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SUPPORT FOR ADOPTION OF IMMEDIATE ANTI-CRISIS SOLUTIONS IN THE MANAGEMENT OF ORGANIZATION AND TECHNICAL SYSTEMS

І.І. Становська, К.В. Колеснікова, Д.В. Лук'янов, М.М. Костіна. **Підтримка прийняття термінових антикризових ріщень при управлінні організаційно-технічними системами.** Пропонується метод підтримки прийняття термінових антикризових рішень при управлінні складними організаційно-технічними системами відповідального призначення, наприклад, при управлінні проектами / програмами / портфелями. Оскільки антикризові рішення повинні прийматися в найкоротші терміни, а параметри як керованих процесів, так і криз, що їх спіткають, відрізняються граничною багатофакторністю та стохастичністю аж до повної невизначеності, запропоновано при розв'язанні задач оптимізації використовувати підходи, які базуються на організаційно-фізичні аналогії. При цьому при прийнятті антикризових рішень іноді приходиться нехтувати точністю та адекватністю використовуваних моделей заради виявлення напрямку та параметрів дій, які можуть врятувати процес в цілому. Метод полягає у тимчасовій заміні організаційних моделей, які недоступні (за наявністю, часовою складністю, неточністю, стохастичністю, тощо) особі, яка займається антикризовим плануванням, на віртуальні фізичні (наприклад, термофізичні), розв'язанні задачі оптимізації антикризових дій на цьому рівні та поверненні до організаційних моделей. Розглянуті приклади організаційно-гідравлічних, організаційно-електричних та організаційно-механічних аналогій, а також використання таких аналогій в оптимізації процесів та спрощення моделей. Для організаційно-теплофізичної аналогії виконано експериментальне підтвердження висунутої гіпотези та запропонованої моделі. Наведено позитивний приклад використання запропонованого методу в практиці проектного управління. Запропоновано підхід до позначення відповідних перемінних, що дозволяє відрізняти їх від загальноприйнятих позначень фізичних величин.

Ключові слова: антикризове управління, фізична аналогія, віртуальні моделі, експериментальне підтвердження, практичне впровадження

I. Stanovska, K. Kolesnikova, D. Lukianov, M. Kostina. **Support for adoption of immediate anti-crisis solutions in the management of organization and technical systems.** A method of supporting of urgent anti-crisis solution in managing of complex organizational and technical systems of responsible purpose, for example, in managing of projects / programs / portfolios, is proposed. Since anti-crisis decisions have to be made in the shortest possible time, and the parameters of both managed processes and the crises that they encounter differ in marginal multifactoriality and stochasticity until complete uncertainty, it is proposed to use approaches based on organizational-organizational-based optimization. However, when making anti-crisis decisions, sometimes you have to neglect the accuracy and adequacy of the models used to identify the direction and parameters of actions that can save the process as a whole. The method is to temporarily replace organizational models that are inaccessible to the person involved in anti-crisis planning (by presence, time complexity, inaccuracy, stochasticity, etc.) with virtual physical (eg thermophysical) solutions to the problem of optimization of anti-crisis actions at this level and return to organizational models. Examples of organizational-hydraulic, organizational-electrical, and organizational-mechanical analogies are discussed, as well as the use of such analogies in process optimization and model simplification. For organizational-thermophysical analogy, experimental confirmation of the hypothesis and the proposed model was performed. A positive example of the use of the proposed method in the practice of project management is given. An approach to the designation of the relevant variables is proposed, which allows to distinguish them from the conventional notation of physical quantities.

Keywords: anti-crisis management, physical analogy, virtual models, experimental validation, practical implementation

1. Introduction

Managing of the development of complex organizational and technical systems is one of the oldest types of human activity. In fact, almost everything we do whether it's unique structures, modern computer systems, space flight or new therapies and prevention, have the basic property of creative activity, namely, the uniqueness, limited time and resources, the presence of a special team, etc. [1] Special conditions arise when managing an additional anti-crisis project, when the existing conditions in the system can stop the project [2].

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Managing any anti-crisis process or crisis management is a problem of optimization, because in almost all cases there are several ways to achieve the additional goal of overcoming the crisis. When it comes to optimizing any process, one must always determine the goals of such optimization [3]. In the case of finding the optimal crisis solution for organizational and technical systems (for example, in project management), the objective function is obvious: the project should not stop. Of course, with reasonable restrictions on all types of resources [4].

The presence of processes that are characterized by organizational uncertainty, multifactoriality, stochasticity, slow development, etc., as well as processes such as strictly deterministic physical, suggest to use, at least in the main, exact physical laws, to find a connection, for example, between heat transfer, on the one hand, and project logistics or cash flows, on the other, and build a virtual model of such transfer on that basis. Will it be accurate? Unlikely. Will it be at least reasonably adequate? Unknown. But in times of crisis, when decisions need to be made in the face of total uncertainty and made quickly, it is better than doing nothing or doing something at random, at the discretion of some manager.

In order to be able to use this method of supporting timely anti-crisis decisions in the practical management of organizational and technical systems, it is necessary to fulfill its theoretical substantiation, to develop information technology for its implementation, as well as to experimentally confirm its effectiveness.

2. Analysis of recent research and publications

The analysis of recent research and publications is based on the basic logic of the article, which is as follows:

– problems of optimization of parameters of crisis management of organizational and technical systems;

– identification of differences and search for analogies between unauthorized physical and unauthorized organizational and technical processes;

– definition of the physical process as an analogue of organizational measures on the example of a pair of “heat transfer” – “financial flows”;

– areas of application of the approach in other similar pairs are possible.

2.1. Problems of optimization of the parameters of crisis management using organizational and technical systems

It is known that automatic control of technological processes is based on their mathematical models [5]. These models are quite complex, but their main feature is that these models are based on only one variable: temperature, flow, electric current, etc. This greatly simplifies the calculation and execution of management impacts. The paper also deals with the management of a complex system in which such parameters are an order of magnitude higher!

Project management is always carried out on the basis of a pre-built plan that takes into account the mission and purpose of the project. The implementation of this plan (or, as experts in APCS say, “programs”) is the main task of program management. The system of software control in the automatic control system(APCS) is an automatic system whose task is to change the controlled value by a precompiled program, which is determined by the set influence $F(t)$, where $F(t)$ is a known function of time [6]. A project management system is an automated system whose task is also to change many manageable values in a pre-planned plan and under the influence of a turbulent external environment.

In program control in the APCS the “problem” is only the difference between the current value of the controlled parameter and its program value. It is this difference that triggers the intervention into the object and determines the extent of that intervention. Note that in the theory of automatic control is usually carried out by this control, by one parameter. Even having a second parameter that can be managed by an entity can cause serious problems when calculating management impacts. Instead, in project management, the number of such parameters can reach tens of thousands!

After all, it is impossible to build project management according to the process control scheme for a number of reasons:

– there are many parameters and there is no time, money, equipment, performers, etc. to measure their feedback;

– it is not always clear what to measure, because the cause and effect relationship between management and its outcome is not always "on the surface";

– a significant number of parameters are usually measured with very inaccurate or even stochastic results.

2.2. Differences and analogies between unauthorized physical and unauthorized organizational and technical processes

The analogies between individual physical unauthorized processes (thermal, electrical, hydraulic, mechanical) have been known for a long time [7]. This similarity stems from the same (in content) presentation of causes or driving forces (potentials) and the resulting consequences or flows that operate in these systems (columns 1 – 4 in Table 1) [8].

It is also worth noting that in the field of management, in particular project management, its own "term system" is actively developing, which is necessary for the correct understanding between researchers and practitioners in this field of professional activity [9]. Of particular note is the approach to naming variables, including the use of Cyrillic characters [10]. The authors themselves repeatedly faced with the need to choose the correct designation of variables related to the features of organizational and technical systems in their works [7, 8, 11, 12]. To distinguish the proposed factors, including when formalizing the relationship between the relevant parameters related to organizational and technical systems, it is proposed to use Latin letters on the basis of abbreviations from the English version proposed earlier (or existing earlier), as well as for the first time proposed parameter names with the addition of the "@" symbol. The use of the "@" symbol for such purposes by the authors is also possible because its use is considered acceptable in such software products as IBM® SPSS® Statistics, which is widely used both in scientific activity and in practice [13].

According to the authors, this approach also has such an undeniable advantage as providing the ability to spread such cognitive models into the global, as a rule, English-speaking, professional community.

For example, in this case, it is proposed to use "means available" with the designation "MA@" for the designation "available interests", and "financial flows" with the designation "FF@" for "financial flows".

Table 1

Analogy between physical and organizational potentials and flows

System	Thermal Engineering	Electrical Engineering	Hydraulics	Mechanics	Project
	1	2	3	4	5
Potential	T, K, temperature	U, V, voltage	P, Pa, pressure	F, N, power	MA@, UAH, means available
Flow	q, J/s heat flow	I, A, current	Q, m^3/s consumption	σ, N/m^2 stress	FF@, UAH/day, financial flows

In turn, the thermal, electrical, hydraulic and mechanical potentials and flows, which are given in Table 1, related to the factors that cause them, the following relations [7]:

$$T = T(\mathrm{G@, PDE@}, PS@); \qquad q = q(\mathrm{G@, PDE@}, PS@); \tag{1}$$

$$U = U(\mathrm{G@, PDE@}, PS@); \qquad I = I(\mathrm{G@, PDE@}, PS@); \tag{2}$$

$$P = P(\mathrm{G@, PDE@}, PS@); \qquad Q = Q(\mathrm{G@, PDE@}, PS@), \tag{3}$$

$$F = F(\mathrm{G@, PDE@}, PS@); \qquad \sigma = \sigma(\mathrm{G@, PDE@}, PS@), \tag{4}$$

where G@ – geometric characteristics of the propagation medium of the corresponding substance; PDE@ – properties of the Distribution Environment; PS@ – is the power of an external or internal source of the relevant substance. Expressions (1) – (4) are separately known thermodynamic laws [14].

As mentioned above, models (1) – (4) are strictly deterministic in terms of direction and intensity and are subject to management only in part of the conditions in which they occur. Instead, you can do anything with organizational flows: the direction of movement, the magnitude, and the law (depending on time) of moving resources are determined solely by the manager and his organizational and technical capabilities.

Therefore, in a purely cognitive stream model S@ of some means M@, by analogy with (1 – 4), we can write, for example, such a model:

$$\begin{aligned} \text{M@} &= F_1(\text{CEP@org, POP@org, PAS@org}); \\ \text{S@} &= F_2(\text{CEP@org, POP@org, PAS@org}), \end{aligned} \tag{5}$$

where CEP@_{org} – characteristics of the environment occupied by the project; POP@_{org} – properties of the environment outside the project (banks, transport, etc.); PAS@_{org} is the power of additional sources of transport (money, energy, materials, etc.) [11].

Recall that in (5), the functions F_1 and F_2 are not deterministic and, in general, they are unknown in advance. These functions are a reflection of the purely arbitrary influences of organizational system management on the processes described by the model (5).

2.3. Definition of the physical process as an analogue of organizational measures on the example of steam "heat transfer" – "financial flows"

In thermodynamics, thermal processes (heat transfer) are described by the known Fourier equation [15, 16]:

$$\frac{\partial T}{\partial \tau} = a\left(\frac{\partial^2 T}{\partial^2 x} + \frac{\partial^2 T}{\partial^2 y} + \frac{\partial^2 T}{\partial^2 z}\right), \tag{6}$$

where T – temperature, K; τ – time, s; x, y, z – Cartesian coordinates, m; a – coefficient of thermal conductivity, m^2/s.

Since (6) is an equation continuous and the parameters of organizational processes are usually discrete, let us go to finite differences, which in two-dimensional formulation look like this:

$$\frac{T_2 - T_1}{\Delta\tau} = a\left(\frac{T_2^2 - 2T_2T_1 + T_1^2}{(\Delta\tau)^2}\right). \tag{7}$$

Equations of type (7) are used to describe the analogies between heat transfer and projected resource movement. We include the known similarity criteria used in thermophysics [17] and proposed in project management [7, 8] (Table 2).

Another kind of analogy follows from the fact that in the experimental study of physical processes to obtain analytical functions, the data are presented in the form of dependencies between dimensionless complexes, called the criteria of similarity. For example, the following criteria are used for heat transfer processes (Table 2). Here are their organizational criteria, analogues.

2.4. Areas of application of the approach in other similar pairs (analogies with other physical processes)

The method of diffusion-design analogies. Management of organizational and technical systems is sometimes accompanied by transitions of states of such systems to other classes of abstraction. Such transitions are desirable or undesirable, but they are always accompanied by a fundamental change in subsystem models. For example, project management differentiates between tasks that are solved at the technological, variational or creative levels. The conditions of penetration of one level into another are functionally related to different parameters of project implementation, first of all, economic, and numerically estimated. In this case, there is an additional opportunity to manage such projects by influencing the penetration conditions.

Table 2

Thermodynamic criteria and their organizational counterparts

TEMODYNAMIC CRITERIA [3]	PHYSICAL ESSENCE OF CRITERION	ORGANIZATIONAL CRITERIA [7, 8]	DESIGN ESSENCE OF CRITERION (EXAMPLES)
1. Nusselt heat transfer criterion: $\mathrm{Nu} = \frac{\alpha l_0}{\lambda}$ where α is the average heat transfer coefficient, $J/(m^2 \cdot K)$; αl_0 is the characteristic linear size of the heat transfer surface, m; λ is the coefficient of thermal conductivity, J/(m·s·K);	characterizes the intensity of heat transfer on the boundary of the liquid – wall	1. Return resource criterion RRC@: $\mathrm{RRC@} = \frac{\alpha_{\mathrm{pr}} l_0}{\lambda_{\mathrm{pr}}}$, where α_{pr} is the average coefficient of resource efficiency, l_0 is the characteristic discrete size of the resource sharing area; λ_{pr} – transmission coefficient;	characterizes the intensity of resource sharing at the border project environment – turbulent environment
2. The criterion of convective heat transfer $\mathrm{Pe} = \frac{w l_0}{\alpha}$: where *w* is the velocity of liquid or gas, m/s ,	characterizes the ratio of convective and conductive heat fluxes under convective heat transfer	2. Criterion for unregulated resource sharing CUS@: $\mathrm{CUS@} = \frac{w_{\mathrm{pr}} l_0}{\alpha_{\mathrm{pr}}}$, where w_{pr} – rate of transfer of funds	characterizes the ratio of regulated (managed) and spontaneous cash flows in the case of unmanaged resource exchange
3. Reynolds Viscosity Inertia Criterion: $\mathrm{Re} = \frac{w l_0}{v}$, where: *w* is characteristic speed, m/s; l_0 is the hydraulic diameter, m; λ is the kinematic coefficient of viscosity, m^2/s;	characterizes the ratio of inertia forces and viscosity forces in the fluid flow,	3. Criterion, inhibiting resource sharing CIS@: $\mathrm{CIS@} = \frac{w_{\mathrm{pr}} l_0}{v_{\mathrm{pr}}}$, where w_{pr} –dynamic braking factor; ν_{pr} – kinematic braking factor	characterizes the attitudes that impede resource exchange and the circumstances in the flow of funds
4. Geometric similarity criteria: l_1/l_0; l_2/l_0, where l_1 and l_2 – dimensions of heat exchange surface, m	characterizes the configuration and size of the environment	–	–
5. Prandtl's physical properties criterion: $\mathrm{Pr} = \frac{\mathrm{Pe}}{\mathrm{Re}} = \frac{v}{\alpha}$	characterizes the thermophysical properties of the material	The criterion of financial properties CFP@: $\mathrm{CFP@} = \frac{\mathrm{CUS}}{\mathrm{CIS}} = \frac{v_{\mathrm{pr}}}{\alpha_{\mathrm{pr}}}$	characterizes the financial capacity of the project environment

Suppose, that at the boundaries of levels there are some conditional filters (diffusion layers) that have a capacity, which by analogy with physical phenomena we will call the diffusion coefficient D_{AV} – at the boundary between absorbing and variational levels and D_{VC} – between the variable and creative levels. It is clear that some of the driving forces of projects, such as financial capacity, should be included in the D_{AV} and D_{VC} ratios, because, the higher they are, the more variative and creative the possibilities and, accordingly, the less diffusion. In addition, the coefficients should include other "positive" factors, such as the level of competence and experience of management, as well as the versatility of the hired personnel and the purchased equipment.

Instead, there are negative impacts. First of all, it is the technical and financial crises of projects that threaten the loss and reduction of choices, the instability of the project environment, the focus of the current regulatory framework on increasing the level of unification of technical and technological solutions and more.

In this case, the purpose of the project management will be to reduce the value of the D_{AV} throughout its lifetime. Such control can be calculated relatively quickly with the help of diffusion-design analogy.

The method of electro-design analogies. A significant number of projects or their products in one way or another touch on the solution of problems, in the process of which a unique project product is obtained by solidification from liquid (plastic) or pseudo-liquid (foundry, concrete products, sintegran) state. The main step in such processes is to fill the molding tool with a suitable mixture. At this stage, not only the configuration and properties of the future product are created, but also the preconditions for the future quality of the latter are created, namely density, uniform distribution of components, presence or absence of sinks or cavities, etc., which requires the technologist to constantly monitor the filling [18].

This monitoring is especially relevant when there are any fittings in the body of the product: rods, plates, grilles, etc. After all, they are installed in the snap-in tooling and significantly impede the flow of this part of the project activity. In this case, it is very difficult to control the results of the project stages, especially when, for example, a large-size transmission line support, hydroelectric dam and others, the size of which reaches tens and hundreds of meters, acts as a concrete product. In such cases, the destructive control of the finished products is unacceptable and the responsibility for the state of the concrete products is very high.

The most promising is the non-destructive capacitive method of measuring the state of a building, based on the method of electro-design analogies, as well as on the unambiguous correspondence between the density of a material and its electrical capacity [18].

Thus, by analogy, it is possible to replace rather complex and long calculations of project results with relatively simple and rapid electrical measurements.

Method of mechanical-design analogies. If individual parts of the project team consistently or in parallel execute similar parts, it is obvious that the highest efficiency can be expected if work on such sites is carried out with the same load on the project components, first of all, on the project team members [19].

In this case, it is very useful to use the concept of physical equilibrium, which is attempted to achieve in the mechanics of individual elements of structures [20]. In project activity, one of the components of efficiency is the requirement of equilibrium of project elements.

Unfortunately, it is impossible to achieve full equality of workloads, especially in conditions of anti-crisis activity. But here, by analogy, it is possible to replace the rather complicated and long calculations of the results of the project activity with relatively simple and fast measurements of mechanical characteristics on a computer model.

There are no strict restrictions on the choice of an analogy. Here are just some background maps of using physical and organizational analogies in project management (Fig. 1).

Unauthorized process: heat transfer **ALL TYPES OF TRANSFER OF RESOURCES** **Main model: Fourier law**	**Unauthorized process: diffusion** **ALL KINDS OF INTERACTION** **Main Model: Darcy's Law**
Unauthorized process: electric current flow **ALL TYPES OF CONTROL IN THE PROJECT AND PRODUCT** **Models: the laws of Ohm and Kirchhoff**	**Unauthorized process: stress and strain distribution** **INTENSITY OF WORK OF INDIVIDUAL PART OF THE PROJECT** **Models: Newton's Laws**

Fig. 1. Roadmap for the use of analogy methods in project management

Unfortunately, complexes of mathematical models for the optimization of all aspects of the evolution of complex systems do not exist today or are insufficiently developed. In particular, the models of tasks that arise in the management of organizational and technical systems are not offered, methods of optimization of the structure and parameters of management, which is carried out in an expanding time environment and involving more and more aspects of internal and external influence, are not developed.

3. The purpose and objectives of the study

The aim of the study is to increase the speed while maintaining the acceptability of the results of optimization of the structure and parameters of anti-crisis actions when managing the organizational and technical system (for example, in project management) due to the substantiation, creation and experimental confirmation of a fast-moving method based on organizational-physical analogy between the flow of organizational and physical systems.

To achieve this goal, the following tasks have been formulated and solved.

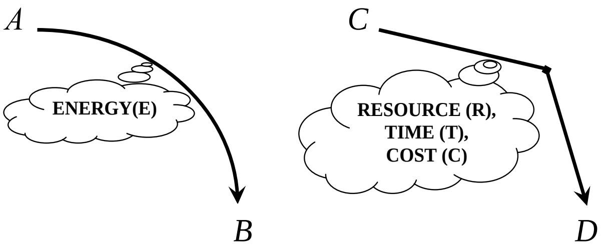
1. To develop theoretical bases of application of design-physical analogies.
2. To develop information technology of application of design-physical analogies.
3. Perform experimental verification of the adequacy of the method.
4. Perform a practical test of the method and evaluate its technical effectiveness.

4. Presentation of basic material

4.1. Theoretical foundations of the method of application of design-physical analogies for optimization of anti-crisis solutions

Consider a model of some physical isolated system that spontaneously moves in the space of its states (in the general case, *n*-dimensional) from point A to point B (Fig. 2 *a*).

If the path AB is full and the driving force of such movement is exhausted on it, point B in the absence of time constraints tends to become an attractor of unauthorized movement. This model implies an arbitrary, natural movement of the system, the purpose of which is the redistribution of internal potentials: temperatures, voltages, pressures, and loads. The difference of such potentials is a part of the internal energy of the system, which in unauthorized processes tries to decrease to zero [13,19].



a *b*

Fig. 2. Phase portrait of the unauthorized movement of an isolated physical system on its path from point A to point B (a) and a non-authorized organizational system on its path from point C to point D (b)

If we denote the magnitude of such energy (E), then we can estimate its value using the integral:

$$\int_L E(x,y,z)dl = \int_A^B E(x,y,z)\sqrt{x'^2(t)+y'^2(t)+z'^2(t)}dt, \tag{8}$$

where $x = x(t)$, $y = y(t)$, $z = z(t)$. $L \in [A, B]$

Accordingly, in unauthorized natural processes we have:

$$\Delta E = \int_L E(x, y, z)\, dl \to \max. \tag{9}$$

Then, changing the energy of the system can be represented as a goal function of an unauthorized process, which seems to be “outside” the latter, but completely affect its course. Next, we introduce additional analogies between physical and organizational processes:

– in the organizational process it is also possible to allocate some objective function (function of expediency) optionally energy, for example, time T@, resource consumption R@, cost C@, etc. (Fig. 2 *b*);

– the curvilinear integral of the function of expediency along the trajectory of the system during crisis management can be a measure of the effectiveness of such management.

The difference is that, unlike the direct problems of thermodynamics (known laws of nature, boundary conditions, configuration and properties of an object, find potentials and flows) (Fig. 3 *a*), cognitive models of project activity allow to solve inverted problems project management [7, 8]. Their essence is that known laws of management, boundary conditions, environmental properties, object configuration and available finances and it is necessary to find optimal recommendations for the distribution of financial flows) (Fig. 3 *b*).

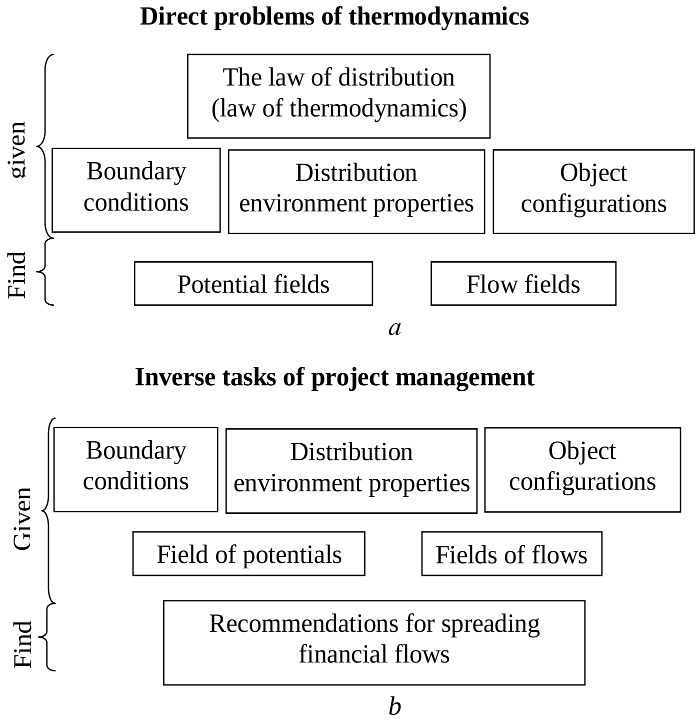


*Fig. 3. Diagrams: direct tasks of thermodynamics (a);
reverse project management tasks (b)*

Reverse tasks are inherently incorrect: they may not have solutions at all or (worse) have multiple solutions. In this case, thermodynamic criterion support for cognitive transfer models in project and program management may be the sole basis for decision making by the project manager [8].

The essence of this support is simple: do as you would in nature, and then maximum efficiency in some sense of your decisions will be guaranteed automatically!

Based on this, and in view of comparative Tables 1 and 2, the following scientific hypothesis can be proposed: *if you organize the process of planning and management of the organizational and technical system so that its entire length is similar to the changes in the parameters of this system and changes in the parameters of one of the known physical processes, then the result of the management of the organizational and technical system reaches extreme expediency in time, cost, etc.*

4.2. Development of information technology using the method of application of design-physical technologies

The optimization process takes place in two stages (Fig. 4). The former solves the usual direct transfer problem, such as heat, and produces a continuous schedule of temperature changes at the end point.

In Fig. 4 are marked:

– initial parameters of the direct problem:

λ – is the thermal conductivity of the communication channel material;

ρ – is the density of the communication channel material;

c – is the heat content of the material of the communication channel;

h – is the length of the communication channel;

t_0 – is the surface temperature of the beginning of heat exchange;
τ – time of heat exchange;
– final parameters of the direct problem:
T – surface temperature of heat transfer end;
– initial parameters of the inverse problem:
TR@ – the resource to be transported through the communication channel;
FR@ – the flow of the resource in the communication channel;
ρ – the density of the resource in the communication channel;
c – the capacity of the resource in the communication channel;
h – the length of the communication channel;
τ_{log} – transportation time (logistics);
– final parameters of the inverse problem:
SCH@ – *schedule and technical means for traffic.*

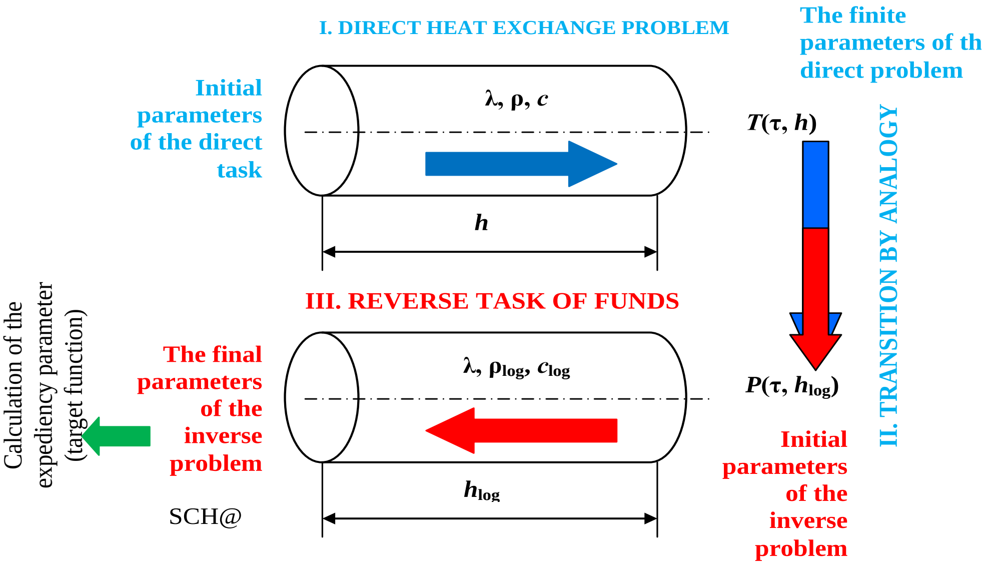


Fig. 4. Structure of the method of optimization of crisis solutions based on organizational-thermophysical analogy

In the second, the inverse problem is solved: its starting point is a discrete graph of change in the amount of resource, similar to a continuous temperature graph.

At the output of the inverse problem – the required parameters of movement (logistics) and the result of the calculation of the project feasibility (Fig. 4).

The first stage. Solving the direct heat transfer problem.

In the *first step*, we consider a one-dimensional thermophysical problem in which the initial temperature of some copper insulated cylinder on the sides of the length h is the same. A constant medium температура ϑ is set at one end of it, and on the other surface the heat flow $\left.\frac{dt}{dx}\right|_{x=h}$ is zero.

The solution to this problem is as follows [21]:

$$T_k = T_0 + \Theta(\vartheta - T_0); \tag{10}$$

$$\Theta = 1 - \sum_{n=1}^{\infty} A_n \cos[\mu_n(1-\eta)]\exp(-\mu_n^2 \mathrm{Fo}); \tag{11}$$

$$\mathrm{Fo} \equiv \frac{a\tau}{h^2}; \quad \mathrm{Bi} \equiv \frac{\alpha h}{\lambda}; \quad \eta \equiv \frac{x}{h}; \tag{12}$$

$$\mathrm{ctg}\mu_n = \frac{1}{\mathrm{Bi}}\mu_n, \quad A_n = (-1)^{n+1}\frac{2\mathrm{Bi}\sqrt{\mu_n^2+\mathrm{Bi}^2}}{\mu_n(\mu_n^2+\mathrm{Bi}^2+\mathrm{Bi})}, \tag{13}$$

and a cognitive plot of the heating of the surface, located at a distance *h* from the heating surface, is shown in Fig. 5.

This dependency is the output of the first stage.

In the second stage, the transition is made by analogy from the direct heat exchange problem to the reverse resource exchange problem.

To do this, points were drawn on the graph (Fig. 4) with some interval over the time axis (Fig. 6).

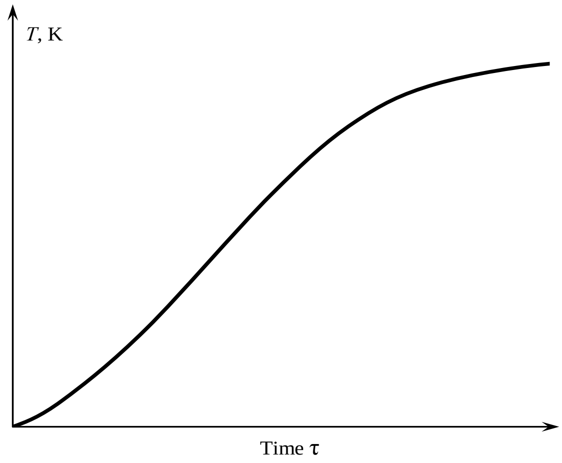


Fig. 5. Cognitive example of a graph of the heating of a surface h over time, calculated from (10) – (13)

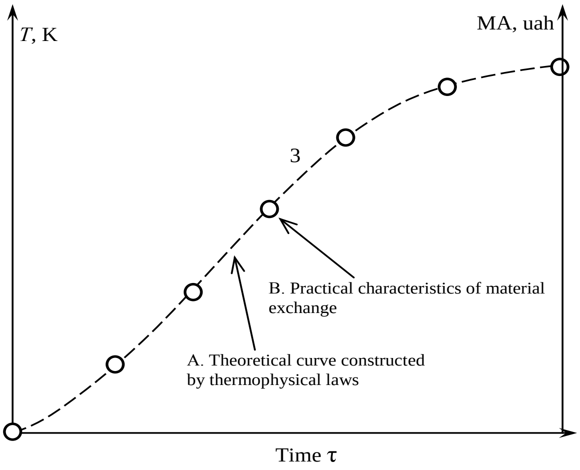


Fig. 6. Before the transition from the direct heat transfer problem (solid curve) to the reverse resource exchange problem (points on the curve)

The coordinates of these points are the initial parameters of the reverse resource-sharing task.

In the third stage, the reverse phase of optimization is performed, during which it is found out which specific resource plan leads to an analogy between physical and organizational processes.

4.3. Experimental confirmation of the adequacy of the method of design-physical analogy

Experimental confirmation of the adequacy of the design-physical analogy method was performed for the thermophysical subsystem according to the information technology presented in the previous subsection. For this purpose, a laboratory unit was created, based on a copper cylinder with a heat-insulated lateral surface (Fig. 7). Wall material: copper; λ=401.9 W/(m·K); ρ=8.933 kg/m^3; c=385.0 J/(kg·K): h=0.1 m

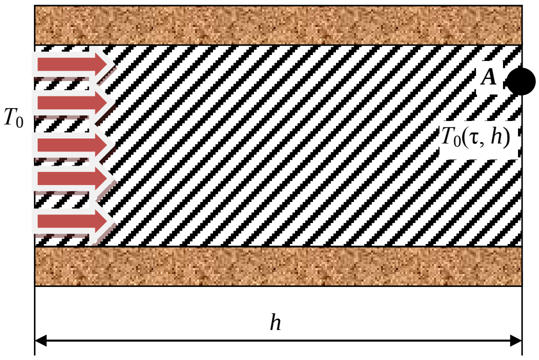


Fig. 7. Schematic diagram of the main part of the experimental setup for checking the adequacy of the analogy method

For these conditions, temperature dependences were obtained at point A of the main part of the installation, which is located at a distance h from the heated surface (see Fig. 7) as a function of time (Fig. 8).

The first graph (1, Fig. 8) was obtained by calculation according to the theoretical thermal model (10) – (13). The second graph (2. Fig. 8) is based on the results of the experimental measurement of the temperature on the surface A using a chromel-aluminum thermocouple. In Fig. 8 these results are represented by triangles.

Next, we construct the input problems for the reverse phase of the method. There were three such tasks. Each of them has a separate set of points marked with circles in Fig. 8. For each of them we carry out a computer experiment, the essence of which was to conditionally transport some means M@ from one point to another. Moreover, the manager of this logistic part of the project can influence the cost of transportation M@ by purposefully changing the speed of the vehicle w, the number of units z and the capacity of each unit m_z:

$$\Sigma M@ = \Sigma M@ \, (w, z, m_z). \tag{14}$$

The first and second sets differ significantly in their location from the theoretical and experimental curves (ie, the condition of similarity of the physical and organizational subsystems is not fulfilled for these tasks), and the third set is chosen as close as possible to these curves.

Solving three back problems, we get three sets of recommendations for organizing resource sharing and calculate for (14) the value of the target function (cost) for each of the ways to organize traffic. As a result, we obtain a cost diagram (Fig. 9), which shows that the lowest cost corresponds to the logistics constructed by analogy with the thermophysical curve.

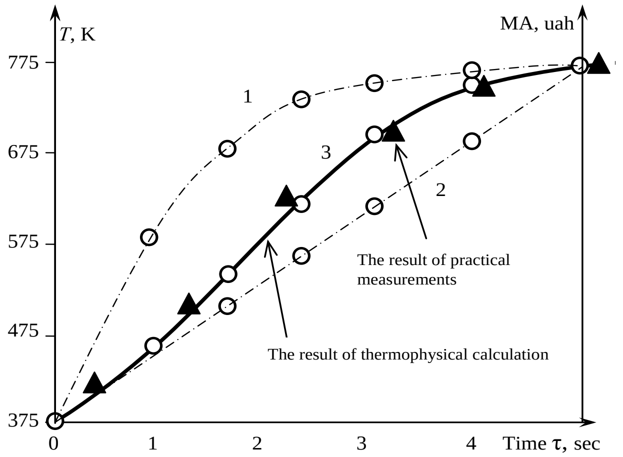


Fig. 8. The result of the direct thermophysical calculation (1) and the experimental tests (2) with the applied points of the problems for the reverse calculation

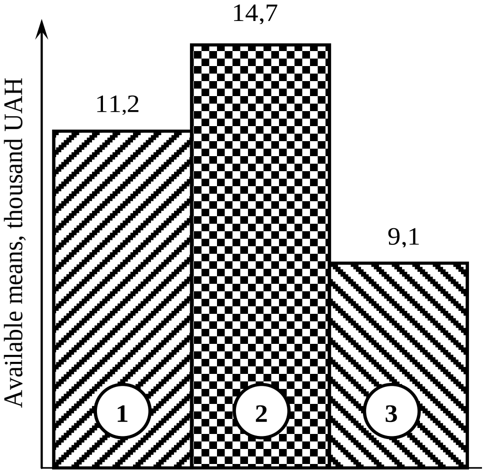


Fig. 9. Final costs when using the three initial tasks of optimizing resource movement

4.4. Practical testing of the method and evaluation of its technical efficiency

EHO Private Enterprise (Odessa region, Bilyaevka city), which specializes in transportation of large cargoes, has carried out practical tests of the “SOLINTR” system in the course of logistic operations on the construction of an electrical substation - electrical installations intended for receiving, converting and distributing electrical energy, consists of transformers or other electrical converters, controls, switchgear and auxiliary devices.

The “SOLINTR” system was used to control the transportation routine of the large-sized transformer. Tests of the “SOLINTR” system showed that its use made it possible to achieve the following design results:

– regarding the interaction with the turbulent environment:

  – developed instructions for the development and implementation of methods of technical and economic interaction of stakeholders: owners of road infrastructure of various purpose (bridges, overpasses, power lines, urban and long-distance transport, etc.) with representatives of the authorities in the transportation area;

– for the project product:

  – terms of construction of electric substation reduced by 11 % compared to the planned ones;

  – planned construction time: 3 months (91 days). It was planned to deliver the transformer for 55 days of construction. Actual construction time: 81 days. The transformer was de-

livered within 45 days due to the use of “SOLINTR”. I had to lift a network of trolleybus suspension wires;
– the cost of construction has been reduced, on average, 1.12 times more than planned;
– no antagonistic conflict situations related to the impact of the transportation process on the surrounding infrastructure have been recorded.

Conclusions

1. Within the theoretical foundations of the proposed method, the scientific hypothesis is formulated that when to organize the process of planning and crisis management of a project so that throughout its length the similarity between changes of parameters of this project and changes of parameters of one of the known physical processes is observed, then the result of the crisis management of the project under this scheme reaches the extreme expediency of time, money, etc.

2. The description of the processes of crisis management of projects by means of thermodynamic analogies allows us to take advantage of the well-known commonality between thermal, hydraulic, mass, electrical and mechanical processes. This allows you to choose a convenient form of presentation of the model, depending on the scope of its application in the project activity: planning, self-management, response to external challenges, project crises, etc. Comparisons of mathematical models of unauthorized thermodynamic processes and similar unauthorized organizational processes of anti-crisis project management are given, as well as “auxiliary” (restrictions, criteria, etc.), and analogues of such auxiliary relationships in project management are developed.

3. The computer and laboratory experiment confirmed the adequacy of the method of using the project-physical analogy between organizational and natural processes for accelerated optimization of decisions in crisis management of projects and programs.

4. In the EHO Private Enterprise (Odessa region, Bilyaevka city), which specializes in transportation of large cargoes, practical tests of the “SOLINTR” system were carried out when performing logistic operations on the construction of an electrical substation – electrical installations intended for receiving, converting and distributing electricity. The “SOLINTR” system was used to control the transportation routine of the large-sized transformer. Tests of the “SOLINTR” system showed that its use made it possible to achieve positive design results.

Література

1. Бушуєв С.Д., Ярошенко Ю.Ф. Антикризове управління фінансовими установами в умовах турбулентності. *Управління розвитком складних систем.* 2013. № 15. С. 5–10.
2. Schmidt R., Lyytinen K., Keil M., Cule P. Identifying software project risks. An international Delphi study. *Journal of Management Information Systems*. 2006. № 7 (4). P. 5–36.
3. Determination of similarity criteria in optimization tasks by means of neuro-fuzzy modeling / O.O. Rubanenko, V.O. Komar, O.Y. Petrushenko, A. Smolarz, S. Smailova, U. Imanbekova. *Przegląd elektrotechniczny*. 2017. 1(3). 95–98. DOI: 10.15199/48.2017.03.22.
4. Становська І.І., Колеснікова К.В. Стратифікація індивідуальних компетенцій з метою побудови динамічних морфологічних моделей проектного управління. *Вісник НТУ «ХПІ». Серія: Стратегічне управління, управління портфелями, програмами та проектами.* Харків, НТУ «ХПІ». 2019. № 1 (1326). С. 30 – 36. DOI: 10.20998/2413-3000.2019.1326.5.
5. Втюрин В.А. Основы АСУ ТП. 2006. 154 с.
6. Сосонкин В.Л., Мартинов Г.М. Программирование систем числового программного управления. Изд. Логос, Университетская книга, 2008 г., 344 с. ISBN 978-5-98704-296-0.
7. Разработка термодинамической критериальной поддержки когнитивных моделей переноса в управлении проектами и программами / О.С. Савельева, И.И. Становская, А.В. Торопенко, И.Н. Щедров, Е.И. Березовская. *Восточно-европейский журнал передовых технологий. Информационные технологии.* 2015. № 6/3 (78). С. 53–59. DOI: https://doi.org/10.15587/1729-4061.2015.55714.
8. Розробка термодинамічних когнітивних моделей проектної діяльності / О. С. Савєльева, І. І. Становська, А.В. Торопенко, К.І. Березовська, І. Хеблов. *Вісник НТУ «ХПІ» Нові рішення в сучасних технологіях*. НТУ «ХПІ». 2015. № 62 (1171). С. 89–93.

9. Лукьянов Д.В., Колесникова Е.В., Негри А.А. Подходы, методы и инструменты как составляющие терминосистемы управления проектами. *Электротехнические и компьютерные системы.* 2015. № 19. С. 322–325. DOI: http://dx.doi.org/10.15276/eltecs.19.95.2015.70.
10. Очков В.Ф. Формулы в научно-технических публикациях: проблемы и решения. *Cloud of science.* 2014. Т. 1. №. 3.
11. Второе начало термодинамики / С. Карно , Р. Клаузиус, У. Томсон (лорд Кельвин) и др. ; под ред. А.К. Тимирязева. 4-е изд. М. : Либроком, 2012. 312 с. ISBN 978-5-397-02688-8.
12. Лукьянов Д.В. Коэффициент «ВЕРА В УСПЕХ» для формулы Бекхарда успешных изменений при оценке реализуемости дорожных карт развития организаций. *Тези доп. І Міжнар. наук.-практ. конф.:«Управління проектами, програмами, портфелями.* Т. 2. Одесса : ФОП Бондаренко, 2016.
13. Blunch N. Introduction to structural equation modeling using IBM SPSS statistics and AMOS. Sage, 2012. 312 p.
14. Управление проектами по созданию программного обеспечения. Среда проекта. URL: https://project.dovidnyk.info/index.php/home/upravlenieproektamiposozdaniyuprogrammnogoobespecheniya/106-sreda_proekta.
15. Mathematical modeling of nonstationary thermophysical processes in spacecraft onboard-apparatus bays / E.A. Ashurkov, V.A. Burakov, A.G. Kozlov, V.P. Kozhukhov, E N. Korchagin, G.V. Kuznetsov, S.F. Sandu. *Russian Physics Journal.* 1993. 36(4), 392–399. DOI: https://doi.org/10.1007/BF00570748.
16. Кузнецов Е.А., Шапиро Д.А. Методы математической физики. НГУ, 2011. Ч. I. 131 с.
17. Пехович А. И., Жидких В. М. Расчёты теплового режима твердых тел. Л. : Энергия, 1976. 352 с.
18. Становский, А. Л. Прокопович И. В., Духанина М. А. Неразрушающий метод измерения плотности фрагментов песчаных литейных форм. *Збірник наукових праць. «Інформаційні технології в освіті, науці та виробництві»*. 2013. Вип 4(5). С. 104–110.
19. Buvik M.P., Rolf M. Prior ties and trust development in project teams – A case study from the construction industry. *International Journal of Project Management.* 2015. Vol. 33, 7. P. 1484–1494.
20. Становский А.Л., Савельева О.С., Бибик Т.В. Прогнозирование и предупреждение техногенных катастроф при автоматизированном проектировании сложных технических систем. *Труды Одесского политехнического университета.* 2010. № 1(33) – 2(34). С. 136–139.
21. Жилин П.А. Рациональная механика сплошных сред. 2-е изд. СПб. : Изд-во Политехн. ун-та, 2012. 584 с. ISBN 978-5-7422-3248-3

References

1. *Bushuyev, S.D., & Yaroshenko, Yu.F. (2013). Anti-crisis management of financial institutions in the conditions of turbulence.* Management of the development of complex systems, 15, *5–10*
2. Schmidt, R., Lyytinen, K., Keil, M., & Cule, P. (2006). Identifying software project risks. An international Delphi study. *Journal of Management Information Systems,* 7 (4), 5–36.
3. Rubanenko, O.O., Komar, V.O., Petrushenko, O.Y., Smolarz, A., Smailova, S., & Imanbekova, U. (2017). Determination of similarity criteria in optimization tasks by means of neuro-fuzzy modeling. *Przegląd elektrotechniczny,* 1(3). 95–98. DOI: 10.15199/48.2017.03.22.
4. Stanovska, I.I., & Kolesnikova, E.V. (2019). The individual competences stratification in order to build the dynamic morphological models of project management. *Bulletin of the National Technical University “KhPI”. Series: Strategic Management, Portfolio, Program and Project Management,* 1 (1326), 30–36. DOI: 10.20998/2413-3000.2019.1326.5.
5. Vtyurin, V.A. (2006). *Fundamentals of APCS.* 154 p.
6. Sosonkin, V.L., & Martinov, G.M. (2008). *Programming of systems of numerical program control*. Ed. Logos, University Book. ISBN 978-5-98704-296-0.
7. Savelieva, O.S., Stanovskaya, I.I., Toropenko, A.V., Shchedrov, I.N., & Berezovskaya, E.I. (2015). Thermodynamic criterial support for the cognitive transfer models in the project and program management. *Eastern-European Journal of Enterprise Technologies***,** 6/3 (78), 53–59. DOI: https://doi.org/10.15587/1729-4061.2015.55714.
8. Saveleva, O.S., Stanovska, I.I., Toropenko, A.V., Beresovska, K.I., & Heblov, I. (2015). Development of thermodynamic cognitive models of project activity. *Bulletin of NTU “KhPI” New solutions in modern technologies,* 62 (1171), 89–93.
9. Lykianov, D., Kolesnikova, K., & Negri, A. (2015). Approaches, methods and tools as a component terminosistemy of project management. *Electrotechnic and computer systems, 19 (95),* 322-325. DOI: http://dx.doi.org/10.15276/eltecs.19.95.2015.70.

10. Ochkov, V.F. (2014). Formulas in scientific and technical publications: problems and solutions. *Cloud of Science*, T. 1, 3.
11. Carno, S., Clausius, R., & Thomson, W. (Lord Kelvin) et al. (2012). *The second law of thermodynamics*. A.K. Timiryazev (Ed.). (4th ed.). Moscow: Librocom. ISBN 978-5-397-02688-8.
12. Lukianov, D.V. (2016). The coefficient "FAITH IN SUCCESS" for the formula for successful changes in assessing the scalability of roadmaps for the development of organizations. *Tezi add. I Міжнар. science.-practical. Conf.: “Project, program, portfolio management.* T. 2.
13. Blunch, N. (2012). *Introduction to structural equation modeling using IBM SPSS statistics and AMOS*. SAGE Publications Ltd.
14. Project management software development. *Project Environment.* Retrieved from: https://project.dovidnyk.info/index.php/home/upravlenieproektamiposozdaniyuprogrammnogoobespecheniya/106-sreda_proekta.
15. Ashurkov, E.A., Burakov, V.A., Kozlov, A.G., Kozhukhov, V.P., Korchagin, E.N., Kuznetsov, G.V., & Sandu, S.F. (1993). Mathematical modeling of nonstationary thermophysical processes in spacecraft onboard-apparatus bays. *Russian Physics Journal*, *36*(4), 392–399. DOI: https://doi.org/10.1007/BF00570748.
16. Kuznetsov, E.A., & Shapiro, D.A. (2011). *Methods of mathematical physics.* NGU, Part I.
17. Pekhovich, A.I., & Zhidkikh, V.M. (1976). *Calculations of the thermal regime of solids.* Leningrad: Energy.
18. Stanovsky, A.L., Prokopovich, I.V., & Dukhanina, M.A. (2013). Non-destructive methodfor measuring the density of fragments ofsand molds. *Information Technologies in Education, Science and Production*, 4(5), 104–110.
19. Buvik, M.P., & Rolf, M. (2015). Prior ties and trust development in project teams – A case study from the construction industry. *International Journal of Project Management, 33*, 7, 1484–1494.
20. Stanovsky, A.L., Savelyev, O.S., & Bibik, T.V. (2010). Prediction and prevention of technological disasters in the automated design of complex technical systems. *Trudy Odesskogo politehničeskogo universiteta*, 1 (33) – 2 (34), 136–139.
21. Zhilin, P.A. (2012). *Rational continuum mechanics*. (2nd ed.). SPb.: Publishing house of the Polytechnic University. ISBN 978-5-7422-3248-3.

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