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DEVELOPMENT OF A CASH FLOW MODEL FOR THE ECO-LOGISTICS SYSTEM PROJECT

The object of this study is the flow of funds received during the life cycle of the project of an eco-logistics system as a modern transformational model of the logistics system, which makes it possible to achieve the environmental goals within the concept of sustainable development. Changing the worldview of mankind requires the application of contemporary approaches for managing the projects of eco-logistics systems that meet the requirements for reducing the eco-destructive impact on the environment.

The need to take into consideration and eliminate the negative consequences of the functioning of the eco-logistics system has led to the need to prolong the life cycle of the project through the introduction of additional environmentally-oriented phases: regenerative and revitalization. Changing the composition of a life cycle affects the cash flows generated throughout the life cycle of the project that are dependent on the factors of the internal environment and the external environment. One of the most complicated issues in assessing the effectiveness of the project of the eco-logistics system is the modeling of cash flows at different stages of the project.

The project management methodology has been applied to determine the cash flow generated during the project lifecycle. The reported results reflect the interrelation between the time and monetary parameters of the project of the eco-logistics system. The existence of a given interdependence has made it possible to develop a mechanism for modeling the cash flows of the project, taking into consideration two variants for determining the duration of its life cycle (strictly and broadly defined). Depending on the possibility to influence the duration of the project life cycle, it is envisaged to apply situational or compensatory changes in the duration of time stages, which affects the value of the project's cash flows. The application of the estimation formulae given in this work makes it possible to model cash flows for stages, time intervals, and the entire life cycle of the project of the eco-logistics system. The proposed mechanism of cash flow modeling could be applied in assessing the effectiveness of the project of the eco-logistics system.

Keywords: *eco-logistics system, project lifecycle, project time and money parameters, cash flow.*

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1. Introduction

Taking into consideration modern trends in human development based on the concept of sustainable development, aimed at preserving decent living conditions for the next generations, requires that all human activities should be environmentally-friendly. It is possible to achieve a reduction in the eco-destructive impact of economic activity on the environment by taking into consideration environmental aspects in the process of functioning of economic systems, in particular logistics. Prevention and elimination of the consequences of negative environmental eco-destructive impact require the transformation of logistics systems corresponding to the modern linear model of the economy into more environmentally-friendly eco-logistics systems.

Increasing the success of the implementation of projects of eco-logistics systems is possible due to the use of tools of modern management methodologies, in particular project management. Consequently, it is a relevant scientific task to model the cash flows for the project of the eco-logistics system, generated during its life cycle, taking into consideration the specific features of a given category of projects.

2. The object of research and its technological audit

The *object of this study* is the flow of funds received during the life cycle of the project of the eco-logistics system as a modern transformational model of the logistics system, which makes it possible to achieve the environmental goals of the concept of sustainable development. Cash flows are generated throughout the entire project life cycle and can take, depending on the project stage, both positive and negative values. The values of cash flows consist of inflows and outflows of funds, depending on the factors of the internal environment and the external environment. Thus, one of the most complicated issues in assessing the effectiveness of the project of the eco-logistics system is the modeling of cash flows. The issue has not been studied in detail and thus needs additional research.

3. The aim and objectives of research

The *purpose of this work* is to determine patterns in modeling cash flows over the life cycle of the project of the eco-logistics system.

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

1. Determine the flow of funds during the life cycle of the project of the eco-logistics system.

2. Develop a mechanism for influencing the time parameters of the life cycle of the project of the eco-logistics system.

3. Model the flow of funds in the project of the eco-logistics system.

4. Research of existing solution of the problem

Life cycle (LC) is one of the main concepts of project management methodology. Depending on the examined object, there are many types of the life cycle: for the organization, product, goods, information, client, team, project, document, innovation, logistics system, etc. In project management, the life cycle of a project is the period from the beginning to the completion of the project (Table 1).

Table 1

Interpretation of the concept of «project life cycle»

A Guide to the Project Management Body of Knowledge (PMBoK) [1]. The period from the beginning to the completion of the project is termed the life cycle of the project
The national standard of the Russian Federation (RF). The guide to the project management [2]. The life cycle of the project covers the period from the beginning of the project to its scheduled completion or early termination
P2M «Program & Project Management for Enterprise Innovation» [3]. Each project can be characterized by duration – the period from the formation of the project's plot to the completion of the project

LCs of a project are divided into phases, the composition and content of which is determined by the needs of management and control. The phases of the project are separate parts within the project that require additional control to effectively manage the achievement of the main result of the project [2].

The phases of the project may differ not only quantitatively but also qualitatively – with the same name, phases in different applied spheres may have a different meaning. Even in one applied area, projects can differ in the number and duration of lifecycle phases [4].

According to P2M, each phase of the project can be characterized by a certain property within the framework of the mission being carried out and the problems solved. Thus, the process of formation of the project LC is universal. The typical LC of the project includes the initial, intermediate, and final phases. The intermediate phase can be divided into two or more phases [1].

The project is considered to be finished when its goals are achieved. However, in today's conditions, the project objectives do not always include the environmental aspect, and the project is considered complete when the production of products or services and the receipt of funds from their implementation are stopped. In the Standards that regulate management activities, the life cycle has its specific features taking into consideration the environmental aspect (Table 2).

The growing importance of environmental protection and possible impacts associated with manufactured and consumed products requires an extension of the life cycle by adding ecologically oriented phases (stages). According to [5], the stages of the life cycle should include the purchase of raw materials, design work, production, transportation/supply, application, processing after the loss of suitability, and final disposal. In [6], lifecycle assessment includes consideration of the product lifecycle, from raw material extraction and its purchase to the application of the product and subsequent termination of its use and final disposal. To take into consideration the specific features of the life cycle of various systems, including projects, a lifecycle model is usually built. The model represents the structure of processes and actions related to the life cycle, organized in stages that also serve as a common link for establishing connections and mutual understanding of the parties. Each stage is described by stating the goals and outputs.

Table 2

Interpretation of the concept of «life cycle», taking into consideration the ecological aspect

International ISO Standard 14001:2004. Environmental management systems. Requirements and guidance on the use [5]. Life cycle is the consecutive stages within a system of goods production (or rendering services) from the purchase of raw materials or production from natural resources to the final disposal
The national standard of the Russian Federation. Environmental management. Assessment of the life cycle [6]. Life cycle is the consecutive and interrelated stages of the product lifecycle system from acquisition or production from natural resources or raw materials to final placement in the environment
The national standard of the Russian Federation. Sustainable development in communities. The system of management [7]. Lifecycle is the consecutive and interconnected stages of production (or rendering services), from the purchase of raw materials or production from natural resources to disposal

Changing views on the duration and composition of lifecycle phases affects the process of forming project parameters – specific characteristics on which the success of the managed project depends. The importance of managing the time and cost of the project is confirmed by bringing these issues to certain areas of knowledge within the project management methodology [1].

The object, time, monetary parameters of a project are addressed in many papers by modern scientists. Study [8] proposed using a genetic approach to the formation of the object and monetary characteristics of project products. Work [9] suggest the optimization of time parameters of the project based on the parameters of project products. The object and time parameters of the project are substantiated in [10]. The authors of [11, 12] emphasize the need to manage the time characteristics of project phases. In works [13, 14], the issues of project time management are considered at the level of the formation of the project schedule. In [15], it is proposed to use artificial intelligence tools, namely genetic algorithms, to make up a schedule of project operations. The method of static and dynamic planning of project characteristics with limited resources is suggested in [16]. Researchers focus on taking into account the limited resources when determining the parameters of the project in [17, 18]. It is proposed in work [19] to make compromise decisions between the time and monetary characteristics of the project in case of limited resources.

The life cycle of a project (the composition and duration of phases, stages, time, and monetary parameters corresponding to them) largely depends on the characteristics of the project itself (the scope, scale, complexity, etc.). A special category of projects includes projects of eco-logistics systems, the life cycle of which has undergone transformational changes in connection with the environmentally-oriented systems. The corresponding changes occurred to the time and monetary characteristics of the project lifecycle. The modeling of cash flows of projects related to eco-logistics systems has not been paid proper attention in the works by modern scientists, so it requires research.

5. Methods of research

In the process of this scientific research, general scientific and special methods of research were applied.

Methods of analysis, synthesis, analogies have been used in the analysis of the modern definition of the life cycle of the project, its phases, products; the issues of taking into consideration the ecological component in the projects of eco-logistics systems have been identified. The tools of project management methodology, namely, models and methods of project time management have been used in determining the duration of stages, time intervals of the project lifecycle. The methods of project cost management have been applied in modeling the flows of funds generated during the life cycle of the project. In addition, when modeling cash flows, the method of integrated mathematical analysis has been employed.

6. Research results

The life cycle of the project of the eco-logistics system has differences from the project of the life cycle of the project of the logistics system, justified by the specific features of this type of project. It is proposed to divide the life cycle of the project of the eco-logistics system into the following phases: pre-investment, investment, operational, regenerative, revitalization.

The first three phases (pre-investment, investment, operational) are standard phases for modern investment projects, including logistics systems. The existence of the fourth, the regenerative phase reflects the specifics of the environmentally-oriented logistics system and ensures closing the supply chain. It is during this phase that circular processes occur to return the product (parts or materials) to the production and consumption processes. The last, fifth revitalization phase is related to the elimination of eco-destructive consequences suffered by the ecosystem from the creation and functioning of the eco-logistics system. It can be long-lasting because the negative impact on the environment may not manifest itself immediately and have a prolonged effect while the ecosystem also needs time to recover. Each phase of the project ends with a certain result – the product:

1) in the pre-investment phase: a documented project of the eco-logistics system;

2) in the investment phase: the eco-logistics system in material representation;

3) in the operational phase: a set of logistics services for the promotion of direct material and related flows;

4) in the regenerative phase: a set of logistics services for the promotion of reverse recycling and related flows;

5) in the revitalization phase: a set of actions on the revival, rehabilitation of the ecosystem (Fig. 1).

The lifecycle model is represented as a sequence of stages that can overlap and/or repeat cyclically according to the application area, size, complexity, need for changes and capabilities [4].

In the projects of eco-logistics systems, the phases of the life cycle can proceed both sequentially one by one and overlap. The investment phase comes after the completion of the pre-investment phase. The regenerative phase begins before the end of the operational phase when the product from the end-user enters the backflow of material resources. The revitalization phase begins with the investment phase and proceeds almost until the end of the project.

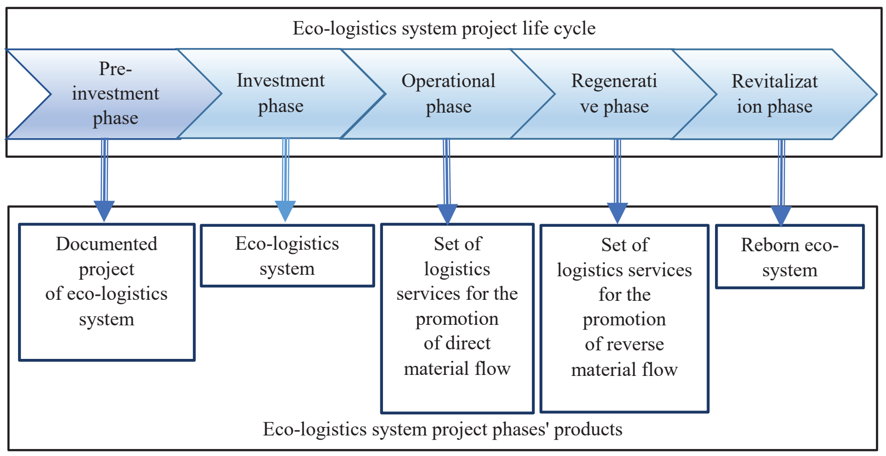

Fig. 1. The life cycle and products of eco-logistics system project

The phases in the life cycle of the project of the eco-logistics system constitute a set of phases of the projects C^f, $(f=\overline{1;F})$. Stages (phases) of the project are a set S^{fj}, f $(f=\overline{1;F})$ is the phase of the project; j $(j=\overline{1;J})$ is the stage of the phase.

The stages of project phases correspond to the following time intervals:

$$[t_i;\ t_{i+1}]\ \left(i=\overline{1;I-1}\right),$$

where t_i is the beginning, t_{i+1} is the end of the time interval of the duration of the project phase stage, which are the milestone events. It is proposed to highlight the following milestone events during the life cycle of the project of the eco-logistics system:

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

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

t_2 – the beginning of the operational phase, the end of the investment phase;

t_3 – the beginning of the regenerative phase;

t_4 – the end of the operational phase;

t_5 – the end of the regenerative phase;

t_6 – the end of the project, the revitalization phase.

Thus, the life cycle includes a set TI^i, of $\left(i=\overline{1;I-1}\right)$ time intervals of $[t_i;t_{i+1}]$ periods, the beginning and completion of which are the milestone events that correspond to the beginning or completion of the phase (stage) of the project, characterized by obtaining a certain result. The life cycle of the project of the eco-logistics system includes phases that differ in the number of stages in their composition (Fig. 2):

– first, pre-investment phase – $P^{11}_{[t_0;t_1]}$;
– second, investment phase – $I^{21}_{[t_1;t_2]}$;
– third, operational phase – $O^{31}_{[t_2;t_3]}$, $O^{32}_{[t_3;t_4]}$;
– fourth, regenerative phase – $R^{41}_{[t_3;t_4]}$, $R^{42}_{[t_4;t_5]}$;
– fifth, revitalization phase – $V^{51}_{[t_1;t_2]}, V^{52}_{[t_2;t_3]}, V^{53}_{[t_3;t_4]}, V^{54}_{[t_4;t_5]}, V^{55}_{[t_5;t_6]}$.

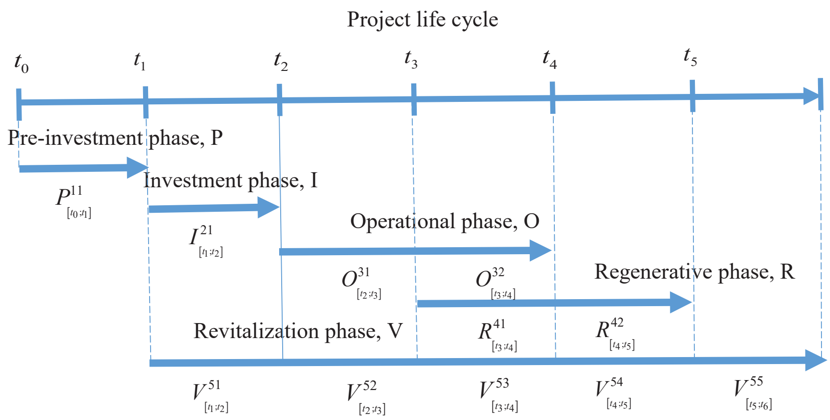

Fig. 2. The life cycle of eco-logistics system project

The stages in the eco-logistics system (ELS) project's lifecycle are completed by obtaining an intermediate result – the product of the phase (stage) of the project, which belongs to a set of products of the project (Table 3):

$$R^{fj}_{[t_i;t_{i+1}]},\ f\left(f=\overline{1;F}\right),\ j\left(j=\overline{1;J}\right),\ \left(i=\overline{1;I-1}\right).$$

Table 3

Results of stages in the life cycle of the project of the eco-logistics system

Time interval	Stage of the LC phase of ELS project	Intermediate result – product of the phase (stage) of the project
$[t_0;t_1]$	pre-investment phase, $P^{11}_{[t_0;t_1]}$	ELS documented project, $PD^{11}_{[t_0;t_1]}$
$[t_1;t_2]$	investment phase, $I^{21}_{[t_1;t_2]}$	ELS, $ELS^{21}_{[t_1;t_2]}$
	revitalization phase stage, $V^{51}_{[t_1;t_2]}$	ELS creation consequence revitalization, $RV^{51}_{[t_1;t_2]}$
$[t_2;t_3]$	operational phase stage, $O^{31}_{[t_2;t_3]}$	ELS (direct material flow), $DMF^{31}_{[t_2;t_3]}$
	regenerative phase stage, $V^{52}_{[t_2;t_3]}$	ELS consequence revitalization (direct material flow), $RV^{52}_{[t_2;t_3]}$
$[t_3;t_4]$	operational phase stage, $O^{32}_{[t_3;t_4]}$	ELS (direct material flow), $DMF^{32}_{[t_3;t_4]}$
	regenerative phase stage, $R^{41}_{[t_3;t_4]}$	ELS (reverse material flow), $RMF^{41}_{[t_3;t_4]}$
	revitalization phase stage, $V^{53}_{[t_3;t_4]}$	ELS consequence revitalization (direct and reverse material flows), $RV^{53}_{[t_3;t_4]}$
$[t_4;t_5]$	regenerative phase stage, $R^{42}_{[t_4;t_5]}$	ELS (reverse material flow), $RMF^{42}_{[t_4;t_5]}$
	revitalization phase stage, $V^{54}_{[t_4;t_5]}$	ELS consequence revitalization (reverse material flow), $RV^{54}_{[t_4;t_5]}$
$[t_5;t_6]$	revitalization phase stage, $V^{55}_{[t_5;t_6]}$	ELS project consequence revitalization, $RV^{55}_{[t_5;t_6]}$

The life cycle of the project of the eco-logistics system is characterized by time and cost parameters. The main cost indicators are the flows of funds of the project $CF^{fj}_{[t_i;t_{i+1}]}$, $(f=\overline{1;F})$, $(j=\overline{1;J})$, $(i=\overline{1;I-1})$, which are generated from $IF^{fj}_{[t_i;t_{i+1}]}$ inflows and $OF^{fj}_{[t_i;t_{i+1}]}$ outflows of funds, the values of which differ at different time intervals and stages of the project. Consequently, the following sets are formed for the characteristics of the life cycle of the project of the eco-logistics system:

– the set of phases of the project lifecycle:

$$C^f=\{P;I;O;R;V\};$$

– the set of time intervals of the project lifecycle:

$$TI^i=\begin{Bmatrix}[t_0;t_1];[t_1;t_2];[t_2;t_3];\\ [t_3;t_4];[t_4;t_5];[t_5;t_6]\end{Bmatrix};$$

– the set of stages of the project lifecycle phases:

$$S^{fj}_{[t_i;t_{i+1}]}=\begin{Bmatrix}P^{11}_{[t_0;t_1]};I^{21}_{[t_1;t_2]};O^{31}_{[t_2;t_3]};O^{32}_{[t_3;t_4]};\\ R^{41}_{[t_3;t_4]};R^{42}_{[t_4;t_5]};V^{51}_{[t_1;t_2]};V^{52}_{[t_2;t_3]};\\ V^{53}_{[t_3;t_4]};V^{54}_{[t_4;t_5]};V^{55}_{[t_5;t_6]}\end{Bmatrix};$$

– the set of results of stages – intermediate products of the project:

$$R^{fj}_{[t_i;t_{i+1}]}=\begin{Bmatrix}PD^{11}_{[t_0;t_1]};ELS^{21}_{[t_1;t_2]};DMF^{31}_{[t_2;t_3]};\\ DMF^{32}_{[t_3;t_4]};RMF^{41}_{[t_3;t_4]};RMF^{42}_{[t_4;t_5]};\\ RV^{51}_{[t_1;t_2]};RV^{52}_{[t_2;t_3]};RV^{53}_{[t_3;t_4]};\\ RV^{54}_{[t_4;t_5]};RV^{55}_{[t_5;t_6]}\end{Bmatrix};$$

– the set of cash flows generated by intermediate project products:

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

The cash flows $CF^{fj}_{[t_i;t_{i+1}]}$ vary throughout the life cycle and take positive and negative values depending on the project stage (Fig. 3).

A distinctive feature of eco-logistics systems projects is the presence of additional ecologically-oriented phases of the life cycle: regenerative and revitalization. Adding these phases to the life cycle introduces some changes in the formation of cash flows of the project. The number of phases in which cash inflows are generated due to the regenerative phase is increasing. In addition, the number of phases, during which cash outflows are generated due to the regenerative and revitalization phase, increases (Table 4).

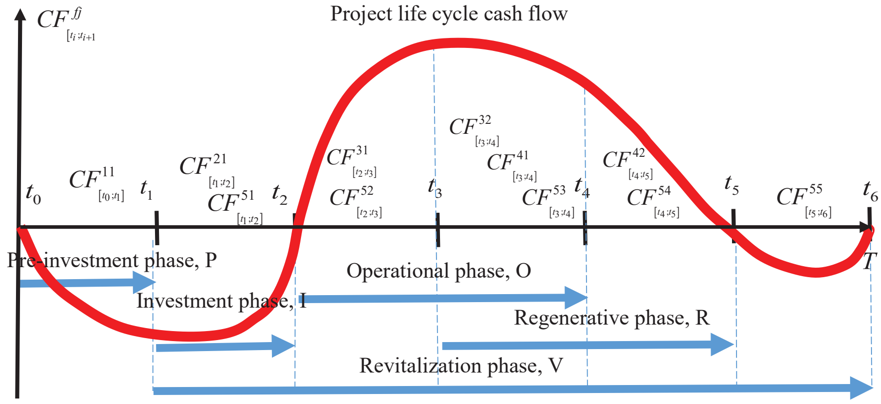

Fig. 3. Cash flows during the life cycle of the project of the eco-logistics system

Table 4

Cash flows of stages in the life cycle of the project of the eco-logistics system

Time interval	ELS project LC phase stage	Project phase (stage) product	Cash inflow	Value	
				cash inflow	cash outflow
$[t_0;t_1]$	$P^{11}_{[t_0;t_1]}$	$PD^{11}_{[t_0;t_1]}$	$CF^{11}_{[t_0;t_1]}$	$IF^{11}_{[t_0;t_1]}=0$	$OF^{11}_{[t_0;t_1]}<0$
$[t_1;t_2]$	$I^{21}_{[t_1;t_2]}$	$ELS^{21}_{[t_1;t_2]}$	$CF^{21}_{[t_1;t_2]}$	$IF^{21}_{[t_1;t_2]}=0$	$OF^{21}_{[t_1;t_2]}<0$
	$V^{51}_{[t_1;t_2]}$	$RV^{51}_{[t_1;t_2]}$	$CF^{51}_{[t_1;t_2]}$	$IF^{51}_{[t_1;t_2]}=0$	$OF^{51}_{[t_1;t_2]}<0$
$[t_2;t_3]$	$O^{31}_{[t_2;t_3]}$	$DMF^{31}_{[t_2;t_3]}$	$CF^{31}_{[t_2;t_3]}$	$IF^{31}_{[t_2;t_3]}>0$	$OF^{31}_{[t_2;t_3]}<0$
	$V^{52}_{[t_2;t_3]}$	$RV^{52}_{[t_2;t_3]}$	$CF^{52}_{[t_2;t_3]}$	$IF^{52}_{[t_2;t_3]}=0$	$OF^{52}_{[t_2;t_3]}<0$
$[t_3;t_4]$	$O^{32}_{[t_3;t_4]}$	$DMF^{32}_{[t_3;t_4]}$	$CF^{32}_{[t_3;t_4]}$	$IF^{32}_{[t_3;t_4]}>0$	$OF^{32}_{[t_3;t_4]}<0$
	$R^{41}_{[t_3;t_4]}$	$RMF^{41}_{[t_3;t_4]}$	$CF^{41}_{[t_3;t_4]}$	$IF^{41}_{[t_3;t_4]}>0$	$OF^{41}_{[t_3;t_4]}<0$
	$V^{53}_{[t_3;t_4]}$	$RV^{53}_{[t_3;t_4]}$	$CF^{53}_{[t_3;t_4]}$	$IF^{53}_{[t_3;t_4]}=0$	$OF^{53}_{[t_3;t_4]}<0$
$[t_4;t_5]$	$R^{42}_{[t_4;t_5]}$	$RMF^{42}_{[t_4;t_5]}$	$CF^{42}_{[t_4;t_5]}$	$IF^{42}_{[t_4;t_5]}>0$	$OF^{42}_{[t_4;t_5]}<0$
	$V^{54}_{[t_4;t_5]}$	$RV^{54}_{[t_4;t_5]}$	$CF^{54}_{[t_4;t_5]}$	$IF^{54}_{[t_4;t_5]}=0$	$OF^{54}_{[t_4;t_5]}<0$
$[t_5;t_6]$	$V^{55}_{[t_5;t_6]}$	$RV^{55}_{[t_5;t_6]}$	$CF^{56}_{[t_5;t_6]}$	$IF^{56}_{[t_5;t_6]}=0$	$OF^{56}_{[t_5;t_6]}<0$

Thus, in addition to the set of cash flows of the project $CF^{fj}_{[t_i;t_{i+1}]}$, the following sets of monetary indicators are formed:

– the set of cash outflows:

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

– the set of cash inflows:

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

When calculating the cash flows received during the time interval $[t_i;t_{i+1}]$, $(i=0;I-1)$, it is necessary to take into consideration the flows of funds generated when creating products of the phases of the project at certain time intervals. Cash flows are calculated according to the following formula:

$$CF_{[t_i;t_{i+1}]}=\sum_{f=1}^{F}\sum_{j=1}^{J}CF^{fj}_{[t_i;t_{i+1}]}=\int_{t_i}^{t_{i+1}} if(t)\,dt+\int_{t_i}^{t_{i+1}} of(t)\,dt, \qquad (1)$$

where $\int_{t_i}^{t_{i+1}} if(t)\,dt$ are the inflows of funds generated during the time interval $[t_i;t_{i+1}]$; $\int_{t_i}^{t_{i+1}} of(t)\,dt$ are the outflows of funds generated during the time interval $[t_i;t_{i+1}]$.

For each time interval of a lifecycle, one can calculate the values of cash flows (2) to (7) (Table 5).

Table 5

Formulae for calculating cash flows in the eco-logistics system project

Time interval	Formula for calculating cash flows	Formula number
$[t_0;t_1]$	$CF_{[t_0;t_1]}=CF^{11}_{[t_0;t_1]}=\int_0^1 cf(t)\,dt=\int_0^1 if(t)\,dt+\int_0^1 of(t)\,dt$	(2)
$[t_1;t_2]$	$CF_{[t_1;t_2]}=CF^{21}_{[t_1;t_2]}+CF^{51}_{[t_1;t_2]}=\int_1^2 cf^{21}(t)\,dt+\int_1^2 cf^{51}(t)\,dt=$ $=\int_1^2 if^{21}(t)\,dt+\int_1^2 of^{21}(t)\,dt+\int_1^2 if^{51}(t)\,dt+\int_1^2 of^{51}(t)\,dt$	(3)
$[t_2;t_3]$	$CF_{[t_2;t_3]}=CF^{31}_{[t_2;t_3]}+CF^{52}_{[t_2;t_3]}=\int_2^3 cf^{31}(t)\,dt+\int_2^3 cf^{52}(t)\,dt=$ $=\int_2^3 if^{31}(t)\,dt+\int_2^3 if^{31}(t)\,dt+\int_2^3 if^{52}(t)\,dt+\int_2^3 of^{52}(t)\,dt$	(4)
$[t_3;t_4]$	$CF_{[t_3;t_4]}=CF^{32}_{[t_3;t_4]}+CF^{41}_{[t_3;t_4]}+CF^{53}_{[t_3;t_4]}=\int_3^4 cf^{32}(t)\,dt+$ $+\int_3^4 cf^{41}(t)\,dt+\int_3^4 cf^{53}(t)\,dt=\int_3^4 if^{32}(t)\,dt+\int_3^4 of^{32}(t)\,dt+$ $+\int_3^4 of^{41}(t)\,dt+\int_3^4 of^{41}(t)\,dt+\int_3^4 if^{53}(t)\,dt+\int_3^4 of^{53}(t)\,dt$	(5)
$[t_4;t_5]$	$CF_{[t_4;t_5]}=CF^{42}_{[t_4;t_5]}+CF^{54}_{[t_4;t_5]}=\int_4^5 cf^{42}(t)\,dt+\int_4^5 cf^{54}(t)\,dt=$ $=\int_4^5 if^{42}(t)\,dt+\int_4^5 of^{42}(t)\,dt+\int_4^5 if^{54}(t)\,dt+\int_4^5 of^{54}(t)\,dt$	(6)
$[t_5;t_6]$	$CF_{[t_5;t_6]}=CF^{56}_{[t_5;t_6]}=\int_5^6 cf^{56}(t)\,dt=\int_5^6 if^{56}(t)\,dt+\int_5^6 of^{56}(t)\,dt$	(7)

The total flows of funds during the life cycle of the project of the eco-logistics system are calculated according to the following formula:

$$CF_{LC}=\sum_{i=0}^{I-1}\sum_{f=1}^{F}\sum_{j=1}^{J}CF^{fj}_{[t_i;t_{i+1}]}=\int_{t_i}^{t_{I-1}} if(t)\mathrm{d}t+\int_{t_i}^{t_{I-1}} of(t)\mathrm{d}t, \qquad (8)$$

where $\int_{t_i}^{t_{I-1}} if(t)\mathrm{d}t$ are the inflows of funds generated during the life cycle of the project; $\int_{t_i}^{t_{I-1}} of(t)\mathrm{d}t$ is the outflows of funds generated during the life cycle of the project.

Cash outflows accept values that do not equal zero, during all time intervals of the project. Unlike them, inflows of funds are generated only during the operational and regenerative phases of the project. In this case, the total value of the cash flow, which is scheduled to be received during the project, is determined as the amount of inflows and outflows of funds at certain time intervals of the project: it is calculated according to the following formula:

$$CF^{plan}_{LC}=IF^{plan}_{LC}+OF^{plan}_{LC}, \qquad (9)$$

where IF^{plan}_{LC} and OF^{plan}_{LC} are the planned values of inflows and outflows of funds respectively, $IF^{plan}_{LC}\geq 0$ and $OF^{plan}_{LC}<0$.

The planned values of monetary indicators of the life cycle of the project of the eco-logistics system are calculated according to the formulae (10), (11):

– the inflows of funds:

$$IF^{plan}_{LC}=\int_{t_2}^{t_5} if(t)\mathrm{d}t=\int_{t_2}^{t_3} if(t)\mathrm{d}t+\int_{t_3}^{t_4} if(t)\mathrm{d}t+\int_{t_4}^{t_5} if(t)\mathrm{d}t; \qquad (10)$$

– the outflows of funds:

$$OF^{plan}_{LC}=\int_{t_0}^{t_6} of(t)\mathrm{d}t=\int_{t_0}^{t_1} of(t)\mathrm{d}t+\int_{t_1}^{t_2} of(t)\mathrm{d}t+$$

$$+\int_{t_2}^{t_3} of(t)\mathrm{d}t+\int_{t_3}^{t_4} of(t)\mathrm{d}t+\int_{t_4}^{t_5} of(t)\mathrm{d}t+\int_{t_5}^{t_6} of(t)\mathrm{d}t. \qquad (11)$$

The duration of stages and phases of the project life cycle may vary under the influence of internal and external factors. There are two possible approaches to modeling the duration of the life cycle of the project of the eco-logistics system:

1. The duration of the project lifecycle may vary; the expiration date of the project is not strictly defined. Then changes in the duration of individual phases would affect the actual total lifecycle duration of the project T^{fact}_{LC}.

2. The duration of the life cycle T^{plan}_{LC} is determined; the project must be completed within a strictly defined period. In this case, in case of changes in the duration of the previous phase, the duration of the next phase or subsequent phases should change to preserve the total life cycle of the project (Table 6).

Table 6

Variants of the life cycle of the project of the eco-logistics system

Project time characteristics	Characteristic's status	
	Variant 1	Variant 2
Project completion planned term, T^{plan}_{LC}	$T^{plan}_{LC}\neq$ const	$T^{plan}_{LC}=$ const
Project completion actual term, T^{fact}_{LC}	$T^{fact}_{LC}\neq T^{plan}_{LC}$	$T^{fact}_{LC}=T^{plan}_{LC}$

Depending on the choice of the variant of managing the duration of the project, the monetary parameters of the project are determined (Fig. 4).

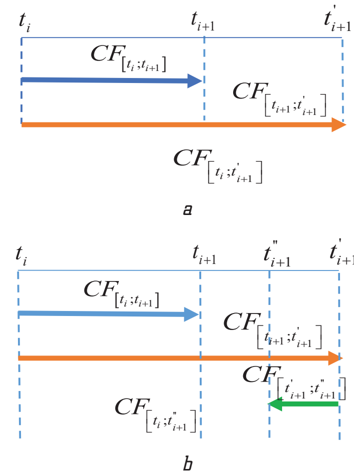

Fig. 4. Cash flows under different variants of the life cycle duration of the project of the eco-logistics system: *a* – broadly defined; *b* – strictly defined

Variant 1. The duration of the life cycle of the project of the eco-logistics system is broadly defined.

In case of situational changes in the duration of the scheduled time interval $[t_i;t_{i+1}]$ of the project to the actual $[t_i;t'_{i+1}]$, the changes would occur in the value of cash flows generated during the project stages $CF^{fj}_{[t_i;t'_{i+1}]}$ and time intervals $CF_{[t_i;t'_{i+1}]}$ (Fig. 4). In the time interval $[t_i;t'_{i+1}]$ the cash inflows $IF_{[t_{i+1};t'_{i+1}]}$ and outflows $OF_{[t_{i+1};t'_{i+1}]}$ are generated, which create the additional unplanned cash flow $CF_{[t_{i+1};t'_{i+1}]}$ that is calculated according to the following formula:

$$CF_{[t_{i+1};t'_{i+1}]}=\sum_{f=1}^{F}\sum_{j=1}^{J}CF^{fj}_{[t_{i+1};t'_{i+1}]}=\int_{t_{i+1}}^{t'_{i+1}} if(t)\mathrm{d}t+\int_{t_{i+1}}^{t'_{i+1}} of(t)\mathrm{d}t, \qquad (12)$$

where $\int_{t_{i+1}}^{t'_{i+1}} if(t)\mathrm{d}t$ are the inflows of cash generated during the time interval $[t_i;t'_{i+1}]$; $\int_{t_{i+1}}^{t'_{i+1}} of(t)\mathrm{d}t$ is the outflows of cash generated during the time interval $[t_i;t'_{i+1}]$.

If the deadline for the previous interval $[t_i;t_{i+1}]$ changes to $[t_i;t'_{i+1}]$ due to situational changes, the start time of the next interval changes to $[t'_i;t''_{i+1}]$.

The total amount of funds throughout the life cycle of the project of the eco-logistics system is calculated according to the following formula:

$$CF^{fact}_{LC}=\sum_{i=0}^{I-1}\sum_{f=1}^{F}\sum_{j=1}^{J}CF^{fj}_{[t'_i;t'_{i+1}]}=\int_{t'_i}^{t'_{I-1}} if(t)\mathrm{d}t+\int_{t'_i}^{t'_{I-1}} of(t)\mathrm{d}t, \qquad (13)$$

where $\int_{t'_i}^{t'_{I-1}} if(t)\mathrm{d}t$ are the inflows of funds generated during the life cycle of the project; $\int_{t'_i}^{t'_{I-1}} of(t)\mathrm{d}t$ is the outflows of funds generated during the life cycle of the project.

Variant 2. The duration of the life cycle of the project of the eco-logistics system is strictly defined.

It is required to solve the task of stabilizing the duration of the project lifecycle by taking measures to compensate for changes in the duration of the life cycle stages, which in turn affects the change in the duration of time intervals that correspond to these stages. Certain funds are

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required to implement measures to return the duration of the scheduled time interval $[t_i;t_{i+1}]$ from the actual $\left[t_i;t'_{i+1}\right]$ to the adjusted $\left[t_i;t''_{i+1}\right]$. The amount of money is determined by the amount of money spent on adjusting the duration of each stage of the project, the duration of which changes over the time interval $\left[t_i;t'_{i+1}\right]$, which is given by the following formula:

$$CF^{cor}_{[t'_{i+1};t''_{i+1}]}=\sum_{f=1}^{F}\sum_{j=1}^{J}CF^{fj}_{[t'_{i+1};t''_{i+1}]}=-\int_{t'_{i+1}}^{t''_{i+1}}of(t)\mathrm{d}t, \tag{14}$$

where $\int_{t'_{i+1}}^{t''_{i+1}}of(t)\mathrm{d}t$ is the cash outflows required to adjust the time interval $\left[t_{i+1};t'_{i+1}\right]$ to $\left[t_{i+1};t''_{i+1}\right]$.

The effect of situational changes in the time interval $[t_i;t_{i+1}]$ to $\left[t_{i+1};t'_{i+1}\right]$ $[t_i;t_{i+1}]$ and compensatory changes $\left[t_{i+1};t'_{i+1}\right]$ to $\left[t_{i+1};t''_{i+1}\right]$ on cash flows is calculated according to the following formula:

$$CF^{fact}_{[t_i;t''_{i+1}]}=\int_{t_i}^{t_{i+1}}cf(t)\mathrm{d}t+\int_{t_{i+1}}^{t''_{i+1}}cf(t)\mathrm{d}t+\int_{t'_{i+1}}^{t''_{i+1}}cf(t)\mathrm{d}t=$$
$$=\int_{t_i}^{t_{i+1}}if(t)\mathrm{d}t+\int_{t_i}^{t_{i+1}}of(t)\mathrm{d}t+\int_{t_{i+1}}^{t''_{i+1}}if(t)\mathrm{d}t+$$
$$+\int_{t_{i+1}}^{t''_{i+1}}of(t)\mathrm{d}t-\int_{t'_{i+1}}^{t''_{i+1}}of(t)\mathrm{d}t, \tag{15}$$

where t_i is the beginning of the scheduled time interval $[t_i;t_{i+1}]$; t_{i+1} is the end of the scheduled time interval $[t_i;t_{i+1}]$; t'_{i+1} is the end of time intervals $\left[t_i;t''_{i+1}\right]$ and $\left[t_i;t'_{i+1}\right]$ after situational changes; t''_{i+1} is the end of time intervals $\left[t_i;t''_{i+1}\right]$ and $\left[t_{i+1};t''_{i+1}\right]$ after compensatory changes.

In case of changes at the end of the previous interval $[t_i;t_{i+1}]$ after compensatory changes to $\left[t_i;t''_{i+1}\right]$, the start time of the next interval changes to $\left[t''_i;t''_{i+1}\right]$.

The total amount of funds throughout the life cycle of the project of the eco-logistics system is calculated according to the following formula:

$$CF^{fact}_{LC}=\sum_{i=0}^{I-1}\sum_{f=1}^{F}\sum_{j=1}^{J}CF^{fj}_{[t''_i;t''_{i+1}]}=\int_{t''_i}^{t''_{I-1}}if(t)\mathrm{d}t+\int_{t''_i}^{t''_{I-1}}of(t)\mathrm{d}t, \tag{16}$$

where $\int_{t''_i}^{t''_{I-1}}if(t)\mathrm{d}t$ are the inflows of funds generated during the life cycle of the project; $\int_{t''_i}^{t''_{I-1}}of(t)\mathrm{d}t$ is the outflows of funds generated during the life cycle of the project.

7. SWOT analysis of research results

Strengths. The strengths of this study relate to the possibility to take into consideration the eco-destructive impact of logistics activities on the environment due to the change in the structure and duration of the life cycle of the project of the eco-logistics system. The phases characteristic of the classical idea of the life cycle of a project, specifically the pre-investment, investment, and operational ones, are supplemented with the environmentally-oriented regenerative and revitalization phases.

Weaknesses. The weak side of this study is a failure to account for, when modeling cash flows of the project of the eco-logistics system, the depreciation of cash over time. Obtaining a revitalization phase product can be long in time, so the cash needed to get it may be underestimated to date. Disregarding this fact can lead to a false assessment of the effectiveness of the project.

Opportunities. In further research, the promising direction is to identify analytical dependences between the duration of the life cycle stages and the cash flows received.

Threats. It should be noted that the application of the proposed mechanism of cash flow modeling does not relieve the project from the risks caused by changes in the planned values of the duration of individual stages, time intervals of the life cycle. Significant changes in project time parameters can lead to excessive costs or non-receipt of funds. Thus, despite the possibility of using the compensatory mechanism, it is necessary to constantly monitor the time and diverse monetary parameters of the project.

8. Conclusions

1. The patterns in the life cycle of the project of the eco-logistics system, which differs from the classical idea of the life cycle of a project by the presence of ecologically-oriented phases, have been defined. It consists of pre-investment, investment, operational, regenerative and revitalization phases, interconnected by the created consecutive and overlapping links.

2. The mechanism of influence on the time parameters of the life cycle of the project of the eco-logistics system, which includes separate stages, phases, time intervals, was developed. Time parameters may vary under the situational influence of the internal environment and the external environment of the project. Two possible variants for determining the duration of the project life cycle have been investigated, depending on which the mechanism of formation of time parameters is developed. The mechanism involves the situational and compensatory changes in the time parameters of the project.

3. The modeling of cash flows during the life cycle of the project of the eco-logistics system, the value of which is influenced by the change in time characteristics, has been performed. For each of the variants, the cash flows for stages, time intervals, and the entire life cycle of the project have been determined.

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