_2;t_3]}}\right)(t)\mathrm{d}t+$ $+\int_2^3 of\left(S_{P^{31}_{[t_2;t_3]}}\right)(t)\mathrm{d}t+\int_2^3 of\left(L_{P^{31}_{[t_2;t_3]}}\right)(t)\mathrm{d}t,$ (24) $\int_2^3 cf_{P^{52}_{[t_2;t_3]}}(t)\mathrm{d}t=\int_2^3 if_{P^{52}_{[t_2;t_3]}}(t)\mathrm{d}t+\int_2^3 of_{P^{52}_{[t_2;t_3]}}(t)\mathrm{d}t=\int_2^3 if\left(S_{P^{52}_{[t_2;t_3]}}\right)(t)\mathrm{d}t+\int_2^3 of\left(S_{P^{52}_{[t_2;t_3]}}\right)(t)\mathrm{d}t+\int_2^3 of\left(R_{P^{52}_{[t_2;t_3]}}\right)(t)\mathrm{d}t+\int_2^3 of\left(L_{P^{52}_{[t_2;t_3]}}\right)(t)\mathrm{d}t$ (25)

Continuation of Table 2

1	2
$W_{[t_3;t_4]}$	$CF_{[t_3;t_4]}=CF\left(P^{32}_{[t_3;t_4]}\right)+CF\left(P^{41}_{[t_3;t_4]}\right)+CF\left(P^{53}_{[t_3;t_4]}\right)=\int_3^4 cf_{P^{32}_{[t_3;t_4]}}(t)\mathrm{d}t+\int_3^4 cf_{P^{41}_{[t_3;t_4]}}(t)\mathrm{d}t+\int_3^4 cf_{P^{53}_{[t_3;t_4]}}(t)\mathrm{d}t, \quad (26)$ $\int_3^4 cf_{P^{32}_{[t_3;t_4]}}(t)\mathrm{d}t=\int_3^4 if_{P^{32}_{[t_3;t_4]}}(t)\mathrm{d}t+\int_3^4 of_{P^{32}_{[t_3;t_4]}}(t)\mathrm{d}t=\int_3^4 if\left(C_{P^{32}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 if\left(S_{P^{32}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(R_{P^{32}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(S_{P^{32}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(L_{P^{32}_{[t_3;t_4]}}\right)(t)\mathrm{d}t, \quad (27)$ $\int_3^4 cf_{P^{41}_{[t_3;t_4]}}(t)\mathrm{d}t=\int_3^4 if_{P^{41}_{[t_3;t_4]}}(t)\mathrm{d}t+\int_3^4 of_{P^{41}_{[t_3;t_4]}}(t)\mathrm{d}t=\int_3^4 if\left(C_{P^{41}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 if\left(S_{P^{41}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(R_{P^{41}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(S_{P^{41}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(L_{P^{41}_{[t_3;t_4]}}\right)(t)\mathrm{d}t, \quad (28)$ $\int_3^4 cf_{P^{53}_{[t_3;t_4]}}(t)\mathrm{d}t=\int_3^4 if_{P^{53}_{[t_3;t_4]}}(t)\mathrm{d}t+\int_3^4 of_{P^{53}_{[t_3;t_4]}}(t)\mathrm{d}t=\int_3^4 if\left(S_{P^{53}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(S_{P^{53}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(R_{P^{53}_{[t_3;t_4]}}\right)(t)\mathrm{d}t+\int_3^4 of\left(L_{P^{53}_{[t_3;t_4]}}\right)(t)\mathrm{d}t \quad (29)$
$W_{[t_4;t_5]}$	$CF_{[t_4;t_5]}=CF\left(P^{42}_{[t_4;t_5]}\right)+CF\left(P^{54}_{[t_4;t_5]}\right)=\int_4^5 cf_{P^{42}_{[t_4;t_5]}}(t)\mathrm{d}t+\int_4^5 cf_{P^{54}_{[t_4;t_5]}}(t)\mathrm{d}t, \quad (30)$ $\int_4^5 cf_{P^{42}_{[t_4;t_5]}}(t)\mathrm{d}t=\int_4^5 if_{P^{42}_{[t_4;t_5]}}(t)\mathrm{d}t+\int_4^5 of_{P^{42}_{[t_4;t_5]}}(t)\mathrm{d}t=\int_4^5 if\left(C_{P^{42}_{[t_4;t_5]}}\right)(t)\mathrm{d}t+\int_4^5 if\left(S_{P^{42}_{[t_4;t_5]}}\right)(t)\mathrm{d}t+\int_4^5 of\left(R_{P^{42}_{[t_4;t_5]}}\right)(t)\mathrm{d}t+\int_4^5 of\left(S_{P^{42}_{[t_4;t_5]}}\right)(t)\mathrm{d}t+\int_4^5 of\left(L_{P^{42}_{[t_4;t_5]}}\right)(t)\mathrm{d}t, \quad (31)$ $\int_4^5 cf_{P^{54}_{[t_4;t_5]}}(t)\mathrm{d}t=\int_4^5 if_{P^{54}_{[t_4;t_5]}}(t)\mathrm{d}t+\int_4^5 of_{P^{54}_{[t_4;t_5]}}(t)\mathrm{d}t=\int_4^5 if\left(S_{P^{54}_{[t_4;t_5]}}\right)(t)\mathrm{d}t+\int_4^5 of\left(S_{P^{54}_{[t_4;t_5]}}\right)(t)\mathrm{d}t+\int_4^5 of\left(R_{P^{54}_{[t_4;t_5]}}\right)(t)\mathrm{d}t+\int_4^5 of\left(L_{P^{54}_{[t_4;t_5]}}\right)(t)\mathrm{d}t \quad (32)$
$W_{[t_5;t_6]}$	$CF_{[t_5;t_6]}=CF\left(P^{55}_{[t_5;t_6]}\right)=\int_5^6 cf_{P^{55}_{[t_5;t_6]}}(t)\mathrm{d}t, \quad (33)$ $\int_5^6 cf_{P^{55}_{[t_5;t_6]}}(t)\mathrm{d}t=\int_5^6 if_{P^{55}_{[t_5;t_6]}}(t)\mathrm{d}t+\int_5^6 of_{P^{55}_{[t_5;t_6]}}(t)\mathrm{d}t=\int_5^6 if\left(S_{P^{55}_{[t_5;t_6]}}\right)(t)\mathrm{d}t+\int_5^6 of\left(S_{P^{55}_{[t_5;t_6]}}\right)(t)\mathrm{d}t+\int_5^6 of\left(R_{P^{55}_{[t_5;t_6]}}\right)(t)\mathrm{d}t+\int_5^6 of\left(L_{P^{55}_{[t_5;t_6]}}\right)(t)\mathrm{d}t \quad (34)$

Thus, using formulas (19), (20), it is possible to calculate cash flows corresponding to the resource balance of products formed during the time intervals of the LC of a project.

5. 3. Building a model for balanced development of the ecologistics system project

After calculating the alternative variants of stationary states of the CES project $EEV(W_{[t_i;t_{i+1}]})$ from the set $W^h_{[t_i;t_{i+1}]}$ $(h=\overline{1;H})$, formed at each time interval $[t_i;\, t_{i+1}]$, it is possible to determine the general *EEV* of the CES project using mathematical programming tools – dynamic modeling.

The calculation of the *EEV* of the project should be carried out using a recurrent equation expressing the conditional gain for the previous stationary state $W_{[t_i;t_{i+1}]}$ of the project thru the already known value of the next stationary state $W_{[t_{i+1};t_{i+2}]}$. The recurrent equation in the model is as follows:

$$EEV\left(W^*_{[t_i;t_{i+1}]}\right)=\max\left\{EEV\left(W^h_{[t_i;t_{i+1}]}\right)+EEV\left(W^*_{[t_{i+1};t_{i+2}]}\right)\right\}, \quad (35)$$

where $EEV(W^*_{[t_i;t_{i+1}]})$ is the total *EEV* of the stationary state $W^*_{[t_i;t_{i+1}]}$ of the project; $EEV(W^*_{[t_{i+1};t_{i+2}]})$ – total *EEV* of the stationary state $W^*_{[t_i;t_{i+1}]}$ of the project; $EEV(W^h_{[t_i;t_{i+1}]})$ – *EEV* of an alternative to the stationary state $W^h_{[t_i;t_{i+1}]}$ of the project.

For an CES project, the calculation starts from the stationary state $W_{[t_5;\, t_6]}$, which corresponds to the last stage of the revitalization phase of the project.

Based on the obtained results, the trajectory of the project development is built, which allows achieving the maximum value of the total *EEV* of the project and is represented as a final graph:

$$G=\left\{W^{opt}_{[t_i;t_{i+1}]},Z\left(W^{opt}_{[t_i;t_{i+1}]}\left(W^{opt}_{[t_{i+1};t_{i+2}]}\right)\right)\right\},\left(i=\overline{0;I-1}\right), \quad (36)$$

where $W^{opt}_{[t_i;t_{i+1}]}$ is the set of vertices corresponding to the finite set of optimal stationary states of the CES project; $Z(W^{opt}_{[t_i;t_{i+1}]}(W^{opt}_{[t_{i+1};t_{i+2}]}))$ – a set of directed arcs corresponding to the method of transition from the previous to the next optimal stationary state of the CES project.

The construction of the trajectory of the CES project is carried out by finding on the graph the path from the initial vertex to the final one, which corresponds to the maximum value of the *EEV* of the project.

5. 4. Experimental calculations on the formation of the trajectory of the ecologistics system project

The formation of the trajectory of the CES project is carried out using dynamic programming tools. In the course of solving the task of constructing the trajectory of the development of a hypothetical example of the CES project, four alternatives were used for each of the stationary states of the project, differing in economic and environmental indicators [29]. For each time interval $[t_i; t_{i+1}]$, $(i=\overline{0;I-1})$ of the LC we calculated the value of *EVV* indicators for alternative variants of the CES project (Table 3).

Using the obtained aggregated values of *EEV* for the time intervals $[t_i; t_{i+1}]$, $(i=\overline{0;I-1})$ of LC, by using a dynamic model, the recurrent equation of which is represented by formula (35), 4096 alternative variants of the trajectories of the CES project development were built. For each time interval, 4 alternative variants of stationary state indicators of the project were envisaged.

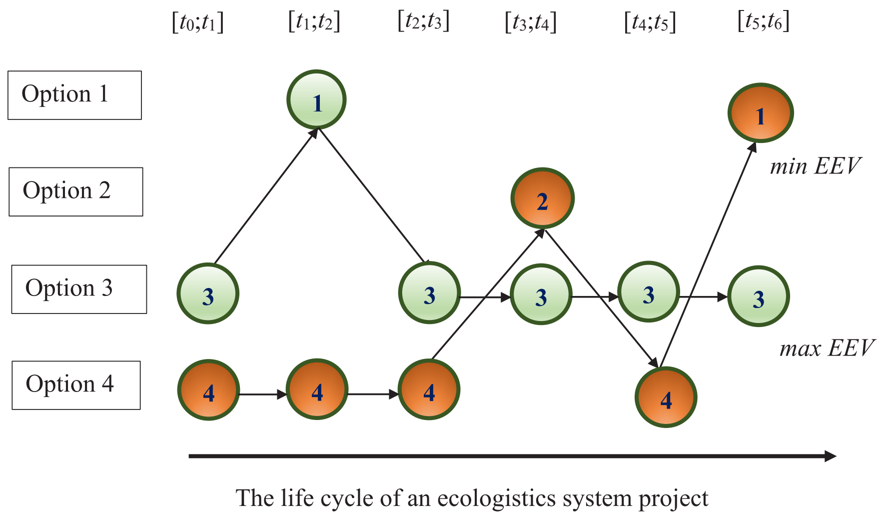

Fig. 3. Development trajectories that ensure the maximum and minimum value of the ecological and economic value of the ecologistics system project

As a result of the calculations, the trajectory of the CES project development was chosen, which makes it possible to achieve the maximum value of *EEV* and consists of stationary states $W_{[t_i;t_{i+1}]}$ of the project:

$$W^3_{[t_0;t_1]} \to W^1_{[t_1;t_2]} \to W^3_{[t_2;t_3]} \to W^3_{[t_3;t_4]} \to W^3_{[t_4;t_5]} \to W^3_{[t_5;t_6]}.$$

The minimum value of the *EEV* of the CES project is achieved at a trajectory consisting of stationary states $W_{[t_i;t_{i+1}]}$ of the project:

$$W^4_{[t_0;t_1]} \to W^4_{[t_1;t_2]} \to W^4_{[t_2;t_3]} \to W^2_{[t_3;t_4]} \to W^4_{[t_4;t_5]} \to W^1_{[t_5;t_6]} \text{ (Fig. 3).}$$

The maximum value of the *EEV* of the CES project is 21877.73 arbitrary units, the minimum is 13617.58 arbitrary units. The ecological and economic effect is 8260.15 arbitrary units.

Thus, it is possible to assert that the use of the proposed model makes it possible to build a set of trajectories of development of the CES project and choose the one that provides the maximum value of *EEV*.

Table 3

Aggregated environmental and economic indicators of the CES project

Project option	Indicators	Time intervals of project LC					
		$[t_0; t_1]$	$[t_1; t_2]$	$[t_2; t_3]$	$[t_3; t_4]$	$[t_4; t_5]$	$[t_5; t_6]$
1	*EVV*	863.64	6628.46	2797.04	3894.89	1335.68	40.88
	V	1200.00	9600.00	3850.00	6280.00	2520.00	310.00
	CF	–250.00	–1215.00	219.00	236.00	–62.00	–231.00
2	*EVV*	954.55	7865.61	3141.43	4139.36	1725.30	71.42
	V	1350.00	11450.00	4320.00	7060.00	2920.00	395.00
	CF	–300.00	–1500.00	250.00	–135.00	255.00	–257.00
3	*EVV*	1140.91	10034.78	3951.88	4869.80	1807.90	72.45
	V	1640.00	14150.00	5100.00	8085.00	3460.00	430.00
	CF	–385.00	–1456.00	649.00	62.00	–133.00	–290.00
4	*EVV*	687.27	5782.61	2391.48	3689.86	1168.86	42.44
	V	940.00	8340.00	3280.00	5870.00	2330.00	280.00
	CF	–184.00	–1025.00	199.00	303.00	–179.00	–198.00

6. Discussion of results of forming the trajectory of balanced development of the ecologistics system project

The proposed mechanism for forming the trajectory of the CES project development is based on the application of an improved model of its LC, which takes into account the peculiarities of CES as an environmentally oriented logistics system. Taking into account the environmental aspect as a component of the balanced development of the CES project justifies the inclusion of ecologically oriented phases in the LC: regenerative and revitalization. In the LC model of the CES project, the phases can proceed in series and in parallel. It is proposed to divide the LC of the CES project into time intervals at which stages of different phases can simultaneously take place (Fig. 1). This makes it possible to imagine the LC of CES as a sequence of changes in stationary states in which the system is at a particular time interval.

The convergence of scientific approaches is expressed in the convergence of systemic and physical approaches. From the standpoint of a systematic approach, the CES project is considered as a complex, open, dynamic, stationary system related to the suprabiological level of the organization. The homeostasis of stationary states of the CES project is maintained through internal and external metabolism. From the standpoint of the physical approach, the CES project obeys the first and second laws of thermodynamics, applying which a system of balance equations of the stationary state of the CES project (2) to (5) has been created. The proposed system of balance equations substantiates the urgency of the goal – to reduce the eco-destructive impact of the CES project on the environment by reducing the waste produced.

During the LC, the CES project changes its state, moving from one stationary state to another. Each stationary state corresponds to a certain time interval and takes into account intermediate products formed at that interval. Each time interval corresponds to a set of intermediate products of the phases of the

CES project. According to the proposed model of the stationary state of the project, each of the intermediate products corresponds to certain values of input resources and waste (Table 1). It is proposed to determine the optimal ratio of resources in the resource balance by using the model of metabolism of the stationary state of the CES project (10), (14) to (16). Solving the problem of multicriteria optimization makes it possible to simultaneously ensure the homeostasis of the system and minimize the ecodestructive impact on the environment.

The process of balanced development of the CES project is defined as a chain of successive stationary states, which correspond to intermediate products synthesized during the LC of the project. According to (11) to (13), there are many alternative steady-state variants of the project, which correspond to certain product parameters reflecting the metabolism of the project. This fact justifies the possibility of choosing from a variety of possible trajectories of the CES project such that will ensure a balance of economic and environmental aspects. As a criterion of efficiency, the *EEV* of the project was applied (17). The introduction of this indicator makes it possible to take into account both the economic and environmental components of project efficiency.

To achieve the sustainable development goals, the overall *EEV* of the project, consisting of individual *EEV* stationary states, is maximized (18). Since each stationary state of the CES project corresponds to a certain ratio of products created at the project stages, the issue of maximizing *EEV* is considered from the standpoint of determining the cash flows necessary to ensure the resource balance of the relevant products (Table 2).

The formation of the trajectory of balanced development of the CES project is carried out by solving the problem of dynamic modeling (35). The trajectory is represented as a final graph (36). Moving along the optimal trajectory during the LC of the project, the maximum value of the *EEV* of the CES project is achieved. This approach allows achieving a balance between the economic and environmental aspects of the project, which meets the conditions for its balanced development and is justified by the principles of the concept of sustainable development.

The advantages of the proposed mechanism for forming the trajectory of balanced development of the CES project are the following:

The use of an improved LC model of the CES project, which, unlike standard approaches, includes environmentally oriented phases, made it possible to take into account the environmental aspect in the process of managing CES projects. Reducing the eco-destructive impact on the environment is currently one of the priorities of economic activity, which allows achieving sustainable development goals.

The convergence of scientific approaches and the view of the CES project as a complex open dynamic stationary system allowed the use of non-standard mechanisms in management. The introduction of the concept of *EEV* of the CES project made it possible to take into account environmental aspects in determining the value of the project. The application of the proposed mechanism for forming the trajectory of the CES project, which has a maximum value of *EEV*, meets the conditions for balanced project development.

The disadvantages of the developed mechanism for forming the trajectory of balanced development of the CES project include:

The proposed mechanism for forming the trajectory of balanced development of the CES project does not take into account the possibility of changing the conditions for project implementation, that is, its application is limited by their determinism. Under modern turbulent conditions, this restriction significantly affects the reliability of the results obtained. Awareness of this fact determines the direction of our further research into the formation of the trajectory of the CES project under conditions of uncertainty.

7. Conclusions

1. A model of stationary state metabolism of the CES project based on the convergence of system and physical approaches has been developed. The systematic approach makes it possible to imagine the CES project as a complex, open, dynamic stationary system of the suprabiological level of the organization, developing from one stationary state to another. A stationary state that CES is in at a time interval $[t_i; t_{i+1}]$ $(i=\overline{1;I-1})$, needs to maintain its homeostasis through metabolism – material-information-energy metabolism. The metabolism of the stationary state is characterized by input and output resources. The physical approach allows applying the first and second laws of thermodynamics to create a system of balance equations, on the basis of which a steady-state metabolism model of the CES project is built. The balanced development of the CES project is aimed at minimizing the cost of input resources for the implementation of the stationary state of the project. At the same time, restrictions on the targeted use of resources and waste should be observed. The solution to the problem of multicriteria optimization, represented by the proposed mathematical model of stationary state metabolism of the CES project, allows determining the optimal ratio of resources in the resource balance and minimizing the ecodestructive impact on the environment.

2. The concept of ecological and economic value of the CES project, which takes into account the economic and environmental component, has been introduced. The economic aspect is determined by the market value of the products obtained as a result of the project; the environmental aspect is determined by taking into account the environmental component in the project's cash flows. Formulas for calculating the *EEV* of a separate stationary state and the entire CES project are provided.

3. A mathematical model of balanced development of the CES project has been developed. Due to the solution of the problem of dynamic programming, such one is chosen from a set of possible trajectories that allows achieving the maximum value of the *EEV* of the CES project and ensuring its balanced development.

4. Experimental calculations confirming the feasibility of using the proposed mechanism to form the trajectory of balanced development of the CES project have been carried out. In accordance with the task, as a result of the calculations, out of 4096 possible trajectories, the trajectory of the CES project was chosen, which makes it possible to achieve the maximum value of *EEV*.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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