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DETERMINING THE INFLUENCE OF TRANSFORMATION CHANGES IN THE LIFE CYCLE ON THE ASSESSMENT OF EFFECTIVENESS OF AN ECOLOGISTIC SYSTEM PROJECT

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The issue of assessing the effectiveness of a project of an ecologistic system using the criterion of «a discounted payback period», which takes into consideration the transformational changes in the project life cycle, was considered.

The specific features of the life cycle of a project of an ecologistic system, in the structure of which it is proposed to include environmentally-oriented regeneration and revitalization phases, were explored. The phases of a life cycle were divided into stages, between which consecutive and parallel relations were established. The project life cycle consists of time intervals, during which from one to three stages of the project phases can run in parallel. A model of the life cycle of an ecologistic system, which shows the relations between time intervals and cash flows that correspond to the stages of the project life cycle phases, was developed. A mathematical formula for calculating the discounted payback period of a project, which takes into consideration the specific features of the formation of cash flows of separate phases of the life cycle of an ecologistic system, was proposed. The application of the formula is possible when assuming the constancy of cash flows of the stages of operational and the regeneration phases, which corresponds to the conditions of uncertainty of their forecasting at the beginning of the project. The functional dependences between the discounted payback period and cash flows during the phases of a project life cycle were studied.

Depending on a phase of the life cycle, the dependence is expressed by a linear, polynomial, or power function. The identification of functional dependences makes it possible to study the dynamics of changes in the discounted payback period with changes in project cash flows, which can be used in forecasting the effectiveness of an ecologistic system project

Keywords: ecologistic system, project, life cycle, cash flows, discounted payback period

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1. Introduction

Preservation of the environment today is one of the most important, urgent, and comprehensive problems on which the future of mankind and life on the planet as a whole depends. The high rate of growth of material production and population, which were the determining factors of civilization development in recent years, led to a dramatic increase in anthropogenic pressure on the environment. Natural assimilation potential no longer ensures the restoration of the status quo of the natural environment – significant changes have begun in ecosystems, which are irreversible in the near future.

Recently, there has been an intensive search for a new strategy for the survival of mankind under conditions of limited natural resources and the deterioration of the natural conditions of existence of humans as biological species [1]. The problem of the future development of civilization, in general, has come to the forefront of scientific research and public awareness in general. The way out of the current situation is the application of the concept of sustainable development, which is a natural reaction of the world community to existing threats and provides for the harmonious coexistence of nature and society. The introduction of the principles of sustainable development involves taking into consideration environmental and social factors in all spheres of human life [2].

Logistics as a field of practical activity makes its negative contribution to the state of the environment, which is explained by an increase in the share of logistic services in the formation of logistic products and the significant eco-destructive component of these services.

Recently, ecological logistics (ecologistics, green logistics) has been used as a modern concept of logistics. Within the concept of sustainable development, ecologistics is considered as an effective approach to the management of material and associated flows in order to reduce environmental and economic damage to the environment [3, 4].

Ecologistics contributes to the prevention and elimination of the consequences of the negative eco-destructive impact on the environment through the transformation of logistic systems, which correspond to the modern linear model of the economy, into ecologistic systems [5]. Closed ecologistic systems make it possible to introduce the principles of the circular economy into economic activity [6, 7].

The transition to a circular economy is becoming global in nature, and the benefits of implementing this concept are getting increasingly apparent. According to experts, the introduction of a closed model will create huge opportunities for the developing of a country, providing annual GDP growth of up to 7 % [8].

Environmentally-oriented logistic systems are a tool for introducing a circular model of the economy. One of the main properties of an ecologistic system is the existence of closed logistic chains, which make it possible to increase the number of products that return to the production cycle in various forms. As a result, the eco-destructive impact on the environment is reduced by minimizing the use of natural resources and reducing environmental pollution by production and consumption wastes [9].

Improvement of the effectiveness of projects of ecologistic systems requires the use of models and methods of modern management methodologies, in particular, project management. Taking into consideration the specific features of this category of projects, due to their environmental orientation, is a relevant issue that requires additional research.

2. Literature review and problem statement

The issues of designing and functioning of ecologistic systems are actively studied by modern scientists. The importance of taking into account environmental requirements in the optimization of logistic structures is noted in paper [10]. The authors propose to solve the problem of optimization of return material flows from consumers to places of production or disposal within the limits of reverse logistics in combination with traditional problems of logistics.

Paper [11] emphasizes the necessity of transition to the economy of the closed cycle, explores the issues of transformation of logistic systems, and develops the structure of a closed supply chain. In article [12], the peculiarities of functioning of direct and reverse material flows are considered, the expediency of introduction of reverse logistic tools into the logistic activity of an enterprise is substantiated. The authors formed the basic models of functioning of reverse material flows under modern economic conditions, revealed the peculiarities of the motion of return and disposable and recyclable reverse material flows.

In articles [10–12], more attention is paid to taking into consideration the technical and technological aspects of the functioning of ecologistic systems during their designing, the problem of the peculiarities of projects of ecologistic systems, which are substantiated by their ecological considerations, is not tackled.

It is possible to enhance the success of the implementation of projects of ecologistic systems through the use of models and methods of project management methodology. From the standpoint of the project approach, an ecologistic system is considered as a unique result obtained from purposeful temporary activity. Thus, a project of creation of an ecologistic system is given a limited period of time from its beginning to completion, which is called the project life cycle [13].

The project approach involves dividing the project life cycle into phases that are characterized by obtaining a specific product. According to the requirements of the World Bank and the United Nations Economic Development Unit (UNIDO), the project life cycle is divided into pre-investment, investment, and operational phases. Paper [14] emphasized that the project life cycle includes the initial, intermediate, and final phases, which is an enlarged version of gradual project splitting. In paper [15], it is proposed to divide a project not only into phases but also into stages, between which a fuzzy correspondence is established. But in research [14, 15], the need to devote time to neutralizing the eco-destructive impact of a project and its products on the environment is not taken into consideration.

The growing importance of the problem of environmental protection and possible impacts associated with the products that are produced and consumed requires the extension of the life cycle through the addition of eco-oriented phases. According to research [16], the life cycle stages should include the purchase of raw materials, production, and pre-processing usage after the end of service life, re-usage and residual disposal. In article [17], the life cycle is understood as successive and interconnected stages of products (or services), from purchasing raw materials or production from natural resources to disposal. The life cycle stages include the purchase of raw materials, designing, production, transportation/supply, use, final treatment, and/or processing, and final disposal. These standards take into consideration the environmental characteristics of a product but do not address the issues of environmental aspects in the life cycles of projects.

Recently, there have been positive trends of taking into consideration the environmental component in the project activity. The P5 standard includes such areas as «Personnel, Planet, Profit, Process, Product» [18]. In paper [19], the P5 standard was developed, a cognitive model of the project life cycle in the form of communications between the states of the project system was constructed, but not enough attention was paid to the environmental component of a project.

A change in views on the duration and composition of the life cycle phases affects the process of forming project parameters – specific characteristics, on the management of which depends on the project success. The importance of project time and costs management is proved by the separation of these problems in certain areas of knowledge of project management methodology [13].

The object and time parameters of a project were explored in [20–23]. It is proposed to optimize the time parameters of a project, based on the parameters of the project products [20]. Object and time parameters of a project are substantiated in study [21]. The authors of papers [22, 23] draw attention to the need to manage the temporal characteristics of life cycle phases. However, the authors of the research do not consider the issue of the impact of the environmental characteristics of project products on the object, cost, and time parameters of a project.

In papers [24, 25], the issues of project time management are considered at the level of studying the formation of the project work schedule. In article [26], it is proposed to use the tools of artificial intelligence to form a schedule of project works. However, environmentally-oriented works of a project do not receive due attention in the time-table and schedule of works.

The method of static and dynamic planning of the characteristics of a project with limited resources is proposed in research [27]. Researchers in papers [28, 29] focus on taking into account the limited resources when determining the project parameters. It is proposed to make compromise decisions between the time and monetary characteristics of a project in case of limited resources in article [30]. But in the above research, the authors, while studying the relationship between limited resources and project parameters very thoroughly, do not separate the environmental component and do not explore its impact on the time and cost parameters of a project.

The performed analysis of scientific research on the subject of the project life cycle and formation of project parameters showed that researchers do not pay enough attention to the impact of the project life cycle characteristics on its effectiveness. The life cycle of a project of an ecologistic system has its own specific features, taking which into consideration will make it possible to determine more accurately the project parameters and their impact on the effectiveness of this type of project.

3. The aim and objectives of the study

The aim of the study is to determine the dependence of the discounted payback period of a project on cash flows during the project life cycle of an ecologistic system. This will make it possible to take into consideration the transformational changes in the life cycle of a project of an ecologistic system due to its environmental focus when assessing the project effectiveness.

To achieve the aim, the following tasks were to be solved:

– to determine the specific features of the life cycle of a project of an ecologistic system;

– to develop the model of the life cycle of a project of an ecologistic system;

– to develop the formula of the discounted payback period of a project, which will take into account the cash flows of the environmentally-oriented phases of a project, and to determine with its help the impact of cash flow of different project phases on its effectiveness.

4. Determining the specific features of the life cycle of a project of an ecologistic system

The tool of the introduction of a new, circular model of the economy is an ecologistic system, which implies a closed logistic system as a set of elements-links, interconnected in the process of managing the motion of logistic flows, which takes into account an eco-destructive impact on the environment [5].

An ecologistic system is based on the creation of recycling and disposal flows, which close logistic chains and ensure the circularity of a system. Recycling and disposal flow return products, their parts, components, materials to the process of production and consumption as secondary material resources, components, and products, which makes it possible to reduce consumption of primary resources and extend the service life of products. Thus, a product goes through certain stages of the life cycle to its full disposal, which is reflected in the standards of environmental management [16, 17]. The product life cycle changes its structure and lasts longer due to the implementation of the process's characteristic of a circular model of economy proposed by the Ellen McArthur Foundation.

Changes in the life cycle of a product are reflected in the composition and duration of the life cycle of a project of its creation, as the life cycle of a product is an integral part of the life cycle of a project. The project life cycle is divided into separate phases, which, in turn, are divided into stages that end with the receipt of intermediate project results. Project phases can differ not only quantitatively, but also qualitatively (having the same name, phases in different application areas may have different content load). Even in one application area, projects can differ in the number and duration of life cycle phases.

The project life cycle of an ecologistic system has differences from the project life cycle of a logistic system in its classical sense, based on the specific features of this type of project. It is proposed to divide the project life cycle of an ecologistic system into traditional pre-investment, investment, and operational phases, as well as environmentally-oriented regeneration and revitalization phases, on which circular processes and works on the ecosystem renewal will be carried out.

At the pre-investment phase, a documented project of an ecologistic system, which must meet all the requirements of project management standards, is designed. The classical definition of a document indicates: a document (from the Latin documentum – an instructive example, sample, proof) is a material object that contains particular information, intended to transmit it in time and space. During the pre-investment phase, project documentation, which is the material carrier of information about a project, is formed from separate documents. Work on project documentation is carried out throughout the phase and includes all project management processes. Based on the information reflected in it, further development of a project until its completion is carried out.

In the investment phase, an ecologistic system in the material representation is created. It is a complex, structured, dynamic system consisting of elements (subsystems, units), interconnected in the process of environmentally-friendly management of the motion of logistic flows. An ecologistic system differs from the logistic one by the existence of the elements that promote the return of material flows. The standard linear logistic system is usually completed by consumers/users of products or services. To ensure the promotion of material flows in direct and reverse directions, it is necessary to create an ecologistic system. In general, it will include the following logistic process participants: suppliers of resources, manufacturers (parts, products), suppliers of services (warehousing, transport, logistic), consumers/users (products, services), centers (collection, disassembly, repair, disposal) (Fig. 1).

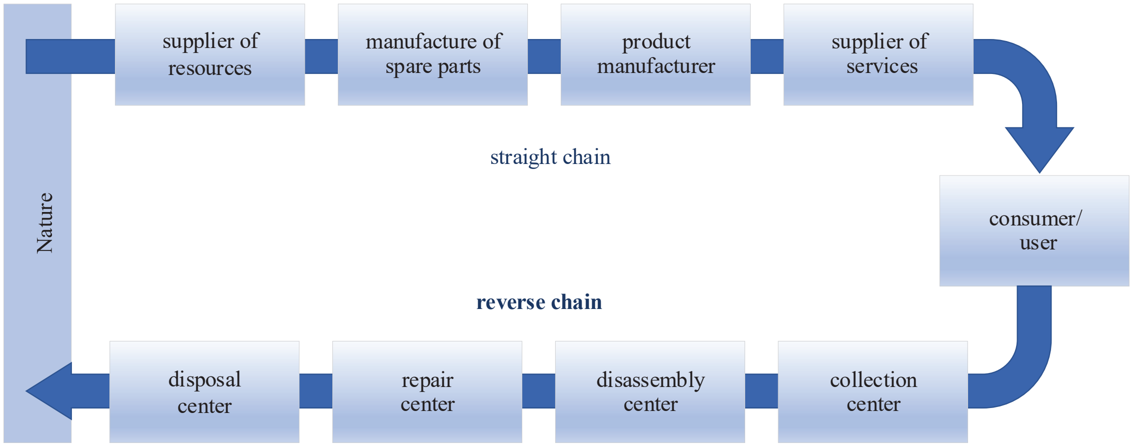


Fig. 1. Ecologistic system

The creation of an ecologistic system in the investment phase makes it possible during the operational and regeneration phases to provide customers with a range of logistic services that contribute to the effective organization of the motion of material flows (direct and reverse). Logistic services (warehousing, transport, sales, supply, etc.) are the parts of a logistic product and are provided during the operational phase of a project. The complex of logistic services provided in the operational phase must ensure the motion of a material flow in compliance with the rules of ecologistics.

In the regeneration phase, recycling logistic services related to the maintenance of return material flows are provided.

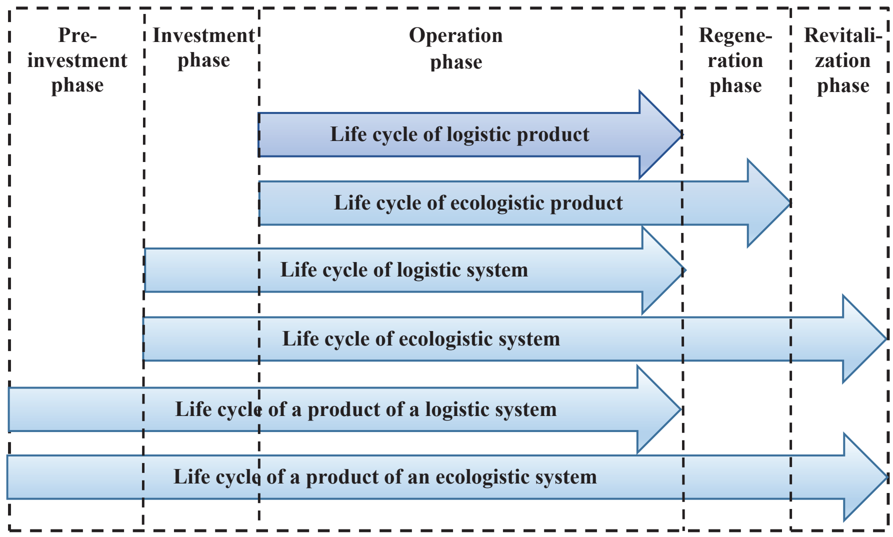


Fig. 2. Structure of life cycles of a project of logistic and ecologistic systems

The logistic operations that form the return logistic services include: collection and return of goods, transportation, warehousing of returned goods and spare parts, recyclables, disassembly of damaged goods or of those with the finished service line, disposal, etc. To provide recycling logistic services, it is necessary to create an ecologistic system, which will include the appropriate infrastructure that will be the material basis for the promotion of recycling and disposal flow.

In the case of the organization of recycling and disposal flows and the closure of logistic chains, we are talking about short-term regeneration, in other words, rapid recovery of products or the formation of recyclable material resources. Establishment and operation of the facilities of the transport and logistic infrastructure of an ecologistic system: cargo terminals, warehousing complexes, distributing, repair centers, and other facilities, as well as the creation of communications between these facilities, have a negative effect on the environment. Negative consequences can appear in the short-term, medium-term, and more often in a long-term prospect. To perform a set of actions to eliminate eco-destructive consequences and restore an ecosystem requires time, which is determined by the duration of the latter, revitalization phase of a project of an ecologistic system (Fig. 2).

Thus, the greening of a logistic system will result in an increase in the number of phases and the duration of the project life cycle.

5. Model of the life cycle of a project of an ecologistic system

The life cycle model is presented in the form of a sequence of stages that can overlap and (or) be repeated cyclically according to the project's field of application, size, complexity. In the projects of ecologistic systems, the phases of the life cycle can proceed both consecutively, one after another, and overlap. The investment phase occurs only after the end of the pre-investment phase. The regeneration phase begins before the end of the operational phase when a product from a final consumer enters the reverse flow of material resources. The revitalization phase begins together with the investment phase, proceeds during the operational and regeneration phases, and lasts until the project completion.

The phases of the life cycle of a project of an ecologistic system make up set $C^f, (f = \overline{1;F})$ are the project phases. Project phases are divided into stages that make up set $S^{fj}, j\ (j = \overline{1;J})$ are the stages of a project phase. The stages are characterized by obtaining intermediate results – intermediate project products.

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 a time interval of the duration of the stage of a project phase that are milestones correspond to the stages of project phases. It is proposed to separate the following significant events of a project that occur at a certain moment within the life cycle of a project of an ecologistic system:

– t_0 is the project beginning, the pre-investment phase;

– t_1 is the beginning of the investment and revitalization phases, completion of the pre-investment phase;

– t_2 is the beginning of the operational phase, completion of the investment phase;

– t_3 is the beginning of the regeneration phase;

– t_4 is the completion of the operation phase;

– t_5 is the completion of the regeneration phase;

– t_6 is the completion of a project, of a revitalization phase.

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

The life cycle of an ecologistic system project includes the phases that differ in the number of stages in their composition:

– phase 1, pre-investment – $P^{11}_{[t_0;t_1]}$;

– phase 2, investment – $I^{21}_{[t_1;t_2]}$;

– phase 3, operation – $O^{31}_{[t_2;t_3]}$, $O^{32}_{[t_3;t_4]}$;

– phase 4, regeneration – $R^{41}_{[t_3;t_4]}$, $R^{42}_{[t_4;t_5]}$;

– phase 5, revitalization – $V^{51}_{[t_1;t_2]}$, $V^{52}_{[t_2;t_3]}$, $V^{53}_{[t_3;t_4]}$, $V^{54}_{[t_4;t_5]}$, $V^{55}_{[t_5;t_6]}$ (Fig. 3) [31].

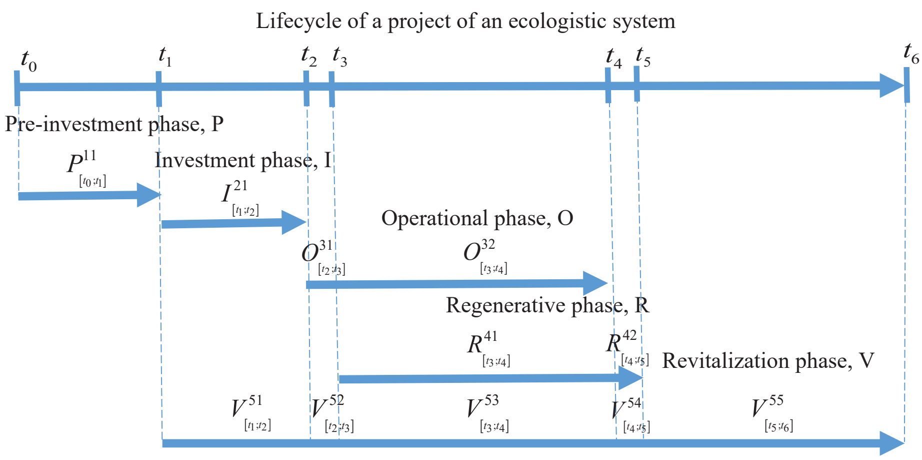


Fig. 3. Graphic model of the lifecycle of a project of an ecologistic system

The stages of the life cycle of a project of an ecologistic system are completed by obtaining a result – an intermediate phase product (in case of a single-stage phase) or a stage product (in case of a multi-stage phase), which belongs to a set of project products $R^{fj}_{[t_i;t_{i+1}]}$, $(f=\overline{1;F})$, $(j=\overline{1;J})$, $(i=\overline{1;I-1})$.

6. Determining the impact of cash flows of different phases of a project of an ecologistic system on its effectiveness

Obtaining project products $R^{fj}_{[t_i;t_{i+1}]}$ is characterized by corresponding cash flows $CF^{fj}_{[t_i;t_{i+1}]}$, $(f=\overline{1;F})$, $(j=\overline{1;J})$, $(i=\overline{1;I-1})$. To characterize cash flows in the life cycle of a project of an ecologistic system, a set of cash flows generated by intermediate project products is used:

$$CF^{fj}_{[t_i;t_{i+1}]}=\left\{\begin{matrix} CF^{11}_{[t_0;t_1]}; CF^{21}_{[t_1;t_2]}; CF^{31}_{[t_2;t_3]}; CF^{32}_{[t_3;t_4]};\\ CF^{41}_{[t_3;t_4]}; CF^{42}_{[t_4;t_5]}; CF^{51}_{[t_1;t_2]}; CF^{52}_{[t_2;t_3]};\\ CF^{53}_{[t_3;t_4]}; CF^{54}_{[t_4;t_5]}; CF^{55}_{[t_5;t_6]} \end{matrix}\right\}.$$

When calculating cash flows that arrive within time interval $[t_i; t_{i+1}]$, $(i=\overline{0;I-1})$, it is necessary to take into account the cash flows generated during the creation of phase products or products of the project's phases or stages that flow during the given interval of time.

$$CF_{[t_i;t_{i+1}]}=\sum_{f=1}^{F}\sum_{j=1}^{J}CF^{fj}_{[t_i;t_{i+1}]}, \quad (1)$$

where $CF^{fj}_{[t_i;t_{i+1}]}$ is the cash flows generated during stage j in phase f of the project that is completed within time interval $[t_i; t_{i+1}]$, $(i=\overline{0;I-1})$.

It is proposed to evaluate the effectiveness of a project of an ecologistic system using the criterion of the *Discounted Payback Period (DPP)* as an integrated indicator that takes into consideration the effectiveness of project management in each time interval of the life cycle.

Since modeling of cash flows is carried out at the beginning of a project when it is difficult to accurately predict their values, we assume that the regeneration phase begins almost simultaneously with the operational phase, in other words, $\Delta t_{23}=(t_3-t_2)\to\min$ and $\Delta t_{45}=(t_5-t_4)\to\min$. In this case, it is possible to assume that cash flows during the operational and regeneration phases take conditionally constant values.

$$CF_{[t_2;t_3]}=CF_{[t_3;t_4]}=CF_{[t_4;t_5]}=$$

$$=CF^{\text{const}}_{[t_i;t_{i+1}]}, \ (i=\overline{2;5}). \quad (2)$$

The discounted payback period corresponds to the point in time when the NPV (Net Present Value) of a project is equal to zero, that is, according to formula:

$$-I_0+\sum_{i=1}^{T}CF_i\cdot q^i=0, \quad (3)$$

where I_0 is the initial investment in a project; $q=1/(1+r)$ is the discount factor; r is the discount rate.

According to [32], to calculate the discounted payback period at constant values of cash flows, we used:

$$DPP=\log_q\left[1-\frac{I_0(1-q)}{CF_{\text{const}}\cdot q}\right], \quad (4)$$

where CF_{const} is the constant cash flows in a project.

Derive the formula of the *DPP* for a project of an ecologistic system, taking into account the specific features of the composition of its life cycle.

Since cash flows during the time interval $[t_2; t_5]$ have constant values, that is $CF_{[t_i;t_{i+1}]}=\text{const}$, $(i=\overline{2;4})$, formula (4) will take the form:

$$CF_{[t_0;t_1]}\cdot q^{t_1}+CF_{[t_1;t_2]}\cdot q^{t_2}+\sum_{i=2}^{T}CF^{\text{const}}_{[t_i;t_{i+1}]}\cdot q^{t_{i+1}}+CF_{[t_5;t_6]}\cdot q^{t_6}=0. \quad (5)$$

Hence, it follows:

$$\sum_{i=2}^{T} CF^{\text{const}}_{[t_i;t_{i+1}]}\cdot q^{t_{i+1}} = -CF_{[t_0;t_1]}\cdot q^{t_1} - CF_{[t_1;t_2]}\cdot q^{t_2} - CF_{[t_5;t_6]}\cdot q^{t_6}, \qquad (6)$$

$$\sum_{i=2}^{T} q^{t_{i+1}} = \frac{-\left(CF_{[t_0;t_1]}\cdot q^{t_1} + CF_{[t_1;t_2]}\cdot q^{t_2} + CF_{[t_5;t_6]}\cdot q^{t_6}\right)}{CF^{\text{const}}_{[t_i;t_{i+1}]}}. \qquad (7)$$

Convert the formula of the sum of the first terms of geometric progression and write it down:

$$\sum_{i=2}^{T} q^{t_{i+1}} = \frac{q^{t_i}\left(1-q^{T}\right)}{1-q}. \qquad (8)$$

Then

$$\frac{q^{t_2}\left(1-q^{T}\right)}{1-q} = \frac{-\left(CF_{[t_0;t_1]}\cdot q^{t_1} + CF_{[t_1;t_2]}\cdot q^{t_2} + CF_{[t_5;t_6]}\cdot q^{t_6}\right)}{CF^{\text{const}}_{[t_i;t_{i+1}]}}, \qquad (9)$$

$$q^{T} = 1 + \frac{\left(CF_{[t_0;t_1]}\cdot q^{t_1} + CF_{[t_1;t_2]}\cdot q^{t_2} + CF_{[t_5;t_6]}\cdot q^{t_6}\right)(1-q)}{CF^{\text{const}}_{[t_i;t_{i+1}]}\cdot q^{t_2}}. \qquad (10)$$

The payback period can be calculated from the following formula:

$$DPP = T = \log_q\left[1 + \frac{\left(CF_{[t_0;t_1]}\cdot q^{t_1} + CF_{[t_1;t_2]}\cdot q^{t_2} + CF_{[t_5;t_6]}\cdot q^{t_6}\right)(1-q)}{CF^{\text{const}}_{[t_i;t_{i+1}]}\cdot q^{t_2}}\right], \qquad (11)$$

if conditions are satisfied:

$$1 + \frac{\left(CF_{[t_0;t_1]}\cdot q^{t_1} + CF_{[t_1;t_2]}\cdot q^{t_2} + CF_{[t_5;t_6]}\cdot q^{t_6}\right)(1-q)}{CF^{\text{const}}_{[t_i;t_{i+1}]}\cdot q^{t_2}} > 0,$$

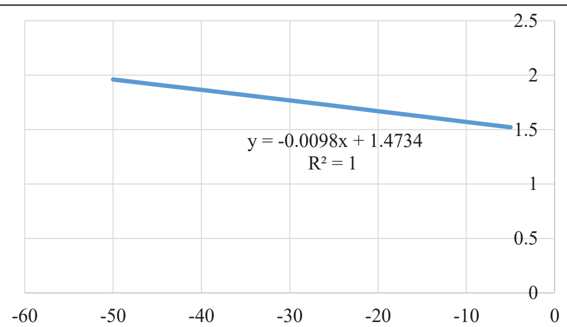
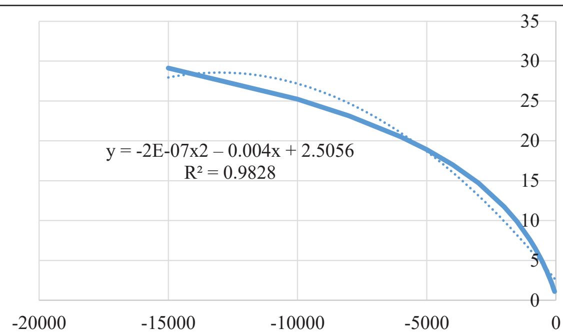
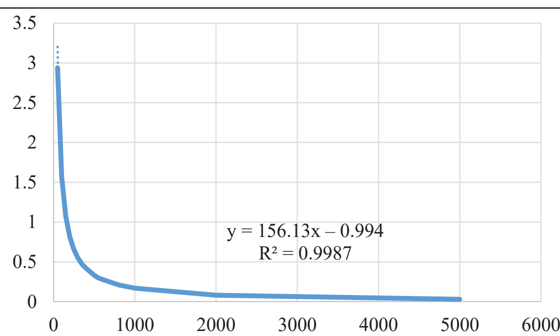
$$q > 0, \quad q \neq 1. \qquad (12)$$

The discounted payback period of a project depends on the values of cash flows in different time intervals $[t_i; t_{i+1}]$, $(i = 0; I-1)$, the duration of these intervals, and the discount factor, the value of which depends on the discount rate.

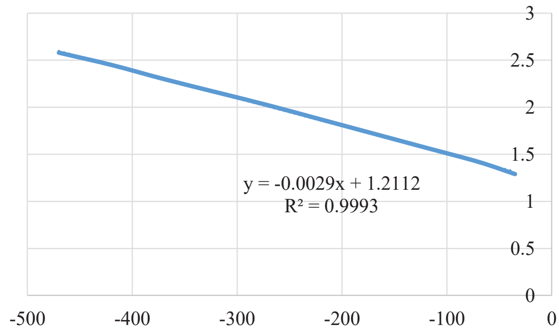
During the study, experimental calculations were performed, which made it possible to identify the dependences between cash flows during the project life cycle and the discounted payback period of a project on an ecologistic system. The obtained results are shown in Table 1.

Table 1

Functional dependences between cash flows and a payback period of a project of an ecologistic system

Indicator	Chart of functional dependence
1	2
Cash flow of pre-investment phase $CF_{[t_0;t_1]}$	
Cash flow of investment phase $CF_{[t_1;t_2]}$	
Cash flows of project's operational and regeneration phases $\sum_{i=2}^{5} CF^{\text{const}(O,R)}_{[t_i;t_{i+1}]}$	

Continuation of Table 1

1	2
Cash flow of revitalization phase $\sum_{i=1}^{5} CF^{V}_{[t_i;t_{i+1}]}$	

The experimental data were approximated, as a result of which the mathematical equations that describe functional dependences between argument and the value of the function were obtained. The cash flow of pre-investment phase $CF_{[t_0;t_1]}$, cash flow of investment phase $CF_{[t_1;t_2]}$, cash flows of project's operational and regeneration phases $\sum_{i=2}^{5} CF^{\text{const}(O,R)}_{[t_i;t_{i+1}]}$, cash flows of revitalization phase $\sum_{i=1}^{5} CF^{V}_{[t_i;t_{i+1}]}$ are the arguments of the function. The value of the function is discounted payback period of a project of an ecologistic system *DPP*.

For each of the analyzed parameters, the degree of approximation was determined with the help of approximation reliability R^2 and the most appropriate functional dependence was chosen.

6. Discussion of results of studying the dependence of discounted payback period on the cash flows of an ecologistic system project

The presented model of the life cycle of a project of an ecologistic system takes into consideration the specific features of this type of project due to the inclusion in the life cycle of ecologically oriented phases (Fig. 2). Thus, the life cycle of an ecologistic system is longer than the life cycle of a logistic system.

Transformational changes in the structure and the duration of the life cycle of a project of an ecologistic system led to the changes in the project's cash flows, which, according to formula (1), are calculated as the sum of cash flows generated over time intervals $[t_i; t_{i+1}]$, $(i=\overline{0;I-1})$. In contrast to the life cycle of a logistic system, the phases of the life cycle of an ecologistic system can occur sequentially and in parallel, as shown in Fig. 3. This structure of the life cycle influenced the formation of cash flows of a project of an ecological system – each time interval corresponds to the sum of cash flows of phases (in the case of single-stage phases) and cash flows of stages (in the case of multi-stage phases) of a project.

Such features in the formation of cash flows during the life cycle of a project of an ecologistic system need to be taken into consideration when assessing the effectiveness of a project. The paper proposes to apply formula (11) when calculating the discounted payback period of a project, assuming that cash flows during the operational and regeneration phases are conditionally constant.

The application of the proposed calculation formula (11) made it possible to determine functional relations between the cash flows of different phases of the life cycle of a project of an ecologistic system and the discounted payback period.

The performed study showed that the dependence between the discounted payback period DPP and cash flow of the investment phase $CF_{[t_1;t_2]}$ is described by a polynomial (square trinomial) $y=-2\text{E-}07x^2-0.004x+2.5056$ at approximation reliability $R^2=0.9828$. Thus, the analytic expression to determine the dependence is the polynomial function of the form $y=ax^2+bx+c$ $(a\neq 0, b\neq 0)$ with the region of determining $(-\infty;\ 0)$. There is an inverse dependence between the payback period and the cash flows of the investment phase, an increase in the payback period gradually slows down at an increase in investment costs in the creation of an ecologistic system.

Dependence of the discounted payback period DPP on cash flows of the project's operational and regeneration phases $\sum_{i=2}^{5} CF^{\text{const}(O,R)}_{[t_i;t_{i+1}]}$ is expressed by function $y=156.13x^{-0.994}$ with approximation reliability $R^2=0.9987$. The analytical expression to determine the dependence is the power function of the form $y=ax^n$ $(a\neq 0)$ with the region of determining $(0;\ +\infty)$. There is a direct relationship between the payback period and the cash flows of the operational and regeneration phases, the rate of an increase in the payback period slows down at an increase in cash flows.

The dependence that is observed between the discounted payback period and cash flows of the pre-investment and revitalization phases is linear and is expressed by function $y=-0.0098x+1.4734$ with approximation reliability $R^2=1$ and $y=-0.0029x+1.2112$ with approximation reliability $R^2=0.9993$, respectively. The dependence in both cases is expressed analytically by a linear function of the form of $y=kx+b$ $(k\neq 0)$ with the region of determining function $(-\infty; 0)$. There is an inverse dependence between the payback period and the costs of the pre-investment and investment phases.

The conducted study revealed the dependences between the criterion of project effectiveness – the discounted payback period and cash flows, which received functional expression. The dynamics of changes in the payback period are represented by various mathematical functions depending on the phase, to which the cash flows belong. Detection of this phenomenon will make it possible to predict the changes in the payback period of a project depending on the changes in cash flows of each phase of the project life cycle.

7. Conclusions

1. The modern linear model of the economy is not perfect, as it constantly requires the involvement of additional primary resources, which passing through a man-made system as a result produce a large amount of waste. The tool for introducing a more humane circular model is an ecologistic system, which makes it possible to significantly reduce the eco-destructive impact on the environment through the creation of closed logistic chains. An ecologistic system has specific characteristics that distinguish it from a logistic system. In particular, the project life cycle of an ecologistic system includes ecologically-oriented phases, during which measures are taken to preserve and restore the ecosystem.

2. The model of the life cycle of a project of an ecologistic system includes five phases: pre-investment, investment, operational, regeneration, and revitalization, which take place over six time intervals. The pre-investment, investment, and operational phases are carried out sequentially, the regeneration phase begins immediately after the start of the operational phase, the revitalization phase proceeds in parallel with the investment, operational, and regeneration phases. The end of the revitalization phase means the end of a project. The model of the life cycle of an ecologistic system, in which the life cycle is divided into phases, stages, and time intervals, was presented.

3. A formula for calculating the discounted payback period of a project of an ecologistic system, which takes into consideration the specifics of cash flows of project phases, was developed. The application of the formula is possible on the condition that cash flows from the beginning of the operational phase to the end of the regeneration phase are conditionally constant. Due to the use of the proposed formula, the functional dependences between the discounted payback period and cash flows during the phases of the project life cycle were determined. It was found that the dependence of the project payback on cash flows has a different nature at different phases of the life cycle. There is a linear relationship between the discounted payback period and the cash flows of the pre-investment and revitalization phases. The dependence on the cash flows of the investment phase is expressed by the polynomial quadratic function, and the cash flows of the operational and regeneration phases are expressed by the power function. Identification of functional dependences makes it possible to explore the dynamics of changes in the discounted payback period and to predict its value in the event of changes in project cash flows.

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