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METHODS OF PROJECT-VECTOR MANAGEMENT OF EDUCATIONAL ENVIRONMENTS

Abstract: Based on the developed mathematical model of the project-vector space, the methods of determining the endpoints of the objects of the project-vector space (PVS) and the calculation of the trajectory of the movement to these points are proposed. It is shown that the problem of developing these methods is related to the definition of such projects (project integration), which will correspond to the maximum expansion of "Universal Projects" educational environment. Calculation of the trajectory of the movement in the project-vector space ensures the achievement of the objectives of the project with minimal time and financial resources. It is proposed to use the Monte Carlo method to calculate the options for the trajectory of PVS subjects. This distribution of probabilities when choosing the displacement of objects and subjects of PVS corresponds to the priority of subjects and the impact of objects on the displacement of these subjects. For the assessment of the magnitude of the impact on the movement of PVS subjects it was developed the structure of the expert table and the model of the calculation of the average expert assessment of such an impact. Implementation of the given methods will allow to dynamically evaluate the most important goals for all interested parties of the project, as well as to develop ways to achieve them in real terms. In this case, the real conditions of the projects are described in the system of impact on the movement of objects and subjects of PVS in the expanding "Universal Projects".

Keywords: project-vector space, educational environments, trajectory of movement in project-vector space.

Introduction

Effective project management in the methodology of project-vector management of educational environments is:

1. The result of the exact calculation of such finite coordinates of objects of the project-vector space, which will correspond to the goals not only of the project as a whole, but also to the goals of participation in the project of all interested parties (project-vector subjects);
2. Organization, planning and control of achievement of these points of objects of project-vector space.

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For the creation of scientific-methodical tools of the methodology of project-vector management of educational environments in the preceding sections it was developed a mathematical model of project-vector space, which provides an opportunity to formally operate on those parts of educational environments that relate to projects. The next task, which is necessary to decide in this direction – to develop a method for determining the finite points of movement of objects in the project-vector space and the method of calculating the trajectory of movement to these points [1-3].

The problem of developing these methods is associated with the definition of such project goals (project goal-setting), which will correspond to the maximum expansion of the "Universe of projects" of educational environments, and the calculation of the trajectory in the project-vector space, ensuring the achievement of the project goals with minimal time and financial resources [4-9].

Mathematically, the project-vector space contains many organizational, methodological and technological vectors of organization, planning and control over the compliance of project activities with the goals and objectives of these projects. The complexity of constructing methods for controlling the movement of subjects and objects in such a space lies in the need to solve a number of interrelated tasks, including the agreement (coordination) of processes along different vectors, standardization of processes in standard vectors, construction of a system of vectors with minimal intersection on functions that are implemented, etc. [10-16]. However to solve all these problems, it is necessary, first of all, to develop a method for determining the corresponding current situation, real and maximum goals of movement of objects and subjects of the project-vector space (end points of movement) – a method of goal-setting in the project-vector space and a method for calculating the optimal trajectory of movement to reach these points [17-18].

The basic material

A method for determining the end points of movement of objects in the project vector space

The search for the optimal goal for a separate project is represented by the task of determining such final coordinates of objects in the project vector space $\Pi_k: \ \forall Q_j: x_{k1}^{(j)}(T), x_{k2}^{(j)}(T), \ldots, x_{kp}^{(j)}(T)$, for which

$$\forall \Pi_k : \sum_{N_p} \left(\lambda_p \cdot \sum_{j} \left(\sigma_j \cdot x_{kp}^{(j)}(T) \right) \right) \to \max,$$

with restrictions

1. Unforced resistance to movement

2. $\forall \Pi_k : E^k \geq \sum_{N_p} \sum_{j} \left[\gamma_i^{jk} \cdot \left(x_{kp}^{(j)}(T) \right)^3 \right],$

where λ_p – priority of movement to the direction N_p (how important it is that the goal reflects the movement in this direction);

Π_k – project;

E^k – resource (energy) of the project Π_k;

Q_j – object / subject of project vector space (PVS);

σ_j – object / subject priority Q_j of project-vector space;

$x_{kp}^{(j)}(T)$ – the final value of the coordinates of the object / subject of the PVS Q_j of the project Π_k along the axis N_p;

γ_i^{jk} – the coefficient of resistance to movement of the object / subject of PVS Q_j of the project Π_k to the direction N_i.

Now two methods need to be developed:

1. The method of determining such goals of projects (goal-setting of the project), which will correspond to the maximum expansion of the “Universe of projects” of educational environments.

2. The method of calculating the trajectory of movement in the project-vector space, which ensures the achievement of the goals of the project with a minimum expenditure of time and financial resources.

When determining stakeholder goals, the most important is the coefficient of resistance to movement. In fact, it means how much energy must be spent in order for some object to move by one unit of distance in the project-vector space. In managerial language, this means: how much resource must be invested in a project so that some of its essence (product, tool or subject) can be developed, which can be represented as a certain conventional unit in the project-vector space.

In other words, the goals of stakeholders should be formally represented by some points in the project-vector space, the achievement of which is carried out in the process of project implementation.

Example: with a given amount of fuel on a given aircraft, a spacecraft must fly to a certain planet in the allotted time. In this task, the planet is the goal of the project. But this task is not analogous to that set in this dissertation work. Indeed, in the methodology of project-vector management, it is paid attention to the movement (development) of a set of project objects of more or less important (coefficient σ_j) in the allotted time (T) to the direction, the importance of which is determined by the coefficient λ_p and taking into account the resistance to movement on these directions γ_i^{jk}. Therefore, it is very difficult to find the most “distant” points of development of all project objects with given resources (energy).

To simplify it, we will select key objects, to ensure the movement of which the movement of all other objects will be formed. To do this, we will first consider the traditional points of view on goal-setting in the project.

1. At the lowest (consumer) level, the need to implement any project is caused by the fact that it creates a certain product necessary for the user that satisfies any of user’s needs.

This point of view does not cover the entire range of issues that accompanies the formation of a project as a subjective category in the development of educational environments. After all, there are always a lot of needs, and the project is focused on creating a product that meets exactly this need. In addition, it does not take into account the «need» in the project of those participants who will not use the product, but are interested in the project itself (project management group (PMG), executors, suppliers). Hence follows a more general point of view on the issues of goal setting in the project.

2. The project ensures the achievement of certain goals of all participants.

Each project is implemented to meet the needs of stakeholders. This means that all interested parties achieve certain goals by implementing a project related to meeting their needs. But the goals are different. If you take all the participants in the project, we get a whole range of different views on the project, on the processes in the project, on goals, etc. (Table 1).

The only thing that unites these views on the project is that it and its product have a certain value for the project participants. Value lies in the ability of a project or product to meet the needs of its stakeholders. This leads to an even more general view of the project’s ability to meet the needs of its stakeholders.

3. The project aims to create value for its participants and consumers of its products. But value is not something that is stated by the goal. The common denominator of the project and product values is that they create a positive attitude among the staff working in the

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stakeholder structure, as well as among the people associated with these stakeholders (for example, family members of employees of companies involved in the project). Therefore, as the target-forming components of the project-vector control (PVS) methodology, it is best to use the relation of the subjects of the project-vector space to the objects of this space.

Table 1. Stakeholder attitudes towards project categories

Stakeholder of the project	Attitude			
	To the project	To the product	To the process	What gets from the project
CUSTOMER	initiator and main stakeholder	Interested	the faster, cheaper and better quality – the better	Product
INVESTOR	interested in successful completion	not interested	the faster and cheaper, the better	profit
EXECUTOR	interested in implementation	not interested	the longer and more expensive the better	work and profit
designer	interested in developing	not interested	the more changes the better	work and profit
provider	interested in its material consumption	not interested	not interested	work and profit
PROJECT MANAGER	interested in success	Interested in quality	interested in good organization	work, career growth
Projects team	interested in the existence	not interested	Interested in good organization	work, career growth

We will assume that the goal of the project meets the needs of the stakeholders if and only if its achievement ensures the maximum satisfaction of the subjects of the projects.

In turn, the movement of subjects in PVS will also lead to the movement of objects, since in this case their impact on the movement of subjects can turn from an obstructing one (the object is against the direction of movement) to a facilitating one (the object is on the direction of movement).

The initial data for determining the goals of projects corresponding to the maximum expansion of the “Universe of projects” will be:

- a set of attitudes towards the project (subjects of the PVS) among the interested parties, the movement of which in the project-vector space corresponds to the degree of satisfaction from the project, product, or tool.
- the direction of unconstrained resistance to the movement of PVS subjects in the project-vector space, generated by the “gravitational” dependence on other objects in this space.
- energy dependence of the movement of target subjects and the objects that determine this movement in the project-vector space (how much resources are needed to move an object or subject in the project-vector space for a certain distance).

The task of the method is to calculate the attainable coordinates for each of the subjects of the PVS project Π_k

$$\Pi_k: \ \forall C_{jk} \in \Gamma_k^C \ (\Gamma_k^C \cup \Gamma_k^O = \Gamma_k \ \wedge \Gamma_k^C \cap \Gamma_k^O = \emptyset): x_{k1}^{(j)}(\overline{T_k^{\partial up}}), \dots, x_{kp}^{(j)}(\overline{T_k^{\partial up}}),$$

where Γ_k – filling the project vector space with objects and subjects of the project Π_k;

Γ_k^C – PVS subjects;

Γ_k^O – objects of the project of PVS Π_k;

C_{jk} – subject of the project of PVS Π_k;

$x_{k1}^{(j)}(\overline{T_k^{дир}}),\ldots x_{kp}^{(j)}(\overline{T_k^{дир}})$ – end coordinates of the subject of PVS C_j^k of the project Π_k at the planned moment of completion of the project $\overline{T_k^{дир}}$.

The calculation of the end points of movement of the subjects of the project-vector space is carried out in accordance with the vector method of goal-setting of projects in educational environments. Below is a diagram of the implementation of this method.

1. Determination of the laws of construction of the project-vector space

The laws set restrictions on the movement of objects in the project-vector space. These restrictions include:

- list of objects and subjects of PVS:

$$\Pi_k:\ \Gamma_k^C = \{C_{jk}\}, j = \overline{1, n_k^C}, \Gamma_k^O = \{O_{jk}\}, j = \overline{1, n_k^O},$$

where n_k^C – the number of subjects of the project-vector space;

n_k^O – the number of objects of the project-vector space.

- the maximum time for the expansion of the “Universe of the project” – the directive time of the project Π_k $(\overline{T_k^{дир}})$;
- potential energy of objects of the project-vector space (resource allocated to the project Π_k) (E_k).

2. Determination of the laws of movement in the project-vector space.

The laws of movement set the conditions for the development of the project-vector space. These conditions include:

- direction of unforced resistance for any interacting pairs of objects/subjects. It is set in tabular form;
- the value of unforced resistance for the subjects of PVS. γ_i^{jk} coefficient of resistance to movement of the subject of PVS C_j of the project Π_k in the direction N_i (shows the amount of costs required to overcome a unit of distance in a given direction).

Within the framework of the developed method of goal setting for projects of educational environments, the direction of unforced resistance for any interacting pairs of objects/subjects is not taken into account. This is due to the fact that in order to take this resistance into account, it is necessary to know the trajectory of movement in the PVS (near which objects and subjects the movement is carried out and how they affect this movement). The trajectory of movement will be determined in the method for calculating the optimal trajectory of movement of the subjects of PVS.

3. ***Determination of the permissible final coordinates of the subjects of PVS***

The permissible final coordinates correspond to the necessary condition for the implementation of the project by this subject. If their achievement in the project is not guaranteed,

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there is no point in participating in the project. These coordinates are set based on an expert assessment of the conditions for the participation of stakeholders in the project:

$$\Pi_k: \ \forall C_{jk} \in \Gamma_k^C \ (\Gamma_k^C \cup \Gamma_k^O = \Gamma_k \ \wedge \Gamma_k^C \cap \Gamma_k^O = \emptyset): \hat{x}_{k1}^{(j)}(\overline{T_k^{\partial up}}), \dots, \hat{x}_{kp}^{(j)}(\overline{T_k^{\partial up}}),$$

where $\hat{x}_{k1}^{(j)}(\overline{T_k^{\partial up}}), \dots, \hat{x}_{kp}^{(j)}(\overline{T_k^{\partial up}})$ – minimum admissible final coordinates of the subject of PVS C_{jk} of the project Π_k at the planned moment of completion of the project $\overline{T_k^{\partial up}}$.

4. Determination of the possibility of achieving the permissible final coordinates of the subjects of PVS.

For all subjects of the PVS, the possibility of reaching the permissible final coordinates is calculated (based on the costs necessary to overcome the resistance of the PVP in the prescribed time)***:***

$$\forall C_j, \Pi_k, N_p: \ E^k \geq \gamma_p^{jk} \cdot \left(\hat{x}_{kp}^{(j)}(\overline{T_k^{\partial up}})\right)^3.$$

5. ***Determination of the importance of the subjects of PVS.***

The importance of PVS subjects is determined so that the goals of the projects are aligned with the goals of the most significant stakeholders:

σ_{jk} – coefficient that determines the priority of the goals of the subject of PVS C_{jk} of the project Π_k.

6. Determination of the importance of the directions of movement in the PVS for each object/subject.

Priority is determined in the development of objects/subjects of PVS, the importance of their direction, the ability to quickly implement the project, spend less money and at the same time improve the quality. It is actual to learn how to manage projects, for which you need to create effective project management tools. Priority of movement in the direction Np given by the coefficient λ_p (how important it is that the goal reflects the movement in this direction).

7. Calculation of specific efforts of movement in directions and subjects.

The following coefficients are set:

1. γ_i^{jk} – coefficient of resistance to movement of the subject of PVS C_j of the project Π_k in the direction N_i (shows the amount of costs required to overcome a unit of distance in a given direction).

2. σ_{jk} – coefficient that determines the priority of the goals of the subject of PVS C_{jk} of the project Π_k.

3. λ_p – priority of movement in the direction N_p (how important it is that the goal reflects the movement in this direction).

We will calculate the required specific efforts when moving in all directions of the project-vector space of all subjects of projects. This specific effort is equal to the ratio of movement resistance to the priorities of subjects and directions:

$$K_i^{jk} = \frac{\gamma_i^{jk}}{\lambda_i \cdot \sigma_{jk}}, \tag{1}$$

where K_i^{jk} – coefficient reflecting the unit costs of moving in the direction N_p per unit of the priority of the goals of the subjects of the PVS and the priority of a given direction (how easy and necessary it is to move in this direction).

For some subject C_1 of the project Π_1 two directions correspond to the movement resistance coefficients $\gamma_1^{11} = 3,\ \gamma_2^{11} = 1$ (in the second direction, the resistance is less), and the priority of movement in the directions, respectively, $\lambda_1 = 2$ and $\lambda_2 = 6$. Its prioritization of goals σ_{11}=2. For the subject C_2 of the project Π_1 the coefficients of resistance to movement in the same directions are $\gamma_1^{21} = 5,\ \gamma_2^{21} = 2$ (in the second direction the resistance is less). Prioritizing goals σ_{21}=5. Then

$$K_1^{11} = \frac{\gamma_1^{11}}{\lambda_1 \cdot \sigma_{11}} = \frac{3}{2 \cdot 2} = 0{,}75; K_2^{11} = \frac{\gamma_2^{11}}{\lambda_2 \cdot \sigma_{11}} = \frac{1}{6 \cdot 2} \approx 0{,}083;$$

$$K_1^{21} = \frac{\gamma_1^{21}}{\lambda_1 \cdot \sigma_{21}} = \frac{5}{2 \cdot 5} = 0{,}5; K_2^{21} = \frac{\gamma_2^{21}}{\lambda_2 \cdot \sigma_{21}} = \frac{2}{6 \cdot 5} \approx 0{,}067.$$

8. Setting the initial energy costs for projects.

The starting point from which each project starts is given by the values:

$$\forall \Pi_k:\ E_{plan}^k = e_0^k,$$

where E_{plan}^k – planned project costs Π_k;

e_0^k – initial project costs Π_k (incurred before the start of the project Π_k).

9. Selection of the most significant direction of movement and the subject of PVS.

The significance of the subject and the direction of movement is assessed by the specific efforts for the displacement of this object in a given direction and the priority of this direction. It corresponds to the minimum value of the coefficient (formula 1):

$$\min_{\Pi_k, C_j, N_p} \left(K_p^{jk}\right).$$

Option

$$\Pi_{k_0}, C_{j_0}, N_{p_0} : K_{p_0}^{j_0 k_0} = \min_{\Pi_k, C_j, N_p} \left(K_p^{jk}\right).$$

10. Calculation of the target bias of the PVS subject C_{j_0} of the project Π_{k_0} in the direction N_{p_0}.

If

$$E^{k_0} - E_{план}^{k_0} \geq \gamma_{p_0}^{j_0 k_0} \cdot \left(\hat{x}_{k_0 p_0}^{(j_0)}\left(\overline{T_{k_0}^{дир}}\right)\right)^3,$$

then it is accepted:

$$x_{k_0 p_0}^{(j_0)}\left(\overline{T_{k_0}^{дир}}\right) = \hat{x}_{k_0 p_0}^{(j_0)}\left(\overline{T_{k_0}^{дир}}\right);$$

$$E_{plan}^{k_0} = E_{plan}^{k_0} + \gamma_{p_0}^{j_0 k_0} \cdot \left(\hat{x}_{k_0 p_0}^{(j_0)}\left(\overline{T_{k_0}^{дир}}\right)\right)^3.$$

Movement of the subject of PVS is excluded from consideration C_{j_0} of the project Π_{k_0} in the direction N_{p_0}.

The limit coordinate is calculated differently

$$x_{k_0 p_0}^{(j_0)}\left(\overline{T_{k_0}^{дир}}\right) = \sqrt[3]{\frac{E^{k_0} - E_{plan}^{k_0}}{\gamma_{p_0}^{j_0 k_0}}}.$$

Accepted

$$E_{plan}^{k_0} = E^{k_0}.$$

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The project is excluded from consideration Π_{k_0}.
If all projects are excluded from consideration – go p. 11. Goes to p.9.

11. Evaluation of the received target coordinates of movement in PVS.
An expert assessment of the obtained values is carried out. If the values do not satisfy the project management, then the initial data are corrected and everything is repeated from p. 1. If satisfied – completion.

A method for calculating the optimal trajectory of movement to reach the target points of the project-vector space

In contrast to the goal-setting method (calculating the most distant attainable points of PVS by all its subjects), the method for calculating the optimal trajectory of movement will take into account the resistance in PVS created by other objects and subjects. Since this resistance depends on the coordinates of the subjects and objects of PVS (and they change in the process of their movement), it is necessary to consider many options for movement and choose the best one. Enumeration of all motion options is huge and beyond the control of even modern computers, so it will be impossible to find the optimal solution. We will replace it with a search for a rational solution and use the Monte Carlo method for this. In this case, the probability distribution when choosing to displace objects and subjects of the PVP will be calculated through the priority of subjects and the influence of objects on the displacement of these subjects.

In the method for determining the goals of projects (goal-setting of the project), which correspond to the maximum expansion of the "Universe of projects" of educational environments, the end points of movement of the subjects of PVS are calculated

$$\forall \Pi_k, C_j: A_k^{(j)}(\overline{T_k^{\partial up}}) = \left[x_{k1}^{(j)}(\overline{T_k^{\partial up}}), x_{k2}^{(j)}(\overline{T_k^{\partial up}}), \ldots, x_{kp}^{(j)}(\overline{T_k^{\partial up}})\right],$$

where

$x_{k1}^{(j)}(\overline{T_k^{\partial up}}), \ldots, x_{kp}^{(j)}(\overline{T_k^{\partial up}})$ – end coordinates of the subject of PVS C_j^k of the project Π_k at the planned moment of completion of the project $\overline{T_k^{\partial up}}$.

In the method for calculating the optimal trajectory of movement, additional information is the relationship of objects and subjects of the PVS in the direction of movement in the project-vector space. This relationship (more precisely, interactions) determines how much energy (money) must be additionally spent in order for a certain subject to move one unit of distance in the project-vector space, taking into account the impact of other objects and subjects. In a project management methodology, this means what needs to be done in a project to satisfy stakeholders. And accordingly, how many and what resources are needed for this.

In other words, the movement of stakeholders in the project-vector space should be linked to the movement of various objects in such a way that the interactions existing in the PVS contribute to the achievement of goals (movement to end points), and not hinder it. To do this, it is necessary to take into account the relationship between the objects themselves, determined by their interdependence in projects. The movement of one object/subject overcomes resistance zones caused by the movement of other objects (obtaining permission, spending resources on creating planning, budgeting, monitoring tools, etc.). Therefore, it is very difficult to find the optimal trajectory of movement in a set of interacting objects and subjects.

To solve this problem, let us consider the structure of interactions between objects and subjects in the project-vector space.

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Let it be $F\left[Q_j\left(A_k^{(j)}(t)\right)/Q_i\left(A_k^{(i)}(t)\right)\right]$ – impact of Q_i object / subject with coordinates $A_k^{(i)}(t)$ per object / subject Q_j with coordinates $A_k^{(j)}(t)$. This impact leads either to resistance to the movement of the object/subject of the PVS, or to facilitate this movement. Let us introduce a number of definitions

Definition 1. Under the influence $F\left[Q_j\left(A_k^{(j)}(t)\right)/Q_i\left(A_k^{(i)}(t)\right)\right]$ object Q_i it will be called a source of influence.

Definition 2. Under the influence $F\left[Q_j\left(A_k^{(j)}(t)\right)/Q_i\left(A_k^{(i)}(t)\right)\right]$ object Q_j it will be called the result – the receiver of the action.

Definition 3. Coefficient of interaction of objects/subjects of PVS $\varphi\left[Q_j\left(\mathrm{A}_\mathrm{k}^{(\mathrm{j})}(t)\right)/Q_i\left(\mathrm{A}_\mathrm{k}^{(\mathrm{i})}(t)\right)\right]$ reflects the required amount of energy costs (costs) to displace the receiver with the coordinates of the impact per unit distance, if the source of impact has coordinates in the project vector space:

$$\varphi\left[Q_j\left(\mathrm{A}_\mathrm{k}^{(\mathrm{j})}(t)\right)/Q_i\left(\mathrm{A}_\mathrm{k}^{(\mathrm{i})}(t)\right)\right]=f\left(F\left[Q_j\left(\mathrm{A}_\mathrm{k}^{(\mathrm{j})}(t)\right)/Q_i\left(\mathrm{A}_\mathrm{k}^{(\mathrm{i})}(t)\right)\right]\right),$$

Where $\varphi\left[Q_j\left(\mathrm{A}_\mathrm{k}^{(\mathrm{j})}(t)\right)/Q_i\left(\mathrm{A}_\mathrm{k}^{(\mathrm{i})}(t)\right)\right]$ – the coefficient of interaction of objects/ subjects of PVS reflects the possibility of movement of the object/subject of PVS Q_j of the project Π_k in the direction N_i (shows the amount of costs required to overcome a unit of distance in a given direction under the influence of an object Q_i).

The coefficient of interaction of objects can take different values depending on the coordinates of the influencing object.

Consequence 1. The magnitude of the impact on the object/subject Q_j with coordinates $A_k^{(j)}(t)$ depends on coordinates $A_k^{(i)}(t)$ source of impact Q_i.

One very important conclusion can be drawn from this consequence. In order for the impact on the subjects (namely on the subjects, as the essence of the PVS, by which the effectiveness of the project is assessed) was such that it facilitates their movement to the target point in the PVS, it is necessary to choose “beneficial” coordinates for the sources of impact. That is, if the “costs” of bringing the source of influence to the new coordinates are less than the “costs” of bringing the receiver to the target coordinates, and then first it is necessary to “set” the source of influence in motion, transfer it into new coordinates, and then transfer it into new coordinates of the receiver of the impact.

For example. Before starting to form a project plan, it is necessary to implement and master the software product, on the basis of which the project plan will be developed. Because without this software product the resistance to PVS is very high (it is difficult to develop a plan). Therefore, if

$$\varphi\left[Q_j\left(\mathrm{x}_\mathrm{kp}^{(\mathrm{j})}(\Delta\mathrm{t})\right)/Q_i\left(\mathrm{x}_\mathrm{kp}^{(\mathrm{i})}(\Delta\mathrm{t})\right)\right]>\gamma_\mathrm{p}^{jk}\cdot\left(\Delta\mathrm{x}_\mathrm{kp}^{(\mathrm{i})}(\Delta\mathrm{t})\right)^3+\varphi\left[Q_j\left(\mathrm{x}_\mathrm{kp}^{(\mathrm{j})}(\Delta\mathrm{t})\right)/Q_i\left(\mathrm{x}_\mathrm{kp}^{(\mathrm{i})}(\Delta\mathrm{t})+\Delta\mathrm{x}_\mathrm{kp}^{(\mathrm{i})}(\Delta\mathrm{t})\right)\right],$$

then first the movement of the object Q_i must be ensured, which will make it easier for the subject to obtain the target value Q_j.

The method for calculating the optimal trajectory of movement will be based on a sequential recalculation of the interaction of subjects and objects of PVS with each other, the choice of optimal directions of displacement for these objects for a certain interval (quantum) of time, their displacement and again recalculation of interactions.

The initial data for determining the optimal trajectory of movement will be:

- a set of attitudes towards the project (subjects of the PVS) among the interested parties, the movement of which in the project-vector space corresponds to the degree of satisfaction from the project, product or tool;

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- a lot of objects, the placement of which contributes or does not contribute to an increase in the satisfaction of the PVS subjects from the project;
- the direction of unconstrained resistance to the movement of subjects and objects of PVP in the project-vector space, generated by the dependence on other objects of this space;
- energy dependence of the movement of subjects and objects of PVS, which determines how much resources are needed to move an object or subject in the project-vector space for a certain distance.

The task of the method is to find a time series of coordinates for each of the objects and subjects of the PVS:

$$\begin{aligned}
&\Pi_k: \ \forall Q_j \in \Gamma_k: \\
&t_1: \ x_{k1}^{(j)}(t_1), \ldots, x_{kp}^{(j)}(t_1); \\
&t_2: \ x_{k1}^{(j)}(t_2), \ldots, x_{kp}^{(j)}(t_2); \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
&t_i: \ x_{k1}^{(j)}(t_i), \ldots, x_{kp}^{(j)}(t_i); \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
&t_{fin}: \ x_{k1}^{(j)}(t_{fin}), \ldots, x_{kp}^{(j)}(t_{fin}),
\end{aligned}$$

where

$t_1, t_2, \ldots, t_{fin}$ – moments in time (t_{fin} – moment of completion of the project);

$x_{k1}^{(j)}(t_i), \ldots, x_{kp}^{(j)}(t_i)$ – object coordinates Q_j of the project Π_k at the moment t_i.

The calculation of the current coordinates in the process of movement of subjects and objects of the project-vector space is carried out in accordance with the vector method for achieving goals in projects in educational environments. Let's consider the implementation scheme of this method.

1. Determination of the laws of construction of the project-vector space.

The process of building PVS is implemented in accordance with the same paragraph in the vector method of goal-setting in projects of educational environments. In addition to the above, the time interval for recalculating the state of the PVS Δt and the step of displacement of the objects and subjects of the PVS Δx are set.

2. Determination of the laws of movement in the project-vector space.

The laws of movement reflect the magnitude of the interaction of objects and subjects of the project-vector space. The parameters reflecting the characteristics of the interaction of objects and subjects of PVS include:

- γ_i^{jk} – the coefficient of resistance to movement of the subject of PVS C_j of the project Π_k in the direction N_i (shows the amount of costs required to overcome a unit of distance in a given direction) reflects the properties of the object moved in the PVS;
- coefficient of interaction of objects/subjects of PVS $\varphi\left[Q_j\left(A_k^{(j)}(t)\right)/Q_i\left(A_k^{(i)}(t)\right)\right]$ (see definitions 1-3). This coefficient can be obtained by experts. The table of presentation of expert knowledge on determining the characteristics of the interaction of objects and subjects of PVS can be presented in the form of Table 2.

Table 2 reflects the expert's understanding of the interaction of objects and subjects of the project-vector space. Under the coefficient φ in table 4.2 is understood the value set by the expert

$$\varphi_{jip} = \varphi^{e}\left[Q_j\left(x_{kp}^{(j)}(t)\right)/Q_i\left(x_{kp}^{(i)}(t)\right)\right],$$

where $\varphi^{e}\left[Q_j\left(x_{kp}^{(j)}(t)\right)/Q_i\left(x_{kp}^{(i)}(t)\right)\right]$ – the coefficient of interaction of objects / subjects of PVS established by the expert.

The values φ in Table 2 set in the range from 0 (no effect) to 1 (full dependence of the receiver on the source).

Table 2. Expert assessment table of the interaction of objects and subjects of projects

Expert: ______________________
Project: ______________________
Date: ______________________

Impact source	Impact receiver				
	Q_1	Q_2	Q_3	…	Q_s
Q_1	X	φ_{211}	φ_{311}	…	φ_{s11}
Q_2	φ_{121}	X	φ_{321}	…	φ_{s21}
…	,,,	,,,	,,,	,,,	,,,
Q_s	φ_{1s1}	φ_{2s1}	φ_{3s1}	…	X
Q_1	X	φ_{212}	φ_{312}	…	φ_{s12}
Q_2	φ_{122}	X	φ_{322}	…	φ_{s22}
…	,,,	,,,	,,,	,,,	,,,
Q_s	φ_{1s2}	φ_{2s2}	φ_{3s2}	…	X
…	,,,	,,,	,,,	,,,	,,,
Q_1	X	ϕ_{21p}	ϕ_{31p}	…	ϕ_{s1p}
Q_2	ϕ_{12p}	X	ϕ_{32p}	…	ϕ_{s2p}
…	,,,	,,,	,,,	,,,	,,,
Q_s	ϕ_{1sp}	ϕ_{2sp}	ϕ_{3sp}	…	X

The value of the interaction coefficient, averaged over all experts, will be the basis for calculating the optimal trajectory of movement of objects/subjects of PVS.

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$$\varphi^*_{jip} = \frac{\sum_{e=1}^{E} \varphi^e \left[Q_j \left(x^{(j)}_{kp}(t) \right) / Q_i \left(x^{(i)}_{kp}(t) \right) \right]}{E},$$

where φ^*_{jip} – accepted (average) expert coefficient of interaction of objects/subjects of PVS.

3. Determination of the influence of PVS objects

It is determined the importance of the PVS objects in order to prioritize the displacement of objects in the PVS. The importance of the PVS facilities reflects their impact on other PVS facilities. After all, the location (coordinates) of the strongly influencing PVS object will determine how quickly the subjects that are carriers of the goals and values of projects will move in the project-vector space.

$$\theta_{jkp} = \frac{\sum_{i=1}^{K} \varphi^*_{jip}}{K},$$

where θ_{jkp} – coefficient that determines the average value of the impact of the object of the PVS Q_j of the project Π_k in the direction N_p;
K – number of objects/subjects affected by the PVS object Q_j of the project Π_k.

It is also important to consider the impact on each of the subjects/objects of the PVS. This impact is

$$\rho_{ikp} = \frac{\sum_{j=1}^{K} \varphi^*_{jip}}{K},$$

where ρ_{ikp} – coefficient that determines the average value of the impact on the object of PVS Q_i of the project Π_k with other objects and subjects of PVS in the direction N_p.

4. Determination of the goals of the subjects of PVS (final coordinates of movement)

The final coordinates correspond to the objectives of the project implementation by the subjects. They can be obtained using the vector method of goal-setting and presented in the form

$$\Pi_k: \quad \forall C_{jk}: x^{(j)}_{k1}(t_{max}), \ldots, x^{(j)}_{kp}(t_{max}),$$

where C_{jk} – subject of the project PVS Π_k;
$x^{(j)}_{k1}(t_{max}), \ldots, x^{(j)}_{kp}(t_{max})$ – end coordinates of the subject of PVS C^k_j of the project Π_k at the time of completion of the project t_{max};
t_{max} – moment of completion of the project.

5. Determination of the importance of the subjects of PVS

The importance of PVS subjects is determined so that the goals of the projects are aligned with the goals of the most significant stakeholders:

σ_{jk} – coefficient that determines the priority of the goals of the subject of PVS C_{jk} of the project Π_k.

6. Determination of the conditions for achieving the goals of the subjects of PVS (restrictions)

The final coordinates of the movement must not be less than the directive (initially) specified and must be reached before the planned completion date of the project. In addition, the project costs (energy costs) should not exceed the planned

1 . $t_{max} \le t_{fin}$;

2. $\forall i = \overline{1,p}: x_{ki}^{(j)}(\overline{T_k^{\partial up}}) \le x_{ki}^{(j)}(t_{max})$;

3. $E_{fact}^{k} \le E_{plan}^{k}$.

7. Establishment of the initial conditions for calculating the trajectories of movement

Initial conditions include:

1. Time of the start of the project (start of movement)– t_0.

2. The starting point of movement of objects and subjects of PVS. Accepted as:

$$\Pi_k: \ \forall Q_j: x_{k1}^{(j)}(t_0), \dots, x_{kp}^{(j)}(t_0),$$

where $x_{k1}^{(j)}(t_0), \dots, x_{kp}^{(j)}(t_0)$ – initial coordinates of objects and subjects of PVS Q_j of the project Π_k.

3. The most distant from the initial end point of movement of the subjects of PVS. Accepted as:

$$\Pi_k: \ \forall C_{jk}: x_{k1}^{(j)}(t_{fin}) + x', \dots, x_{kp}^{(j)}(t_{fin}) + x',$$

where x' – stock in the assessment of the final coordinates of the movement of the subjects of PVS.

4. The number of options for modeling motion in PVS

$$N_v^{max},$$

where N_v^{max} – number of modeling options.

8. Calculation of specific efforts of movement in directions and subjects

The calculation of specific efforts of movement is carried out according to the formula (1). The result is the amount (in the direction N_i) coefficient of specific effort of subjects when moving in directions K_i^{jk} and a coefficient that reflects the magnitude of the impact of other objects and subjects of PVS ρ_{jki}

$$\delta_{jki} = K_i^{jk} + \rho_{jki},$$

where δ_{jki} – generalized coefficient of resistance to movement of an object Q_j of the project Π_k in the direction N_i.

9. Modeling the movement of objects and subjects in PVS

In order to find a rational trajectory of movement of the subjects of the PVS, modeling of the movement options will be carried out, which will be set by the priority and interaction of the objects of the PVS. The best options will be offered to the project management to choose the best solution in their opinion.

The initial simulation is set to 0.

$$N_v = 0,$$

where N_v – simulation version number.

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9.1.Transition to the next variant of modeling.

The next number of the simulation variant is set

$$N_v = N_v \mid 1,$$

If $N_v > N_v^{max}$, goes to p.10.

Movement step is set

$$N_d = 0,$$

where N_d – movement step number.

The initial coordinates of objects and subjects of PVS and the initial moment of time are set t_0:

$$\Pi_k: \ \forall Q_j: x_{k1}^{(j)}(t_0), \dots, x_{kp}^{(j)}(t_0),$$

where $x_{k1}^{(j)}(t_0), \dots, x_{kp}^{(j)}(t_0)$ – initial coordinates of the object Q_j of the project Π_k.

The initial energy characteristics (costs) of the projects are fixed:

$$\forall \Pi_k: \ E_{fact}^k = e_0^k,$$

where E_{fact}^k – actual project costs Π_k;

e_0^k – initial project costs Π_k (incurred before the start of the project Π_k).

9.2. Proceeding to the next step of movement

$$N_d = N_d + 1.$$

Calculation of the next moment in time

$$t_{N_d} = (N_d - 1) \cdot \Delta t + t_0.$$

If the coordinates of all subjects exceed the target ones, or the actually expended energy (costs) is more than the planned ones, go p.9.1.

9.3. Calculation of efforts when moving in directions at a time t_{N_d}.

The direction of movement of the subjects is assessed by the specific efforts to displace the subject in each direction, the priority of this direction and the magnitude of the impact on the subject in this direction, is determined through δ_{jki}. In order to reduce the costs of the movement of subjects, it is possible that there will be such a PVS object, the displacement of which will reduce the costs for the subjects of the PVS. Moreover, it will reduce more significantly than the cost of movement of the PVS object, i.e., for the direction N_i

$$\Pi_k : Q^* = \{Q_s\}, s = \overline{1, K^*}, K^* > 0 \wedge \delta_{jki}^s < \delta_{jki} :$$

$$\delta_{jki}^s = K_i^{jk} + \rho_{jki}^s \left(x_{kl}^{(j)}(t_{N_d}) = x_{kl}^{(j)}(t_{N_{d-1}}) + \Delta x, \dots, x_{kp}^{(j)}(t_{N_d}) = x_{kp}^{(j)}(t_{N_{d-1}}) + \Delta x \right);$$

$$\delta_{jki} = K_i^{jk} + \rho_{jki} \left(x_{kl}^{(j)}(t_{N_d}) = x_{kl}^{(j)}(t_{N_{d-1}}) + \Delta x, \dots, x_{kp}^{(j)}(t_{N_d}) = x_{kp}^{(j)}(t_{N_{d-1}}) + \Delta x \right);$$

$$\delta_{ski} = K_i^{sk} + \rho_{ski} \left(x_{kl}^{(s)}(t_{N_d}) = x_{kl}^{(s)}(t_{N_{d-1}}) + \Delta x, \dots, x_{kp}^{(s)}(t_{N_d}) = x_{kp}^{(s)}(t_{N_{d-1}}) + \Delta x \right);,$$

where K^* – number of objects, the displacement of which leads to a decrease in the costs of displacement of subjects in the PVS;

Q_s – objects, the displacement of which leads to a decrease in the costs of displacement of subjects in the PVS;

δ_{jki} – generalized coefficient of resistance to movement of the subject C_j of the project Π_k in the direction N_i provided that the coordinates of the object Q_s not changed;

δ^s_{jki} – generalized coefficient of resistance to movement of the subject C_j of the project Π_k in the direction N_i provided that the object was displaced first Q_s;

δ_{ski} – generalized coefficient of resistance to movement of an object Q_s, and the cost of displacing an object is less than compensation for costs due to a decrease in the impact of this object on the subjects

$$\delta^s_{jki} \cdot (\Delta x)^3 + \delta_{ski} \cdot (\Delta x)^3 < \delta_{jki} \cdot (\Delta x)^3 \Rightarrow \delta^s_{jki} + \delta_{ski} < \delta_{jki}, \quad (2)$$

then there is a need for the primary displacement of the object with the subsequent recalculation of the possibilities of displacement of the subjects of PVS.

The fulfillment of these conditions is possible if an increase in the coordinate by some object to a value exceeding the coordinate of the subject of the PVS changes the sign of the coefficient of interaction of objects/subjects of the PVS from "minus" to "plus". That is, "the object attracts the subject."

9.4. Selection of moving objects / subjects

If $K^* = 0$, then:

- if in this step there are movements shifted by Δx • objects, then go to p. 9.2. Otherwise, a choice is made to bias among the subjects of the PVS. The choice of the subject is carried out randomly in accordance with the probability distribution based on the formula
- $p_{jk} = \frac{\sigma_{jk}}{\sum_l \sigma_{lk}}$,

where p_{jk} – probability of choice to bias in direction N_i of the subject C_j and the object Π_k;

- those PVS objects are selected to offset differently $Q^*_U = \{Q^U_b\}, b = \overline{1, U},\ Q^*_U \subseteq Q^*_{\square}$, whose displacement by Δx reduces the resistance of PVP relative to the subjects of projects (in accordance with formula ((2). If the set Q^*_U empty – goes to p.9.2. The choice of an object is carried out randomly in accordance with the probability distribution based on the formula

$$p_{jki} = \frac{\theta_{jki}}{\sum_{b=1}^{U} \theta_{bki}},$$

where p_{jki} – the probability of choosing a displacement in the direction N_i of the project Q_j and the project Π_k;

9.5. Offset calculation.

If

$$E^k_{plan} - E^k_{fact} \geq \delta_{jkp} \cdot (\Delta x)^3,$$

then it is accepted as:

$$x^{(j)}_{kp}(t_{N_d}) = x^{(j)}_{kp}(t_{N_{d-1}}) + \Delta x;$$

$$E^k_{fact} = E^k_{fact} + \delta_{jkp} \cdot (\Delta x)^3.$$

Differently

$$x_{kp}^{(j)}(t_{N_d}) = x_{kp}^{(j)}(t_{N_{d-1}}).$$

Return to p. 9.3.

10. Evaluation of the received target coordinates of movement in PVP

An expert assessment of the obtained variants of the motion trajectory is carried out. If the values do not satisfy the project managers, then the initial data is corrected and everything is repeated from p. 1. If satisfied – completion.

Conclusion

The article proposes methods for determining the end points of movement of objects in the project-vector space and calculating the trajectory of movement to these points. It is shown that the problem of developing these methods is associated with the definition of such project goals (goal-setting of the project), which will correspond to the maximum expansion of the "Universe of projects" of educational environments. The calculation of the trajectory of movement in the project-vector space ensures the achievement of the goals of the project with a minimum investment of time and financial resources. The implementation of the above methods will allow in dynamics to evaluate the most important goals for all stakeholders of the project, as well as to develop ways to achieve them in real conditions. At the same time, the real conditions of projects are described by a system of influences on the movement of objects and subjects of PVS in the expanding "Universe of projects".

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