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DEVISING A METHOD FOR MANAGING THE CONFIGURATION OF PRODUCTS WITHIN AN ECO-LOGISTICS SYSTEM PROJECT

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This paper considers the need to transform logistics systems into eco-logistics ones in order to achieve environmental goals of sustainable development. It was determined that one of the ways to reduce the eco-destructive impact of eco-logistics systems on the environment is the use of project management methodology tools and making changes to the project life cycle by including ecologically oriented phases. The products obtained during the life cycle of an eco-logistics system project have been identified and the links between the products of individual phases of the project have been established.

The object of this study is the method of managing the configuration of products of the eco-logistics system project, which includes three stages: product parameter specification, product clustering, and structuring of the project's product clusters. A description of each stage is provided.

The specification of product parameters is to create descriptive frame models of products that contain the parameters necessary to characterize the product phase of the project, which are reflected in the content of the project's products. Product clustering involves the creation of information models of product clusters that contain information about the set of products of the project phases that have close parameter values. Structuring clusters of project products leads to the creation of a network of clusters between which connections are formed, which makes it possible to build a product configuration.

Experimental calculations confirming the adequacy of the application of the proposed method of managing the configuration of products of the eco-logistics system project are presented. As a result, a network of clusters of project products has been created, using which makes it possible to synthesize product chains that would have maximum value in terms of complying with eco-logistics rules and could minimize the negative impact on the environment

Keywords: eco-logistics system, project life cycle, product content, project product configuration

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1. Introduction

The modern requirement for the implementation of logistics activities from the point of view of the concept of sustainable development is to reduce the environmental impact on the environment. The change in the ideological paradigm of mankind requires the transformation of logistic systems, which correspond to the modern linear model of the economy, into closed eco-logistics systems (ELS) [1, 2]. Eco-logistics systems make it possible to introduce the principles of the circular economy into economic activity [3] and to achieve a reduction in environmental losses incurred by the environment.

Scientific research on the topic of green logistics focuses on the importance of the issue of using modern control mechanisms for closed logistics systems [4]. Improving the success of the creation and operation of ELS can be achieved through the use of project management methodology tools. From the standpoint of the project approach, ELS is considered a unique result obtained from purposeful time-limited activities.

The project approach involves dividing the life cycle (LC) of a project into phases that result in obtaining certain products. The ELS LC, in addition to the main phases such as pre-investment, investment, and operational, includes environmentally-oriented phases: regenerative and liquidation [5]. Due to their presence in the project's LC, it becomes possible to close the supply chains and turn the logistics system into a more environmentally dangerous one from the point of view of ecology – eco-logistics.

The value of this type of project is proposed to be considered not only from the standpoint of fulfilling the basic rules of logistics: the necessary product, in the required quality, in the required quantity, in the required city, at the required time required by the consumer. However, it is necessary to take into consideration the rule of eco-logistics – with minimal costs and minimal environmental impact [6].

The ecological orientation of the created systems is reflected in the composition and characteristics of the products formed during the ELS project's LC. There are links between the products of the phases of the project's LC, which can be reflected in the product configuration. Creating a product configuration is one of the most important stages in planning an ELS project, which requires the use of modern methods that will take into consideration the specific features of this type of project. As a result of applying the proposed approach, it becomes possible to increase the value of the obtained products from the point of view of implementing the rules of eco-logistics.

2. Literature review and problem statement

Configuration management issues are reflected in international and national standards, the study of which led to the conclusion that configuration management in them is considered both at the project level and at the product level. Analysis of the standard from [7] showed that it does not address the issue of project configuration management but focuses on product configuration management. The configuration is represented as the structure of the submitted for development, the one being developed, or the existing product. It includes functional, physical, and operational properties (characteristics) that meet the established requirements. The configuration is represented by various information models that correspond to the LC stages of this product.

Unlike the previous one, the standard in [8] addresses the issues of project configuration management and product configuration management. This view on configuration management in projects is reasonable as it confirms the inseparable connection between these concepts and their impact on the effectiveness of project activities.

The current studies also trace the connection between the configuration of projects and products. In [9], a conceptual model of the configuration management process in projects has been developed, which shows that in order to achieve the goal of this process, it is necessary to manage the configuration of the project, product, and project environment. The cited paper shows the relationship between the tasks of synthesis and configuration management in projects throughout the LC but the main attention is paid to the study of the configuration of the project environment.

Paper [10] outlines the scientific and methodological foundations of the process of coordinating the configurations of system products and their projects. Coordination takes place in relation to four processes – management of the configuration of product systems, formation of the configuration of system products, management of project configuration, and formation of the configuration of project and technological structures that enable the formation of the configuration of product systems. The main attention is paid to the study of configuration alignment, but its essence has not been investigated in detail.

Project configuration management cannot be considered without taking into consideration the management of the content of the project. The standard in [11] distinguishes between the content of the project and the content of the project product. The content of the product of the project refers to the properties and functions that characterize the product, service, or result. In [12], it is proposed to supplement the existing project management methodologies with the process of optimizing the content of the project, which confirms the relevance of the research of content management of the project products as well.

The instability of the project implementation conditions affects the process of managing the content and configuration of projects, which is reflected by taking into consideration the uncertainty of input information about the characteristics of the project [13]. The model and method of multicriterial optimization of the project content with fuzzy input data are reported in [14] but the issue of influence on the configuration of products is not considered. It is proposed to use fuzzy clustering to solve the problems of project planning [15], in which the main attention is focused on taking into consideration the limited resources when determining the parameters of the project. In [16], a model is given that, due to fuzzy logic, can neutralize the vagueness of incoming information about individual projects but does not address the issue of direct impact on the content of project products and their configuration. The issue of the application of frame modeling tools in the formation of the content of the products of the eco-logistics system project is considered in [17]. Links between products were identified when creating a frame network of project products but the process of forming their configuration was not investigated.

Thus, the process of managing the configuration of the project is interpreted quite widely and reflects the various aspects of the configuration in the project. An important aspect is the need to take into consideration uncertainty in the formation of the content and configuration of project products.

It should be noted that an ELS project and its products have a number of specific features, which are reflected in the management of their configuration. The products of the ELS project differ in terms of eco-destructive impact on the environment, so it is necessary to investigate the issue of managing their configuration through the prism of compliance with environmental rules.

3. The aim and objectives of the study

The purpose of this study is the development of a method for managing the configuration of ELS project products, which will take into consideration the specific features of the products being created and will provide an opportunity to achieve maximum project value from the standpoint of implementing eco-logistics rules.

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

– to develop a mechanism for the formation of the content of the products of an ELS project;

– to determine the sequence and provide a description of the stages of configuration management of the ELS project products;

– to carry out experimental calculations confirming the adequacy of the proposed method of managing the configuration of the ELS project products.

4. The study materials and methods

The object of this study is the process of developing a method for managing the configuration of the products of an ELS project.

The research hypothesis assumes that taking into consideration the specific features of the products of the ELS project LC phases and establishing links between them, taking into consideration the uncertainty of the conditions for the implementation of the project, will make it possible to build a method, the use of which will make it possible to achieve the maximum value of the project from the standpoint of implementing eco-logistics rules.

The study is based on the main provisions of the project management methodology, taking into consideration the principles of ecology and logistics in determining the characteristics of the products of the LC phases of ELS projects.

In the development of the proposed method, the tools of pattern recognition theory (frame modeling, cluster analysis), management decision theory (morphological analysis), and the theory of fuzzy sets (fuzzy relations) were used. Frame modeling is used in determining the content of the products of the LC phases of the ELS project at the specification stage.

Descriptive models of products are created in the form of prototype frames containing a set of parameters necessary to characterize the product of the phase of the LC of the project.

Cluster analysis is used in the formation of product clusters of the ELS project's LC at the clustering stage. Somebody is to create information models represented by instance frames of product clusters, which contain information about the set of products of the phases of the project's LC, which have close values of the parameters.

Morphological analysis and fuzzy relations make it possible to create a network of clusters of products of the LC phases of the ELS project at the structuring stage. The use of tools for morphological analysis and fuzzy relations limits the number of elements of sets of clusters of project products that will take part in the formation of product chains of the ELS project, and makes it possible to form the most attractive combination of them from the point of view of eco-logistics.

In the process of developing the method, the following assumptions and simplifications were accepted:

– in ELS projects, the necessary condition is to include the ecologically oriented phases in LC composition;

– the presence of connections between the clusters of products from different LC phases of the project is determined by expert assessment and has a certain degree of subjectivity.

5. Description of the method of managing the configuration of products of the project of an eco-logistics system

5. 1. Formation of the content of the products of the project of an eco-logistics system

According to the substantive essence of an ELS project, it is proposed to divide the ELS project into pre-investment, investment, operational, regenerative, and liquidation phases. The defining points are to obtain the products of the phases of the project, which are:

– in the pre-investment phase – documented ELS project;

– at the investment phase – ELS in the material representation;

– in the operational phase – a logistics product that includes a range of logistics services for the promotion of direct material and related flows;

– in the regenerative phase – an eco-logistics product, which includes a range of logistics services for the promotion of reverse recycling and related flows;

– in the revitalization phase – a revived ecosystem (Fig. 1).

One of the main tasks of the pre-investment phase of the project is to determine the content of the project's products. It is possible to represent information on the content of the project's products through the use of the tools of the theory of artificial intelligence (modeling the representation of knowledge).

Frame modeling of the content of the products of LC phases of the ELS project should be carried out in two stages:

1. Identify abstract concepts of the subject area of the project, namely the products of the phases of the project's LC and related information phenomena, objects, processes, etc., and represent them in the form of prototype frames for the products of LC phases of the project.

2. Describe specific objects of the subject area in the form of frames-instances of the products of LC phases of the project, which will reflect the content of the project's products (Table 1).

A frame is a universal information structure that not only stores the necessary information about the characteristics of the object, phenomenon, or process being investigated but also reflects the connections between them and other information objects.

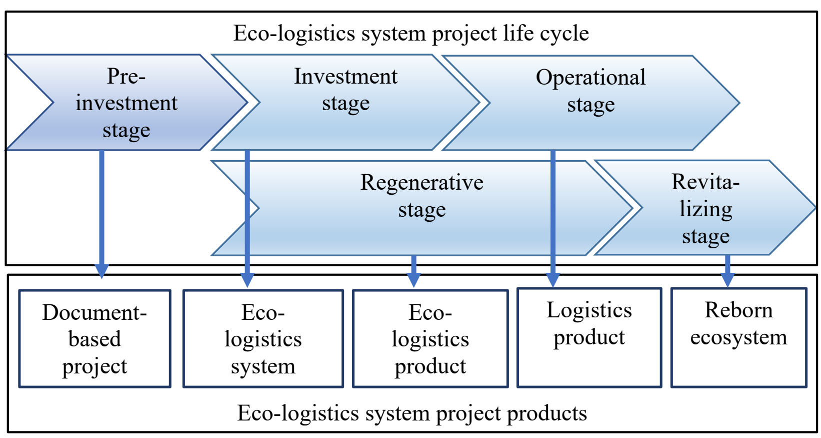

Fig. 1. Eco-logistics system project products

Table 1

Types of frames by information load in the project

Type of frames	Characteristics of frames	Frame slots	Interpretation of frames in the project	An example of a frame in the project
Prototype frames	Patterns for describing abstract entities that share a common structure and behavior	Characteristics (parameters) of the frame without specific values	Reflect knowledge of general concepts in the project	LC phase of the project, product of the LC phase of the project, process, operation, event, risk situation
Instance frames	Implementation of a frame that displays specific objects, phenomena, situations, processes, etc.	Characteristics (parameters) with specific values and corresponding procedures	Reflect knowledge about specific concepts in the project	Product of the investment phase of the ELS project, recycling circular process

Such properties of frames make it possible to create a network of frames in which the relationships between the elements will be taken into consideration, which is an adequate tool for displaying the configuration of the phase products of an ELS project.

5. 2. The sequence of product configuration management of the eco-logistics system project

The specificity of the products resulting from the implementation of phases is reflected in their configuration as a set of functional and physical characteristics of the project products. The formation of the configuration of the products of the phases of the LC of the project is proposed to be carried out in the following sequence:

1. The specification of product parameters is to create descriptive product models that reflect the set of parameters necessary to characterize the product phase of the project's LC phase.

2. Product clustering involves the creation of information models of product clusters that contain information about the set of products of the phases of the project's LC, which have close values of the parameters.

3. The structuring of product clusters leads to the creation of a network of project product clusters, which makes it possible to display the links between the products of the phases of the project's LC and create a potential set of product chains of the phases of the project (Table 2).

The specification of product parameters is to create descriptive models that display the properties of the products that characterize the products of the phases of the project's LC as objects of consumption. To carry out the specification, it is proposed to use the tools of pattern recognition theory (frame modeling).

At the specification stage, it is possible to determine the characteristics that are inherent in the products of the phases of the LC of the project by using prototype frames of products.

In the frame model, each product is described by a set of slots – parameters. The formation of a set of parameters $X^f = \{x_1^f;...;x_j^f;...;x_{J_f}^f\}$, characterizing the product of phase f, $(f = \overline{1;F})$ of the project's LC, is a heuristic operation and depends on the required amount of information about the product for further research.

Relationships are observed between the products of the ELS project phases, which reflect the dependence of the characteristics of some products on the properties of others. The formation of project products over time is the result of an orderly sequence of work for each phase of the project's housing and communal services and is carried out starting from the pre-investment phase and ending with the revitalization phase. From the point of view of the goal-setting process in the development of the project, the sequence of formation of product parameters has the opposite direction and is carried out starting with the products of the operational and regenerative phase, and ending with the product of the pre-investment phase (Fig. 2).

The product of the operational phase is a logistics product that includes a range of services to promote direct material flow, and generates a product of the regenerative phase – an eco-logistics product, which includes a range of services to promote the reverse material flow. The characteristics of the reverse recycling and disposal flow depend on the characteristics of the direct material flow (volumes and composition of the product; the properties of the substances that make up the product, the period of consumption and the possibility of secondary use, etc.). The main characteristics of the recycling and recycling flow include volumes, composition, flow intensity, recycling processes that can be used, etc. It also affects the composition of participants and the structure of ELS (its straight linear section).

The product characteristics of the investment phase are influenced by the product of the regenerative phase – an eco-logistics product, in particular, a set of services to promote the reverse material flow. ELS itself produces a product of the revitalization phase – a revived ecosystem and a set of actions to eliminate the negative consequences of the creation and functioning of ELS.

The characteristics of all phases of the ELS project's LC should be reflected in the documented project. They affect the duration of the project, the amount of work to be done at each phase of the project, their budget, overall project performance, etc.

Table 2

Characteristics of the stages of formation of the products of the phases of the *LC* of the *ELS* project

Stage	Toolkit of research	Model	Result
Specification	Frame modeling	Descriptive product models	Sets of parameters of the products of the LC phases of the project
Clustering	Cluster analysis	Information models of product clusters	Sets of parameter values of clusters of products of the LC phases of the project
Structuring	Method of morphological analysis, fuzzy relations	Network of product clusters	A set of chains of products of the LC phases of the project

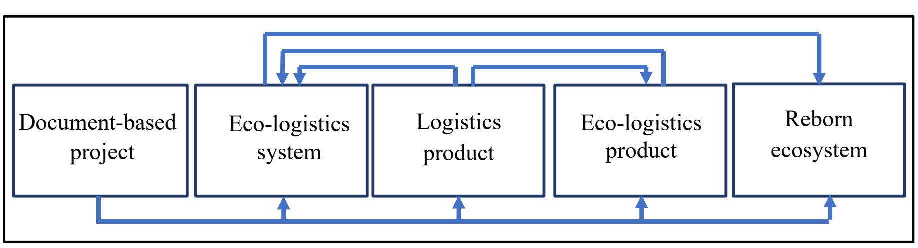

Fig. 2. Relationships between the products of the phases of the life cycle of the project of the eco-logistics system

The connection between the product frames of the phases of the project's LC is displayed thru a subset of the slots $R=\{x_1; ...; x_r; ...; x_R\}$, $(r=\overline{1;R})$, the main task of the elements of which is to take into consideration changes in the content of the recessive product under the influence of changes in the content of the dominant product and create the configuration of the project products. This configuration can be considered basic and applied in further monitoring of the project throughout the entire LC.

Clustering of products of the phases of the LC of the project involves creating clusters of products that have close parameter values. Since the formation of product characteristics is carried out at the beginning of the project's LC, it is quite problematic to accurately determine the values of the parameters. To carry out this procedure, there is not enough necessary information. It is possible to solve the problem by creating clusters of products of the phases of the project's LC with similar parameter values. It is proposed to represent product clusters using instance frames of product clusters, which are created on the basis of product prototype frames and contain information about the values of the slot parameters of products included in a given cluster.

The task of clustering is to divide the value space of product parameters into areas corresponding to certain clusters $(f=\overline{1;F})$, $(g=\overline{1;G_f})$ in such a way as to minimize the possible number of errors in assigning a product to a cluster. Sets of project phase product clusters are formed $C^f=\{c_1^f;...;c_{g_f}^f;...;c_{G_f}^f\}$, $(f=\overline{1;F})$. As a result of clustering the product of the project, which is described by a set of parameters $X^f=\{x_1^f;...;x_{j_f}^f;...;x_{J_f}^f\}$, $(f=\overline{1;F})$, which take values $X_j^f=\{x_{j1}^f;...;x_{jn}^f;...;x_{jN}^f\}$, $(j=\overline{1;J_f})$, belonging to a specific cluster $C_{g_f}^f$.

It is possible to characterize the products of the project with the help of quantitative and qualitative parameters. Depending on the belonging of the parameter to a particular group, the measurement scale and the technique for determining the similarity of the parameter are selected. The cluster instance frame should contain information about the value of the qualitative parameter or the range of values of quantitative parameters.

The structuring of product clusters is the next stage in the formation of project product parameters, which leads to the creation of a network structure, in the nodes of which there are clusters of project products. Clusters are represented by appropriate instance frames, between which there are connections that make it possible to create a set of alternative options for potential product chains of the project.

The apparatus of the theory of fuzzy sets makes it possible to take into consideration the uncertainty when creating chains of products of the phases of the LC of the project. With its help, the analysis of structural relationships between clusters is carried out. The analysis involves not only determining the presence or absence of connections between certain clusters of products of different phases of the project but also identifying the levels of the dominance of these links. This is important for the further creation of product chains of the phases of the LC project.

Relationships between products are proposed to be reflected in the form of fuzzy relationships between product clusters $C_{g_f}^f \underset{\sim}{R} C_{g_{f+k}}^{f+k}$, $(k=\overline{-K,K})$, $(g=\overline{1,G_f})$. Fuzzy relations are understood as a fuzzy ratio $\underset{\sim}{R}$ on the direct product of universal sets $C_{g_f}^f$ and $C_{g_{f+k}}^{f+k}$, which takes values on the set of the membership function.

Fuzzy relationships between project phase product clusters are set using their membership functions $\mu_{\underset{\sim}{R}}(C_{g_f}^f, C_{g_{f+k}}^{f+k})$, which reflect the degree of conformity (affinity) between product clusters that are at the appropriate levels of the network and have connections.

Fuzzy relations between product clusters are represented as matrices of relations, the terms and columns of which are matched by product clusters, and at the intersection of terms and columns are the membership functions of fuzzy relations (Table 3).

Table 3

Matrix of fuzzy relationships between product clusters

Product clusters of phase f of the project	Product clusters of phase $f+k$ of the project				
	C_1^{f+k}	...	$C_{g_{f+k}}^{f+k}$	...	$C_{G_{f+k}}^{f+k}$
C_1^f	$\mu_{\underset{\sim}{R}}\left(C_1^f, C_1^{f+k}\right)$	...	$\mu_{\underset{\sim}{R}}\left(C_1^f, C_{g_{f+k}}^{f+k}\right)$	...	$\mu_{\underset{\sim}{R}}\left(C_1^f, C_{G_{f+k}}^{f+k}\right)$
...	...	...	...	...	...
$C_{g_f}^f$	$\mu_{\underset{\sim}{R}}\left(C_{g_f}^f, C_1^{f+k}\right)$	...	$\mu_{\underset{\sim}{R}}\left(C_{g_f}^f, C_{g_{f+k}}^{f+k}\right)$	...	$\mu_{\underset{\sim}{R}}\left(C_{g_f}^f, C_{G_{f+k}}^{f+k}\right)$
...	...	...	...	...	...
$C_{G_f}^f$	$\mu_{\underset{\sim}{R}}\left(C_{G_f}^f, C_1^{f+k}\right)$	...	$\mu_{\underset{\sim}{R}}\left(C_{G_f}^f, C_{g_{f+k}}^{f+k}\right)$	...	$\mu_{\underset{\sim}{R}}\left(C_{G_f}^f, C_{G_{f+k}}^{f+k}\right)$

Information about fuzzy relationships between product clusters allows us to form a set of product chain options for the phases of the project's LC on the product network, based on fuzzy relations and degrees of the dominance of these relations.

When creating a chain link between clusters located at different levels of the network, those clusters are selected, and the degree of dominance of fuzzy relations between which reaches the maximum possible value.

In hierarchical order, the network levels are arranged as follows (from the bottom up):

– clusters of products of the operational phase – sets of logistics services for the promotion of direct material flow $C_g^3=\{C_1^3;...;C_{g_3}^3;...;C_{G_3}^3\}$;

– clusters of products of the regenerative phase – sets of services for the promotion of reverse material flow $C_g^4=\{C_1^4;...;C_{g_4}^4;...;C_{G_4}^4\}$;

– investment phase product clusters – *ELS* – $C_g^2=\{C_1^2;...;C_{g_2}^2;...;C_{G_2}^2\}$;

– clusters of products of the liquidation phase – options for the revival of the ecosystem $C_g^5=\{C_1^5;...;C_{g_5}^5;...;C_{G_5}^5\}$;

– clusters of products of the pre-investment phase – documented *ELS* projects $C_g^1=\{C_1^1;...;C_{g_1}^1;...;C_{G_1}^1\}$ (Fig. 3).

In addition, when moving around the network, it is necessary to take into consideration the threshold values of the degree of dominance of relations, which is determined by the priority of creating communication between product clusters in terms of achieving the maximum value of an eco-logistics project.

In the event that the membership function does not reach the threshold $\mu_{\underset{\sim}{R}}(C_{g_f}^f, C_{g_{f+k}}^{f+k}) < \alpha_{\mu_{\underset{\sim}{R}}}$, the fuzzy ratio is considered insignificant. Consequently, promotion in this direction and the inclusion of this site in the product chain is not advisable.

Otherwise, when the membership function has overcome the threshold value of $\mu_{\underset{\sim}{R}}(C_{g_f}^f, C_{g_{f+k}}^{f+k}) \geq \alpha_{\mu_{\underset{\sim}{R}}}$, moving to another level of the network along this branch is possible.

Sets of variants of pairs of product clusters of the phases of the project are formed $C^{f;f+k}=\{(C_{g_f}^f;C_{g_{f+k}}^{f+k})_1;...;(C_{g_f}^f;C_{g_{f+k}}^{f+k})_{s_{f;f+k}};...;(C_{g_f}^f;C_{g_{f+k}}^{f+k})_{S_{f;f+k}}\}$, $(f=\overline{1;F})$, $(g=\overline{1;G})$, $(k=\overline{-K;K})$, which include pairs of clusters of certain levels of the network, between which connections are established that have overcome the threshold of the membership function of fuzzy relations.

The following sets of cluster pairs of clusters are created on the network of clusters of *ELS* phase products: $C^{3;4}$; $C^{3;2}$; $C^{4;2}$; $C^{2;5}$; $C^{3;1}$; $C^{4;1}$; $C^{2;1}$; $C^{5;1}$.

The approach, which involves considering all possible variants of cluster pairs, guarantees their participation in further research of product chains and requires considerable time for calculations. To reduce the task to a smaller dimensionality and significantly reduce the number of calculations, one should use the morphological synthesis of product chains, which is aimed at creating an optimal chain value criterion.

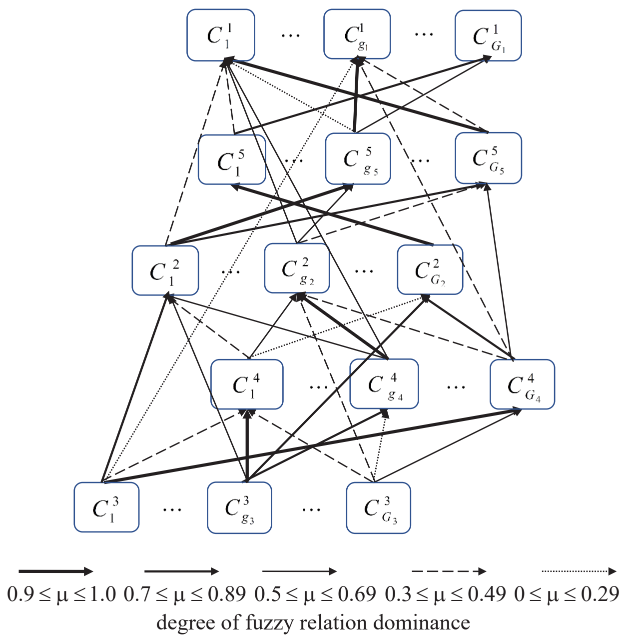

Fig. 3. Network of product clusters of the life cycle phases of the eco-logistics system project

Priority of application of the l_h, $(h=\overline{1;H})$ chain, the products of the phases of the project from the set of chains $L=\{l_1; ...; l_h; ...; l_H\}$ is determined by calculating the total value of the degree of dominance of fuzzy relations. Formalization of the process is carried out by summing up the values of the membership function of fuzzy relationships between clusters of products located on a specific branch of the network,

$$D(l_h)=\sum_f \mu_{\tilde{R}}\left(C^f_{hg_f};C^{f+k}_{hg_{f+k}}\right),\ \forall C^{f;f+k}_{g_f;g_{f+k}}\in l_h. \quad (1)$$

Thus, the product chains include those clusters that provide the maximum possible value of the total value of products that fall into clusters located on the chain.

Therefore, it is possible to form the configuration of the project's products in the form of a chain of products with such values of product parameters, thanks to which it is possible to achieve the maximum value of the ELS project in terms of the implementation of eco-logistics rules.

5. 3. Experimental calculations confirming the validity of the application of the method of managing the configuration of products of the project of the eco-logistics system

The specification of product parameters is to create descriptive models that reflect the set of parameters necessary to characterize the product phase of the LC project. Further research will involve clusters that include products that have valid parameter values. In our example, such clusters are permissible, the values of all expert assessments of the characteristics of products of which exceed the threshold of 4 points (Table 4).

Table 4

Descriptive models of ELS project products

Product cluster	Document-based project – C^1			Eco-logistics system – C^2			Logistics product – C^3			Eco-logistics product – C^4			Reborn ecosystem – C^5		
	Product parameter														
–	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	2	3	4	**7**	**9**	**5**	7	2	3	1	5	6	9	4	2
2	3	4	5	9	7	2	**6**	**4**	**4**	6	3	2	**8**	**9**	**4**
3	1	6	4	8	3	5	**4**	**9**	**7**	**5**	**6**	**8**	4	1	5
4	**4**	**5**	**6**	**9**	**7**	**4**	2	6	5	**8**	**9**	**4**	6	5	2
5	2	1	6	**4**	**9**	**7**	2	5	6	**4**	**8**	**9**	5	1	2
6	3	4	6	9	5	2	1	6	5	4	2	3	**6**	**7**	**8**
7	6	2	5	**6**	**4**	**5**	**6**	**9**	**7**	5	1	3	**5**	**6**	**4**
8	**4**	**6**	**5**	**4**	**8**	**4**	1	3	5	1	6	9	7	5	3
9	3	6	4	**5**	**6**	**5**	**4**	**5**	**8**	9	6	1	2	4	6
10	2	6	4	2	7	9	2	3	6	**4**	**5**	**8**	2	1	6

Fuzzy relationships between project phase product clusters are set using their membership functions, which reflect the degree of correspondence between product clusters that are at the appropriate levels of the network and have integration links. An example of fuzzy relationships between clusters C^3 and C^4 of the products of the LC phases of an ELS project is given in Table 5.

In the subsequent study, four C^3 clusters (2; 3; 7; 9) and four C^4 clusters (3; 4; 5; 10) of ELS project LC phase products will be accepted. 16 connections have been established between clusters, of which 11 have an acceptable value of the membership function of fuzzy relations (≥0.5). Similar calculations are performed for clusters of other products of the project.

Information about fuzzy relationships between product clusters makes it possible to form on the product network a set of variants of individual sections of the product chains of the phases of the project's LC. An example of the formation of a section of product chains $C^{3;4}$ and $C^{4;2}$ is given in Table 6.

In accordance with the obtained variants of the sections of the chains, variants of the chains of the product clusters of the phases of the LC of the ELS project are compiled. As a result of our calculations, taking into consideration all possible options and limitations, 59 chains of product clusters of the phases of the ELS project were formed, which differ in the dominance value of fuzzy relations. For cluster chains, the total value of the degree of dominance of fuzzy relations was calculated. The maximum value of the degree of dominance of fuzzy relations $D(l_{40})=5.4$ was obtained for the chain of product clusters, which is formed from the optimal set of cluster pairs, which is formed by the morphological selection, $\{C^{3;4}_{3;10};C^{4;2}_{10;7};C^{3;2}_{3;7};C^{2;5}_{7;2};\ C^{5;1}_{2;4};\ C^{2;1}_{7;4};\ C^{3;1}_{3;4};\ C^{4;1}_{10;4}\}$. Thus, a cluster configuration is formed, which includes product clusters $\{C^3_3;C^4_{10};\ C^2_7;\ C^5_2;\ C^1_4\}$ (Fig. 4).

Table 5

Fuzzy relationships between clusters C^3 and C^4 of life cycle phase products of the eco-logistics system project

Cluster C^3	2				3				7				9			
Cluster C^4	3	4	5	10	3	4	5	10	3	4	5	10	3	4	5	10
$\mu_R(C^3,C^4)$	0.7	0.6	0.5	0.3	0.4	0.5	0.6	0.8	0.4	0.5	0.2	0.6	0.3	0.5	0.6	0.8

Table 6

Sections of product chains $C^{3;4}$ and $C^{4;2}$ 2 phases of the life cycle of the eco-logistics system project

$C^{3;2}$	$C^{4;2}$															
$C^{3;4}$	3–1	3–4	3–5	3–7	3–8	4–1	4–4	4–5	4–7	4–8	5–1	5–4	5–7	10–4	10–7	10–9
2–3	2–1	2–4	–	2–7	–	–	–	–	–	–	–	–	–	–	–	–
2–4	–	–	–	–	–	2–1	2–4	–	2–7	–	–	–	–	–	–	–
2–5	–	–	–	–	–	–	–	–	–	–	2–1	2–4	2–7	–	–	–
3–4	–	–	–	–	–	3–1	3–4	–	3–7	3–8	–	–	–	–	–	–
3–5	–	–	–	–	–	–	–	–	–	–	3–1	3–4	3–7	–	–	–
3–10	–	–	–	–	–	–	–	–	–	–	–	–	–	3–4	3–7	–
7–4	–	–	–	–	–	–	7–4	7–5	–	–	–	–	–	–	–	–
7–10	–	–	–	–	–	–	–	–	–	–	–	–	–	7–4	–	7–9
9–4	–	–	–	–	–	–	9–4	9–5	–	9–8	–	–	–	–	–	–
9–5	–	–	–	–	–	–	–	–	–	–	–	9–4	–	–	–	–
9–10	–	–	–	–	–	–	–	–	–	–	–	–	–	9–4	–	9–9

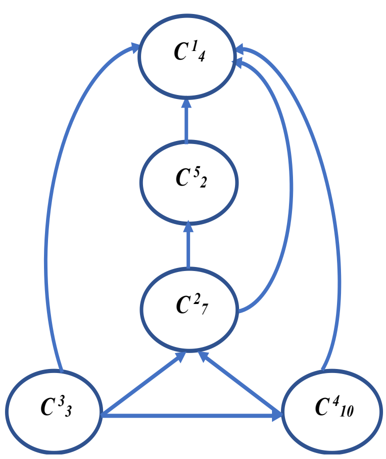

Fig. 4. An example of the configuration of product clusters of the life cycle phases of the eco-logistics system project

In the further formation of product chains of the phases of the ELS project, it is necessary to apply products that fall into the clusters contained in the presented configuration. This will make it possible to achieve the maximum value of the products received in the project in terms of compliance with the rules of eco-logistics.

6. Discussion of results of the development of a method for managing the configuration of products of the eco-logistics system project

The developed method of managing the configuration of the ELS project products is based on the application of an improved model of the ELS project LC. The proposed model, in contrast to the one presented in the standard from [12], which includes generally accepted pre-investment, investment, and operational phases, has ecologically-oriented regenerative and revitalization phases. The presence of ecologically-oriented phases leads to the closure of the logistics system and its transformation into an eco-logistics one. This approach makes it possible to form a set of products of the ELS project, which includes the products of each phase of the LC: a documented project, an eco-logistics system, a logistics product, an eco-logistics product, a revived ecosystem (Fig. 1). The inclusion in the products of the project of those obtained as a result of the implementation of ecologically-oriented phases makes it possible to clearly define their content. In the future, this will affect the composition and the cost of work aimed at minimizing the eco-destructive impact on the environment from the implementation of the ELS project.

Identification of ELS project products and determining their specific features showed the presence of links between products and the influence of product characteristics of some phases on the content of products of other phases (Fig. 2). This property is used in the formation of the content of products using pattern recognition tools (frame modeling) at the stage of specification of the proposed method when creating sets of product parameters (Table 2). The development of descriptive frame models of ELS project products makes it possible to determine the presence of links between the characteristics of products.

The method of managing the configuration of products of the ELS project involves three stages: the specification of product parameters, the clustering of products, and the structuring of product clusters, between which the logic of conducting scientific research is observed. The initial results of the previous stage are justifiably the input data for the next stage (Table 2), which is confirmed by the results of experimental calculations (Tables 4–6).

The use of cluster analysis at the stage of product clustering made it possible to create information models represented by instance frames of product clusters that contain information about the sets of products of the phases of the project's

LC that have close parameter values. Cluster frames-instances contain information about the values of qualitative parameters or the range of values of quantitative parameters, which reduces the degree of uncertainty regarding the content of the products of the ELS project.

The structuring of product clusters implies creating links between clusters (Table 3), which are determined using fuzzy relationships. The presence of links between clusters shows the possibility of moving along the levels of the created network of product clusters (Fig. 4). The use of the tools of the morphological method and fuzzy relations can significantly reduce the volume of calculations since it determines the set of permissible chains of clusters of phases of the project's LC phases. Determining the maximum value of the degree of dominance of fuzzy relationships for product cluster chains using formula (1) makes it possible to choose the best configuration of ELS project products in terms of implementing eco-logistics rules. An example of the created product configuration is shown in Fig. 4.

The advantages of the proposed method of managing the configuration of ELS project products are as follows.

The use of an improved model of the ELS project LC, which, unlike standard approaches, includes ecologically-oriented phases, makes it possible to follow the rules of ecologistics and reduce the environmental impact of logistics activities on the environment. This focus of the research is relevant in terms of achieving environmental goals for sustainable development.

Determining the qualitative and quantitative characteristics of products obtained at different phases of the ELS project LC and establishing links between them at the specification stage allows us to build descriptive product models represented by their prototype frames. This procedure leads to detailing the characteristics of the products necessary for the implementation of the subsequent steps of the method.

Clustering of products using frame-instances of product clusters makes it possible to form clusters, which will include products with similar values of qualitative and quantitative characteristics. Thus, it is possible to reduce the degree of uncertainty when planning the content of future products of the project.

The disadvantages of the developed method of managing the configuration of the ELS project products include:

– the use of fuzzy relationships tools in determining the connections between product clusters and the degrees of the dominance of fuzzy relationships in the formation of a cluster network (Fig. 3) is subjective in nature and may affect the relevance of further research results;

– the configuration built as a result of experimental calculations, consisting of clusters $\{C_3^3; C_{10}^4; C_7^2; C_2^5; C_4^1\}$ (Fig. 4), corresponds to the products whose characteristics were determined at the specification stage. In the case of significant changes in input values, as a result of which there will be changes in the specified affiliation of the product to a particular cluster, the product configuration will also undergo changes. That is, the already built configuration can be used in a limited range of values of the input characteristics of the project products;

– the proposed method does not consider the mechanism for the formation of optimal product chains of the ELS project, which is the object of further scientific research.

7. Conclusions

1. It is possible to take into consideration the eco-destructive impact on the environment due to the inclusion of the ELS project in the LC in addition to the main ones: pre-investment, investment, and operational, ecologically-oriented phases: regenerative and revitalization, that is, its duration will consist of five phases. Each phase corresponds to the production of a specific product, the characteristics of which form the content of the product, which is proposed to be determined using frame models. Based on prototype frames, instance frames are created that contain information about the values of qualitative parameters or the range of values of the quantitative parameters of the project products. The use of frame modeling allows us to take into consideration the specific features of the phase products of the ELS project and determine the connections between them, which will be used in further research.

2. The proposed method of managing the configuration of ELS project products includes three stages: specification of product parameters, product clustering, and structuring of project product clusters. The specification of product parameters is to create descriptive frame models of products that reflect the set of parameters necessary to characterize the product phase of the project. The number and value of the parameters depend on the specificity of the product of the LC phase of the ELS project. Product clustering involves the creation of information models of product clusters that contain information about the set of products of the project phases that have close parameter values. The structuring of product clusters leads to the creation of a cluster network, which makes it possible to display the connections between the products of the phases of the project and create a network of products of the phases of the ELS project. There is a hierarchy of network levels. Clusters of products of the operational phase (complexes of logistics services for the promotion of direct material flow) are located at the first level. Clusters of products of the regenerative phase (complexes of services for the promotion of the reverse material flow) are located on the second level. Investment phase product clusters (ELS) are located at the third level. Clusters of products of the liquidation phase (options for the revival of the ecosystem) are located at the fourth level. Clusters of products of the pre-investment phase (documented ELS projects) are located at the fifth level. Such a distribution of product clusters by network levels allows us to take into consideration the mutual influence of products on each other.

3. Experimental calculations using the proposed method of managing the configuration of ELS project products confirmed the adequacy of the proposed method and allowed us to create a network of ELS product clusters. The network includes clusters of products of all phases of the project's LC, which have maximum value in terms of implementing the rules of eco-logistics studies.

Thus, the use of the proposed method of managing the configuration of products of the ELS project makes it possible to take into consideration the specific features of this category of projects, namely their environmental value. This becomes possible due to the identification of additional ecologically-oriented LC phases of the ELS project and taking into consideration the characteristics of their products in determining the content and configuration of the project products.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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