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EXPERIMENTAL STUDIES OF A MODEL FOR OPTIMIZING THE PORTFOLIO OF A PROJECT-ORIENTED ORGANIZATION BASED ON THE ENTROPY CONCEPT

The **subject** of the research is the optimization of the composition of the project portfolio based on the entropy concept. The **aim** of the study is to experimentally test the model for optimizing the portfolio of a project-oriented organization and substantiate its applicability in practice in management processes to ensure their effectiveness. Research **objectives:** forming a model taking into account the accepted value of the organization; formation of initial data on the organization and alternative projects; portfolio optimization by model and interpretation of results. Research **methods**: system analysis, functional analysis, operations research. **Results.** A model has been developed for forming a portfolio structure from projects of two categories – operational and development; the optimization criterion is to minimize the discrepancy between the desired and actually provided value of the organization. The restrictions take into account the maximum allowable energy limit and the minimum allowable value limit. As a result of the study, the applicability and adequacy of the model for optimizing the portfolio structure of a project-oriented organization were substantiated. The model makes it possible to obtain solutions on the optimal structure of a portfolio of projects in terms of its value under given resource constraints (in the form of a share of total energy and output energy) and energy entropy. The studies substantiated the possibility of adjusting the model in terms of the optimization criterion (maximizing value, minimizing energy entropy) and adding restrictions on the maximum permissible border of information entropy and energy efficiency. **Conclusions.** The model under consideration is characterized by wide practical application, taking into account its possible adjustment without changing the basic essence, taking into account the specifics of a particular field of activity or organization. The practical use of the main indicators of the entropy concept - information entropy, temperature, energy entropy, which characterize the state of organizations, allowing to identify hidden problems before they are reflected on the traditional indicators of organizational performance is demonstrated. Taking this into account, the structure of the project portfolio is being formed within the framework of the considered approach.

Keywords: project; portfolio; model; energy entropy; information entropy; energy efficiency.

Introduction

The specificity of project-oriented organizations is that their current activities and development are carried out through projects [1]. The effectiveness of project-oriented management is justified both in theoretical studies [2] and in applied works related to specific types of activities (for example, [3]).

The project portfolio of these organizations forms the final result, which, in the context of modern project management methodology, represents the value of the organization [4, 5], which can be calculated both in the form of economic indicators and in the form of indicators characterizing, for example, the market status of the organization.

The allocation of the organization's resources between portfolio projects and the formation of its optimal structure allows the organization to build its current activities and development in such a way as to maximize value under certain resource constraints and the desired state.

The entropy concept of managing organizations [6-11] puts forward new requirements that must be taken into account in the processes of optimizing a portfolio of projects in order to ensure not only economic efficiency, but also the sustainability of the organization [12] in the context of information and energy entropy.

Analysis of recent research and publications

A significant number of works are devoted to the problem of forming the optimal composition of portfolios of project-oriented organizations [13-20]. International standards for project portfolio management [13] set a certain benchmark for theoretical research.

Most of the works, for example [14, 15], focus on ensuring the achievement of the strategic goals of organizations, which is the essence of the core value of portfolios. In some works (in particular, [16]), the dynamics of the state of the organization is taken into account and the portfolio of projects is also considered in the form of a dynamic structure. In [17], approaches were proposed to the formation of a portfolio taking into account risks.

Thus, it can be argued that the instrumental basis for the formation of the optimal composition of project portfolios in the form of models and methods has been sufficiently developed in modern research.

Nevertheless, as mentioned above, the new entropic concept of managing organizations, which assesses their state by means of energy entropy [10-12], forms a new approach to optimizing the composition of the project portfolio. In particular, ensuring high economic performance without a corresponding increase in control over the external environment (controlled part of the external environment) [11], which is expressed in a gradual decrease in information entropy, as well as an increase in the efficiency of the use of total energy (resources), will not lead the organization to the required stable state. in a modern turbulent environment.

In [12], on the basis of the entropy concept of management of organizations, a model was developed that allows one to determine the optimal composition of a project portfolio that meets the requirement of balance in terms of the value-entropy ratio. Justification of the reliability and practical applicability of this model is impossible without appropriate experimental studies, which is the essence of this study.

Thus, the aim of this study is to experimentally test

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the model for optimizing the portfolio of a project-oriented organization and justify its applicability in practice in management processes to ensure their effectiveness.

Results

The model for optimizing the composition of a portfolio of projects provides for the following management parameters:

$$x^{dev}_{i\theta}=\{1,0\},i=\overline{1,n},\ x^{cur}_{jv}=\{1,0\},j=\overline{1,m}, \quad (1)$$

selection of development projects and current activities from a variety of alternative options, T_i, T_j – accordingly, the duration of the life cycles of these projects, $\theta=\overline{1,K\text{-}T_i+1},i=\overline{1,n}$ and $v=\overline{1,K\text{-}T_j+1},j=\overline{1,m}$ – alternative options for starting projects of two categories under consideration. Taking into account that K is the end of the portfolio planning period, the values $K\text{-}T_i+1$, $K\text{-}T_j+1$ characterize the latest start of the project, so that its life cycle falls within the planning period of the portfolio K.

After the implementation of projects of current activities, there are no qualitative changes in the state of the organization, after the implementation of development projects, certain "leaps" of the state are formed, for example, the information entropy decreases or the share of possible use of total energy increases (that is, the part of free energy that can be directed to the implementation of new projects).

The objective function ensures that the discrepancy between the actual and desired $V^*(t)$ values of the organization is minimized:

$$Z=\sum_{t=1}^{K}\left[\sum_{i=1}^{n}\sum_{\theta=1}^{K\text{-}T_i+1}\mathbf{V}_{i\theta}(t)\cdot x^{dev}_{i\theta}+\sum_{j=1}^{m}\sum_{v=1}^{K\text{-}T_j+1}\mathbf{V}_{jv}(t)\cdot x^{cur}_{jv}+\mathbf{V}'(t)\text{-}V^*(t)\right]^2\rightarrow\min_{x^{dev}_{i\theta},x^{cur}_{jv}}, \quad (2)$$

where $\mathbf{V}'(t)$ – value provided by current portfolio composition, $\mathbf{V}_{i\theta}(t),\mathbf{V}_{jv}(t)$, accordingly, the contribution to the value of organizing projects of each category.

Condition for ensuring the minimum value boundary:

$$\sum_{i=1}^{n}\sum_{\theta=1}^{K\text{-}T_i+1}\mathbf{V}^{l}_{i\theta}(t)\cdot x^{dev}_{i\theta}+\sum_{j=1}^{m}\sum_{v=1}^{K\text{-}T_j+1}\mathbf{V}_{jv}(t)\cdot x^{cur}_{jv}+\mathbf{V}'(t)\geq V^{min}(t),t=\overline{1,K}. \quad (3)$$

Condition for the maximum allowable value of energy entropy:

$$S(t,x^{dev}_{i\theta},x^{cur}_{jv})\leq S^{\max}(t),t=\overline{1,K}. \quad (4)$$

The formation and formalization of the energy entropy of an organization is presented in detail in [10], where the energy entropy of an organization is determined on the basis of its energy parameters and information entropy, which are formed as a composition corresponding to the characteristics of projects:

$H_{i\theta}(t),H_{jv}(t)$ – information entropy;

$U_{i\theta}(t),U_{j\theta}(t)$ – total energy;

$E^{ex}_{i\theta}(t),E^{ex}_{j\theta}(t)$ – output energy;

$E^{in}_{i\theta}(t),E^{in}_{j\theta}(t)$ – incoming energy.

Limitations on available resources in the form of total energy (potential) and output energy:

$$\sum_{i=1}^{n}\sum_{\theta=1}^{K\text{-}T_i+1}\mathbf{U}_{i\theta}(t)\cdot x^{dev}_{i\theta}+\sum_{j=1}^{m}\sum_{v=1}^{K\text{-}T_j+1}\mathbf{U}_{jv}(t)\cdot x^{cur}_{jv}\leq\mathbf{U}^{max}(t),t=\overline{1,K}, \quad (5)$$

$$\sum_{i=1}^{n}\sum_{\theta=1}^{K\text{-}T_i+1}\mathbf{E}^{ex}_{i\theta}(t)\cdot x^{dev}_{i\theta}+\sum_{j=1}^{m}\sum_{v=1}^{K\text{-}T_j+1}\mathbf{E}^{ex}_{jv}(t)\cdot x^{cur}_{jv}\leq\mathbf{E}^{max}(t),t=\overline{1,K}. \quad (6)$$

Conditions for the selection of projects (that is, at least one project must be selected):

$$\sum_{i=1}^{n}\sum_{\theta=1}^{K\text{-}T_i+1}x^{dev}_{i\theta}\geq 1;\sum_{j=1}^{m}\sum_{v=1}^{K\text{-}T_j+1}x^{cur}_{jv}\geq\mathbf{1}. \quad (7)$$

In addition, from the many options for a project from the point of view of its start, only one should be selected (or none, therefore the sign "less or equal"):

$$\sum_{\theta=1}^{K\text{-}T_i+1}x^{dev}_{i\theta}\leq 1,i=\overline{1,n};\ \sum_{v=1}^{K\text{-}T_j+1}x^{cur}_{jv}\leq 1,j=\overline{1,m}. \quad (7)$$

$$\sum_{\theta=1}^{K\text{-}T_i+1}x^{dev}_{i\theta}\leq 1,i=\overline{1,n};\ \sum_{v=1}^{K\text{-}T_j+1}x^{cur}_{jv}\leq 1,j=\overline{1,m}. \quad (8)$$

Model (1) - (8) provides the formation of a portfolio of projects in accordance with the conditions and criteria described above.

Let us consider the application of this model to optimize the project portfolio of a specific organization (the "Transmarine" company), which operates in the field of sea transportation, providing services for both cargo delivery and storage, and the formation of groupage shipments. The company has many branches, its own storage sites and warehouses, vehicles.

In accordance with the current composition of the portfolio of projects, the forecast of the state and performance of the organization under consideration is characterized by the following indicators (table 1, fig. 1), the prospective period of consideration is 8 years. The energy parameters of the organization are considered in conventional units, 1 c.u = 1 million dollars.

Table 1. *Forecast of the energy parameters of the organization in accordance with the current composition of the project portfolio*

Time	Total energy, U	Input energy, Ein	Output energy, Eex	Information entropy, H	Energy efficiency, η	Temperature, T	Energy entropy, S
0	12						
1	13,5	5,5	4	2	1,125	0,3125	25,920
2	15,5	6	4	2	1,148	0,3189	30,291
3	16	5,5	5	2,5	1,032	0,2294	45,818
4	17	6	5	2,5	1,063	0,2361	46,750
5	18,5	6,5	5	2,5	1,088	0,2418	49,950
6	19,5	6	5	3	1,054	0,1952	69,344
7	20	5,5	5	3	1,026	0,1899	76,390
8	21	6	5	3	1,050	0,1944	77,318

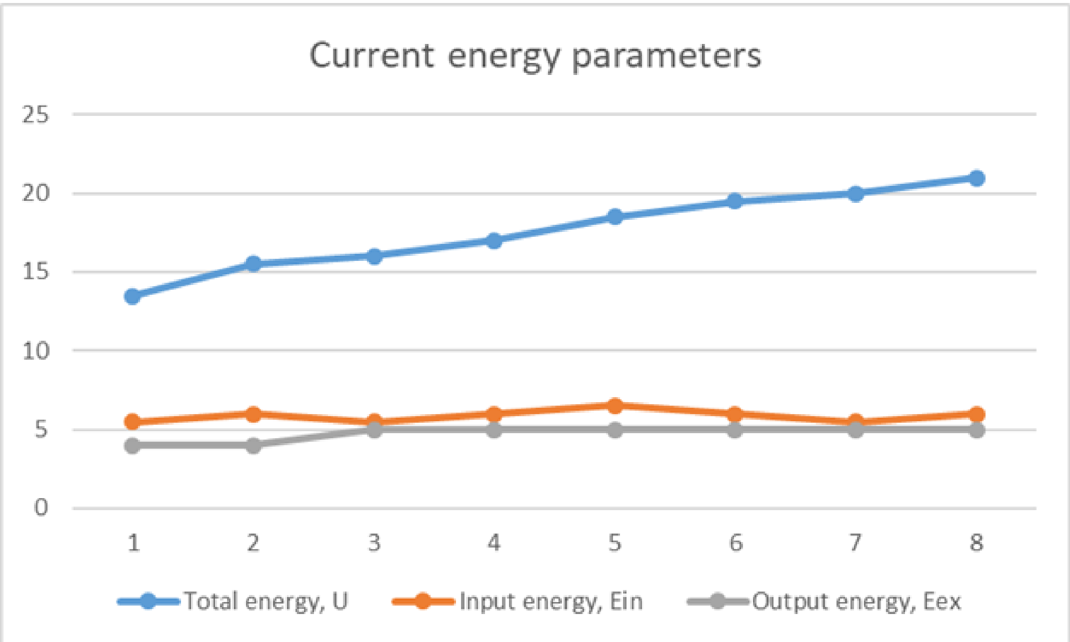

Fig. 1. Forecast dynamics of the organization's energy parameters

Under the value of the organization, in this case, we take the growth of the organization's energy (profit), which is formed as the difference between the incoming and output energy flows. Thus, the value of the organization:

$$V(t) = E^{in}(t) - E^{ex}(t), t = \overline{1,8}. \quad (9)$$

On the basis of the predicted values of the dynamics of the organization's energy parameters $U(t), E^{in}(t), E^{ex}(t), t = \overline{1,8}$, the predicted values of the indicators of its state - information entropy, temperature, energy entropy - were calculated (fig. 2).

It should be canceled that the forecast of the state of the organization, on the one hand, cannot be identified as "bad": in accordance with current projects, the information entropy gradually increases, respectively, the temperature decreases, while the energy entropy increases (fig. 2c), the reason for this is an increase in the total energy of the organization $U(t)$ (fig. 1) despite the fact that the output $E^{ex}(t)$ and input $E^{in}(t)$ energies remain practically unchanged. Thus, in the organization there is an accumulation of "potential" energy, which is not converted into "kinetic" energy, which ensures the movement of the organization to new states in terms of value. Due to this, there is a general downward trend in energy efficiency on average $E^{in}(t)$. The value of the organization is also gradually decreasing (fig. 3).

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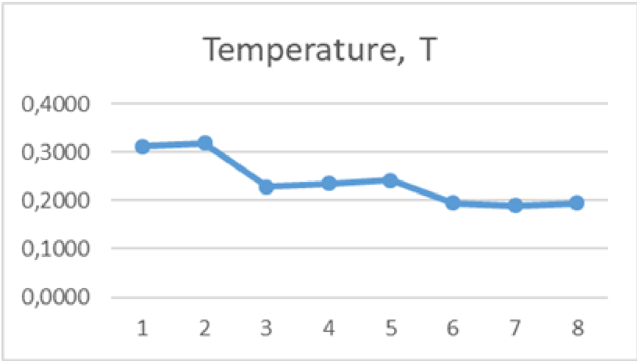
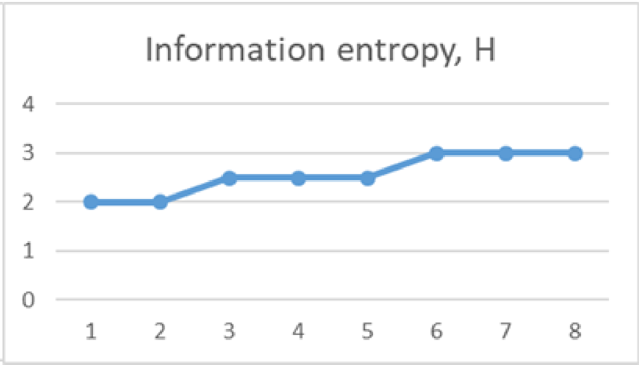
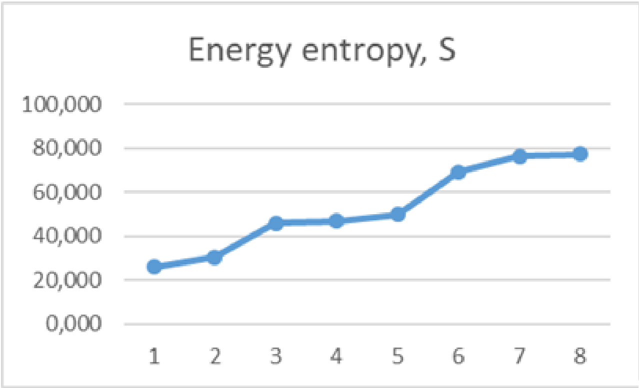


a)



b)



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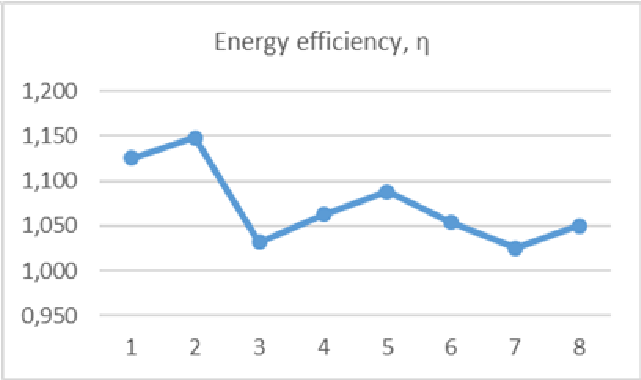

d)

Fig. 2. Forecasted values of indicators of the state of the organization

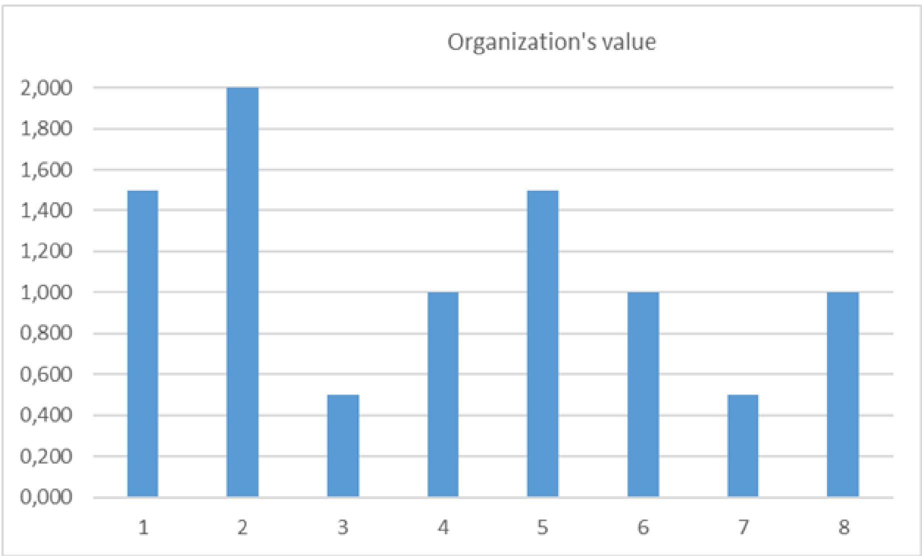

Fig. 3. Forecasted dynamics of the organization's value

Thus, despite the apparent absence of problems in the organization, the entropic concept of management allows you to "reveal" the deep problems that lead to the growth of energy entropy, which can gradually "destroy" the organization.

To avoid this, the organization should supplement its portfolio of projects to address these issues. For this, three alternative operational projects (current activities) and three development projects are proposed for consideration, their main characteristics are presented in tables 2, 3. Note that the energy parameters of projects reflect annual values (total for the year), and informational entropy and energy entropy refer to the beginning of each year. Therefore, their last (zero) value for projects refers to the end of the last year of the project life cycle.

As the effect of development projects on the state of the organization (without limiting the generality), a decrease in information entropy was taken:

$$\Delta H_1 = -0,5; \Delta H_2 = -1; \Delta H_3 = -0,8. \qquad (10)$$

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Table 2. *Characteristics of projects of current activity (dynamics by year of projects)*

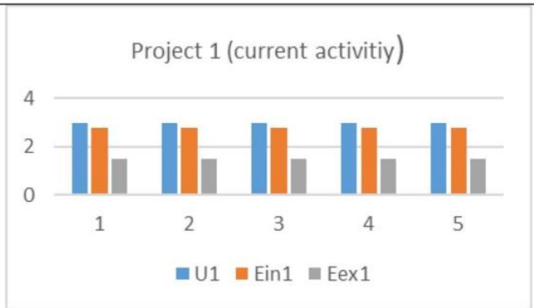
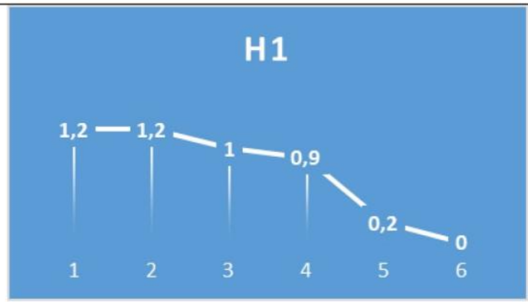
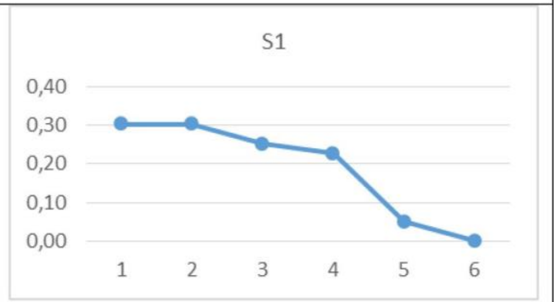
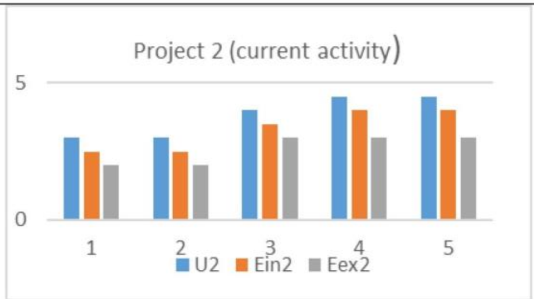
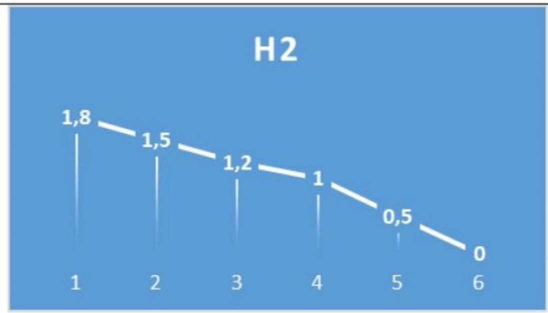
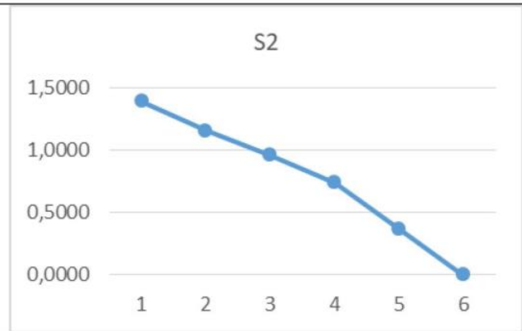
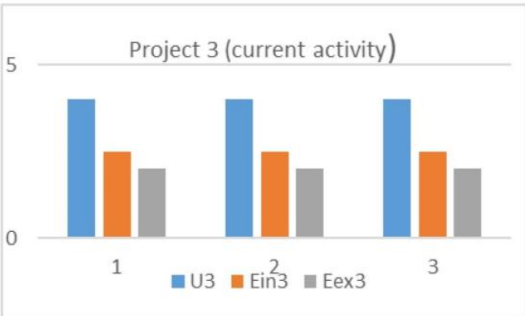
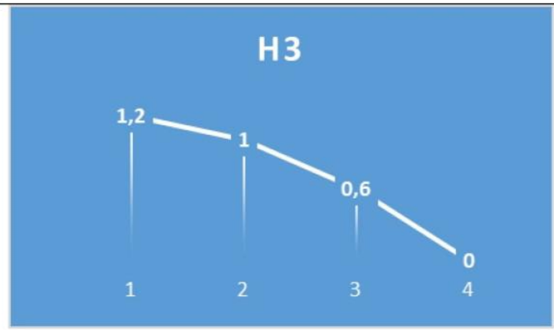
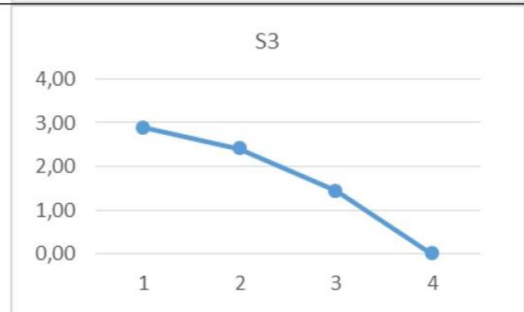
Project	Energy parameters	Information entropy, H	Energy entropy, S
PROJECT 1			
PROJECT 2			
PROJECT 3			

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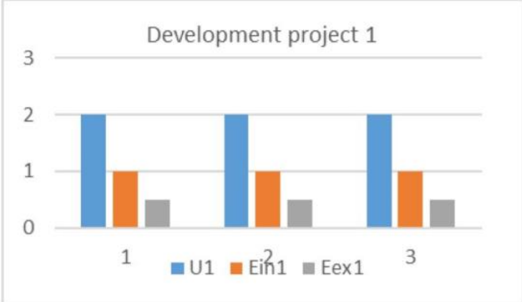
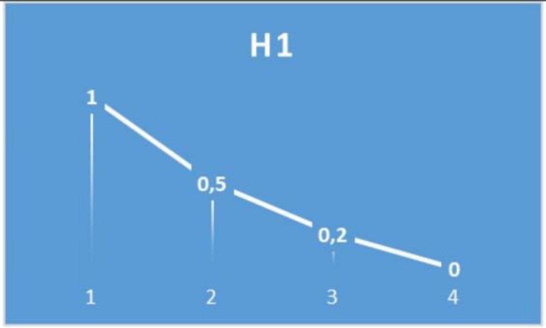
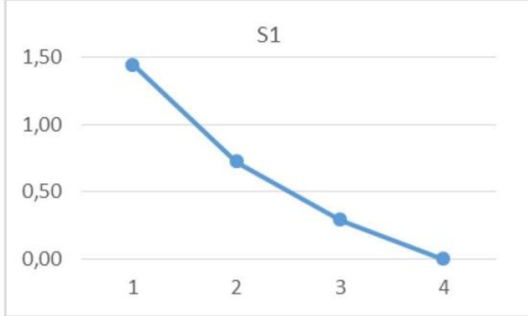
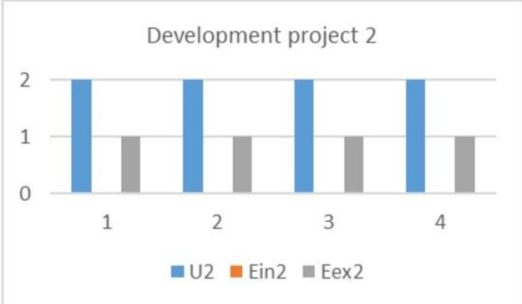
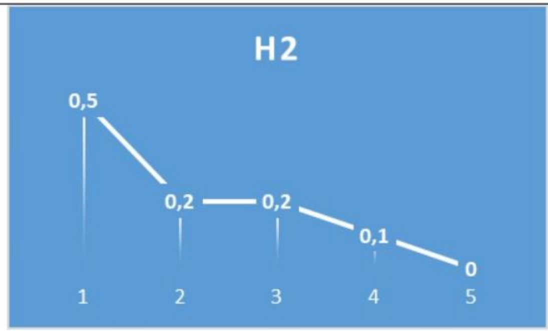
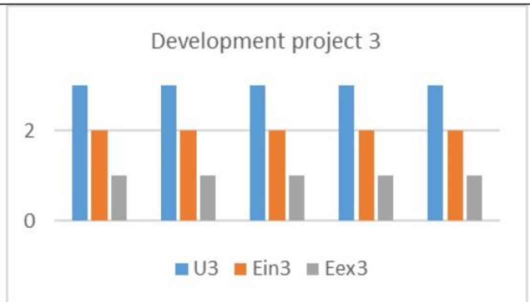
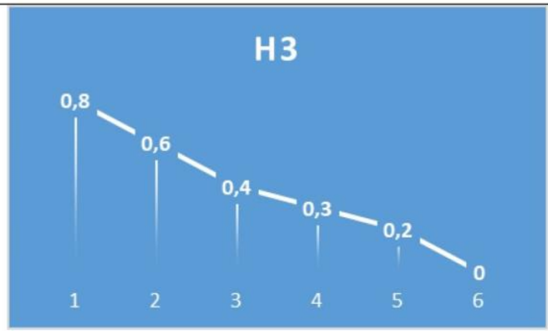
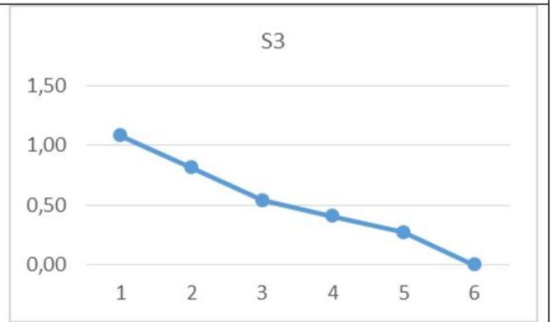
Table 3. *Characteristics of development projects (dynamics by year of projects)*

Project	Energy parameters	Information entropy, H	Energy entropy, S
PROJECT 1			
PROJECT 2			
PROJECT 3			

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The main conditions that were taken into account when forming the project portfolio structure were the following:

- minimum limit values of the organization $V^{\min}(t) = 2$,

- the output energy of the organization can not exceed 40% of the total energy, i.e. $\sum_{i,j}(E_i^{ex}(t)+E_j^{ex}(t)) \leq 0,4 \cdot U(t)$;

- the part of the total energy of the organization that is distributed between projects can not, respectively, exceed 60%, i.e. $\sum_{i,j}(U_i\ (t)+U_j\ (t)) \leq 0,4 \cdot U(t)$.

The following results were obtained for the given conditions:

- all three alternative projects of current activity should be included in the portfolio, respectively, in 4, 4 and 6 years of the period under consideration, that is, in the latest possible start. This is due to the fact that, as previously indicated, the current activities of the organization are characterized by not bad indicators, the problem is, first of all, in the accumulation and non-use of total energy;

- the first and third development projects should be started at the very beginning of the period in question in order to eliminate the problem of accumulating and not using common energy. The specificity of the second development project is that it does not provide for the receipt of input energy $E_2^{in} = 0$, although it provides the maximum reduction in information entropy ($\Delta H_2 = -1$).

Note that experimental calculations were carried out for two variants of the optimization criterion: the first corresponded to (2), the second (taking into account the accepted energy gain in the form of value) - maximization of the organization's value. The results were the same. Thus, despite the fact that in [12] it was declared as an optimization criterion the minimization of the discrepancy between the total value and the desired value, nevertheless, in cases where the value can be interpreted as an increase in energy, the approach implemented within the framework of this research.

So, as a result of the formation of the structure of the project portfolio in accordance with the results of optimization, the predicted values of the results of activities and the state of the organization will be as follows (fig. 4).

Comparison of energy efficiency for the current portfolio and for its new structure is shown in fig. 5, temperature in fig. 6.

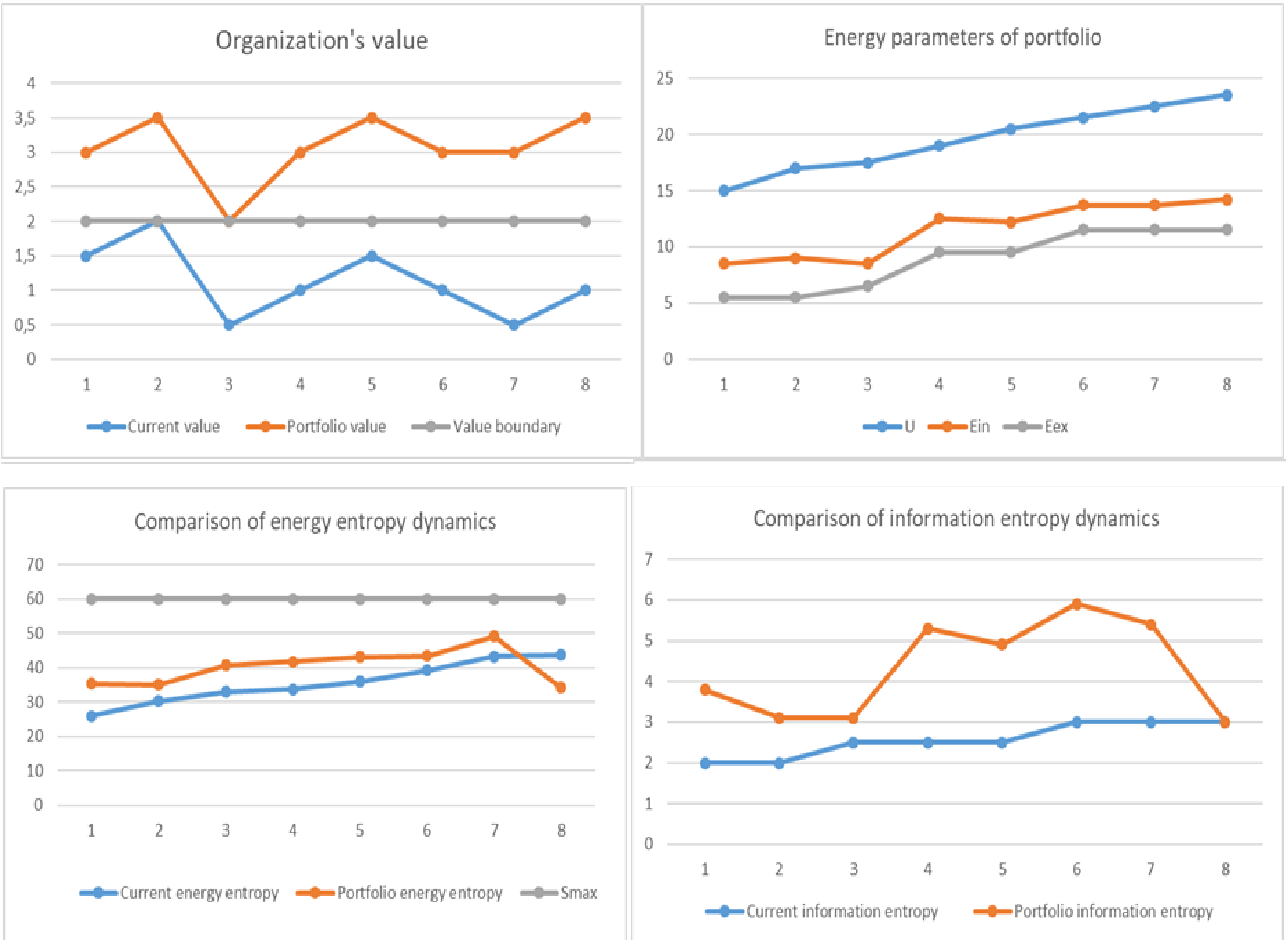

Fig. 4. Forecast values of the company's performance and condition for the proposed portfolio structure

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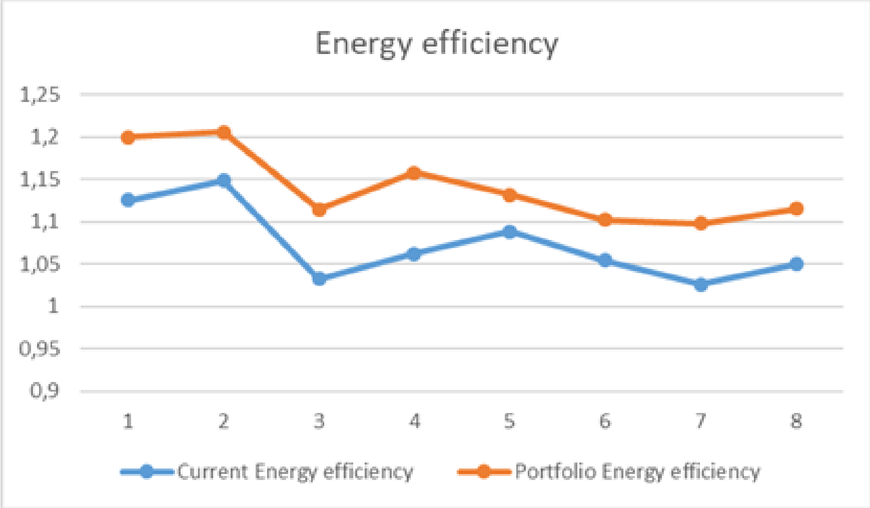

Fig. 5. Comparison of energy efficiency for the current portfolio and for its new structure

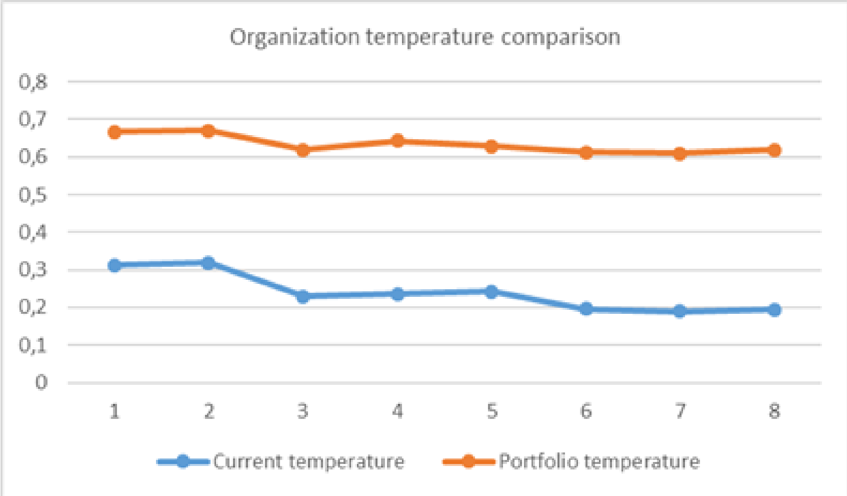

Fig. 6. Comparison of the organization temperature with the existing and new project portfolio structure

The proposed portfolio structure will provide the required level of value for the organization (and, moreover, not below its minimum allowable boundary). The increase in information entropy and energy entropy within the permissible limit is associated with the implementation of new projects, which naturally affects these indicators. But after the implementation of projects, the energoentropy will reach a value lower than it would have been without new projects. The information entropy will return to the "before the new portfolio" level. The temperature increased significantly, which indicates a stronger control over the "external structure" of the organization [11]. So, the model made it possible to form a new structure of the project portfolio, which ensures the fulfillment of the necessary conditions and the achievement of the set result in relation to the value of the organization.

Experiments at varying the initial data also confirmed the accuracy of the obtained optimization results and the adequacy of the model. In particular, changes were made in the current dynamics of information entropy and requirements for the lower boundary of value, which led to the priority of the implementation of projects of current activities and to the postponement of the implementation of development projects.

Conclusions

As a result of the study, the applicability and reliability of the model for optimizing the portfolio structure of a project-oriented organization was substantiated. The model makes it possible to obtain solutions for the optimal structure of a project portfolio in terms of its value under given resource constraints (in the form of a share of total energy and output energy) and energy entropy. The studies substantiated the possibility of adjusting the model in terms of the optimization criterion (maximizing value, minimizing energy entropy) and adding restrictions on the maximum permissible border of information entropy and energy efficiency.

Thus, the developed model (1) - (8) is characterized by wide practical application, taking into account its possible adjustment without changing the basic essence, taking into account the specifics of a particular field of activity or organization.

The practical use of the main indicators of the entropy concept [10-12] – information entropy,

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temperature, energy entropy, which characterize the state of organizations, allowing to reveal hidden problems before they are reflected on the traditional indicators of the effectiveness of organizations.

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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ МОДЕЛІ ОПТИМІЗАЦІЇ СКЛАДУ ПОРТФЕЛЯ ПРОЄКТНО-ОРІЄНТОВАНОЇ ОРГАНІЗАЦІЇ НА БАЗІ ЕНТРОПІЙНОЇ КОНЦЕПЦІЇ

Предметом дослідження є оптимізація складу портфеля проєктів на базі ентропійної концепції. **Метою** дослідження є експериментальна перевірка моделі оптимізації складу портфеля проєктно-орієнтованої організації і обґрунтування її застосування на практиці в процесах управління для забезпечення їх ефективності. **Завдання** дослідження: формування моделі з урахуванням прийнятої цінності організації; формування вихідних даних по організації і альтернативним проєктам; оптимізація портфеля за моделлю і інтерпретація результатів. **Методи** дослідження: системний аналіз, функціональний аналіз, дослідження операцій. **Результати.** Розроблено модель формування структури портфеля з проєктів двох категорій - операційних і розвитку, критерій оптимізації - мінімізація розбіжності бажаної і фактично досяжної цінності організації. Обмеження враховують максимально допустиму межу енергонтропії і мінімально допустиму межу цінності. В результаті проведеного дослідження обґрунтована можливість застосування і достовірність моделі оптимізації структури портфеля проєктно-орієнтованої організації. Модель дозволяє отримувати рішення по оптимальній структурі портфеля проєктів з точки зору його цінності при заданих обмеженнях по ресурсах (у вигляді частки загальної енергії та вихідної енергії) і по енергоентропії. Дослідження довели можливість коригування моделі з точки зору критерію оптимізації (максимізація цінності, мінімізація енергоентропії) і доповнення обмеженнями по максимально допустимої межі інформаційної ентропії і енергоефективності. **Висновки.** Модель, що розглядається, характеризується широким практичним застосуванням з урахуванням можливого її коригування без зміни основної суті з урахуванням специфіки конкретної сфери діяльності або організації. Продемонстровано практичне використання основних показників ентропійної концепції - інформаційної ентропії, температури, енергоентропії, які характеризують стан організацій, дозволяючи виявляти приховані проблеми до їх відображення на традиційних показниках ефективності організацій. З урахуванням цього здійснюється формування структури портфеля проєктів в рамках розглянутого підходу.

Ключові слова: проєкт; портфель; модель; енергоентропія; інформаційна ентропія; енергоефективність.

ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ МОДЕЛИ ОПТИМИЗАЦИИ СОСТАВА ПОРТФЕЛЯ ПРОЕКТНО-ОРИЕНТИРОВАННОЙ ОРГАНИЗАЦИИ НА БАЗЕ ЭНТРОПИЙНОЙ КОНЦЕПЦИИ

Предметом исследования является оптимизация состава портфеля проектов на базе энтропийной концепции. **Целью** исследования является экспериментальная проверка модели оптимизации состава портфеля проектно-ориентированной организации и обоснование ее применимости на практике в процессах управления для обеспечения их эффективности. **Задачи** исследования: формирование модели с учетом принятой ценности организации; формирование исходных данных по организации и альтернативным проектам; оптимизация портфеля по модели и интерпретация результатов. **Методы** исследования: системный анализ, функциональный анализ, исследование операций. **Результаты.** Разработана модель формирования структуры портфеля из проектов двух категорий – операционных и развития, критерий оптимизации – минимизация расхождения желаемой и фактически обеспечиваемой ценности организации. Ограничения учитывают максимально допустимую границу энергонтропии и минимально допустимую границу ценности. В результате проведенного исследования обоснована применимость и адекватность модели оптимизации структуры портфеля проектно-ориентированной организации. Модель позволяет получать решения по оптимальной структуре портфеля проектов с точки зрения его ценности при заданных ограничениях по ресурсам (в виде доли общей энергии и исходящей энергии) и по энергоэнтропии. Исследования обосновали возможность корректировки модели с точки зрения критерия оптимизации (максимизация ценности, минимизация энергоэнтропии) и дополнения ограничениями по максимально допустимой границе информационной энтропии и энергоэффективности. **Выводы.** Рассматриваемая модель характеризуется широким практическим применением с учетом возможной ее корректировки без изменения основной сути с учетом специфики конкретной сферы деятельности или организации. Продемонстрировано практическое использование основных показателей энтропийной концепции – информационной энтропии, температуры, энергоэнтропии, которые характеризуют состояние организаций, позволяя выявлять скрытые проблемы до их отражения на традиционных показателях эффективности организаций. С учетом этого осуществляется формирование структуры портфеля проектов в рамках рассматриваемого подхода.

Ключевые слова: проект; портфель; модель; энергоэнтропия; информационная энтропия; энергоэффективность.

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