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Integrated project management systems as a tool for implementing company strategies

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ABSTRACT

The topic of project management is relevant since the organisation is obliged to be competitive and promptly respond to market conditions. The main goal of any enterprise is to make a profit and create a successful image. In this regard, the company's strategy is being formed, which is implemented through project management. Project management capabilities affect not only the process of forming a development strategy but also methods of managing innovative and strategic development. When structuring management competencies, special attention should be paid not only to the methods that are implemented in the company's management structure, but also to the technological platform on which the entire management system and the programme for building distributed companies are based. The novelty of the study lies in the structuring of methods to improve the enterprise project management efficiency, taking into account project constraints. To achieve this goal, the authors consider it necessary to analyse the features of enterprise project management. The paper presents theoretical provisions on the effectiveness of project management, identifies factors for increasing the project management efficiency. The paper examines the features of the development of information technology for enterprise multi-project managing. The practical significance of the study is determined by the possibilities of forming a long-term development strategy when implementing project management systems in companies that build their activities not only on a local scale but also plan network growth, which in the context of a lockdown of most world economies becomes the only growth driver.

Keywords: Project management, Information technology, Information security, Control, competition, System automation.

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1. Introduction

The functioning of a modern enterprise is associated with the implementation of project activities since any of its actions, decisions or results of activities are either an independent project or an element of a more complex project. As a consequence of the economic transformations that are now taking place, new models and mechanisms of economic relations are being created. Accordingly, for the further profitable activity of the enterprise, it is necessary to develop new approaches to project management. Increasing their complexity, increasing requirements for deadlines, quality of work execution necessitate effective project management using modern information technologies. When creating and managing projects, it is necessary to remember: firstly, they have resource limitations; secondly, they need constant monitoring; thirdly, time is an important

factor. There are various approaches to classifying projects. The most important classification criterion for this study is the degree of complexity (class) of the project. Projects are divided as follows: monoprojects are simple projects of a certain type; multi-projects are complex projects that consist of several monoprojects and require simultaneous management, taking into account organisational, technical, and resource constraints; megaprojects – targeted programmes for the development of regions, industries; the emphasis is placed on mono- and multi-projects. The cost of megaprojects is more than $ 1 billion, and the duration is 5-7 years. The multi-projects can be considered the most interesting because they are most often used in project management.
The concept of "project management" has several interpretations. In a broad sense, it is the preparation of a project from planning to making a decision on its start and implementation by the project team [1-12]. In a broad sense, the term "project management" is used to organise large and independent projects in the implementation phase [13-22]. It is customary to put forward requirements for project management: knowledge of the subject of the project, efficiency of action and personal qualities [23-28]. Knowledge of the subject includes special knowledge and the consistency of its application. Efficiency of action means that all management and control methods used in the project are effective [29]. Personal qualities – communication skills, ability to work in a team [30; 31; 32]. Project management is divided into four key tasks: the formation of project objectives, planning, management and control [33-41]. Performing key tasks, project management goes through the following stages: analysis of market, risks, needs, problems, the likelihood of project success; planning the general principles of the project, determining the initial data for planning project activities; planning functions in the project; planning and determining the efficiency and the economic feasibility of the project; project implementation; transfer of results to the project customer or client, project report; support in implementation [42-47].

High competition in the market requires companies to implement projects quickly, minimise costs and a high level of quality [48-55]. The company's focus on its strategic goals adds another limitation – alignment with the company's strategy [56-73]. The company has two groups of goals: aimed at internal (increasing business value and efficiency of business processes) and external development (increasing sales, entering new markets) [74]. It is necessary to clearly understand the goals of the company and select the projects that would allow to achieve them [75]. In achieving strategic goals, it becomes necessary to manage several different projects efficiently using limited resources [76; 77; 78]. It should be noted that the complexity of projects increases, while additional requirements for information technology (IT) arise [79]. Current trends in project management suggest an increasing role for IT [80]. Project information management systems (PIMS) are designed to improve management efficiency and reduce the percentage of unfinished projects, they allow to manage changes, resources, constraints, communication, work team and other factors that affect the project [81-88].

Project management information technology has evolved in several stages [89]. With the increase in the power of computers, the functionality of the systems has increased. With the introduction of standards for data exchange between systems, the development of Web technologies, new prospects have opened up for the development of project management information systems [90]. Information systems can automate one or more components of project management: work scheduling, resource management, cost, risk, quality, and the like [91]. Project management automation systems include the following structural elements: tools for scheduling and network planning, methods for solving individual tasks (among them, pre-project analysis, development of business plans, risk analysis, time management, cost management), tools for organising communications between project executors should be distinguished [92]. Information technologies make it possible to successfully manage projects, establish stable communication between participants, identify and respond in a timely manner to deviations, document all stages of the project, and promptly exercise control. These systems perform the following tasks: organisation of discussion groups and chatrooms, remote storage of files and decisions made, as well as informing stakeholders [93].

2. Material and methods

The latest trends indicate that IT is becoming quite widespread for simplified access to project information and ensuring effective communication between team members. They do not contain their own tools for scheduling and network planning, but support the function of integration with project management automation systems. One IT group provides tools for design decisions analysis, OLAP processing (online analytical processing) and Data mining (a collection of different methods of obtaining knowledge), the other group is designed to simplify communication between participants and offers the Internet tools. Recently, the simultaneous management of several projects has become increasingly common; in such conditions, more attention should be paid to monitoring the implementation of project stages. IT makes it possible to implement multi-project management, in which the management of several projects is carried out in parallel, independently of each other, but uses common resources.

In multi-project management, IT allows to describe the composition and characteristics of work, resources, revenues and expenses of projects, create a work schedule taking into account project constraints, identify critical operations and time reserves for performing other operations, calculate the project budget, project needs for materials and resources, planned employment of the project resources, analysing risks and reserves, taking into account the success of projects, keeping records and analysing project executors, receiving the necessary reporting on projects. The multi-project management performs additional functions: archive filing and document management, analytical functions of network multi-project planning, control and audit functions. Project information management systems (PIMS) are used to solve the following tasks: development of a schedule for the implementation of project work; determination of the critical path and time reserves for the project work; determination of the project's need for funding, resources; determining the level of resource utilisation; risk analysis; project management; analysis of deviations of the work progress from the planned one and forecasting of the main parameters.

It is advisable to cite several well-known project information management systems. MS Project is used by about 3 million people. Easy interface allows users of different levels to work with the system. The early versions were not impressive in functionality, but MS Project 2000 can be integrated with other Microsoft software products. The advantage of the system is the support of information exchange with Microsoft Outlook. The project manager has the ability to transfer data to the work team about the tasks that need to be completed, and – in the opposite direction – the work team can inform the manager about all changes in the work calendar. To build an integrated project management system, Primavera inc. offers several products: for use at the lower levels of management – SureTrak Project Manager, professional project management package – Primavera Project Planner (P3f, for working with complex multi-level hierarchical projects – Primavera Project Planner for the Enterprise (P3e). System interface – standard, windowed. A set of tools is available for project management, containing up to 20 levels. Implemented 9 types of work, all dependencies between activities and 10 types of restrictions. As a means of risk analysis, the Monte Carlo method is proposed, it allows to assess the likelihood of project failure in a given time frame. The effectiveness of project management systems is determined by the totality of costs and benefits that the system can bring. There are three main parameters that optimise the use of project management – time, cost and quality of work. In case of ineffective project management, the company can incur losses due to delay in fostering innovation; exceeding the project budget; poor quality work.

Ineffective management of work budgets and work quality is associated with underestimating future costs and direct costs due to erroneous actions. The average cost of such errors is 10-20% of the project budget. The main qualitative advantages of using the PIMS include: increased control over projects; classification of projects according to the degree of importance, the goals set, the expected result, this is what allows to give priority to strategically important projects in terms of resources, financing; optimisation of the project schedule allows the most efficient allocation of company resources. This takes into account the availability of resources, priority of projects, resource delivery schedules, funding restrictions; transfer of experience. The experience gained during the implementation of projects can be used to prevent mistakes in future projects, reduce the time for project planning; clear planning of work. Unfortunately, the effectiveness of the use of project management systems in companies has not been evaluated. In the USA and European countries, such studies are carried out regularly.

While implementing the PIMS, it is worth remembering that the use of information systems requires certain changes in the organisation's management processes. Implementation requires a systematic approach that provides for the planning of a set of works and control over their implementation. It is necessary to start by drawing up an implementation plan containing a list of tasks, from formalising the procedures for collecting and storing information to making changes in the organisational structure of the enterprise. The success of the implementation depends on the activities of the organisation as a whole or its individual divisions. Consequently, planning and control over the technical, human aspects of technology implementation is of particular importance. When planning the implementation of information systems, the following mistakes are most often made: goals and expected results are not defined; planning the commissioning of all functions of the project management system; planning the transfer of the entire organisation to the new system.

The development of economic relations and information spheres leads to an increase in the volume of information, the number of information objects and, ultimately, to an increase in competition and an increase in the frequency of attacks. At the same time, the conditions of confrontation are constantly changing, and the process of confrontation must be viewed in a dynamic mode. The reasons for the changes are the attacks of rivals, as well as the aging of information, the introduction of new information and additional resources, and their redistribution between objects. The analysis of confrontation in the information sphere is usually unidirectional and is aimed at developing measures to protect information. At the same time, in a competitive struggle, the confrontation occurs in both directions: each side seeks to protect its information and obtain information from the opponent. The transition to bi-directional confrontation significantly expands the range of problems arising in the design of information security systems.

Each of the parties solves a number of tasks aimed at optimising important indicators associated with the allocation and distribution of resources. These indicators include: the total amount of resources allocated to protect their own information and obtain information from the opponent; the ratio between the amount of resources allocated for protection and for obtaining information; distribution of resources between individual objects. The solution to these tasks depends on the cost of information owned by each of the parties, its placement at the facilities, their vulnerability, the probability of allocating a certain amount of resources by the opposite party and their distribution between the facilities. The optimality criterion is to achieve maximum efficiency of investment in information security, that is, the maximum total cost of protected and extracted information.

A homogeneous system of two competing parties, each of which contains two identical objects, is considered. The resources of opponents are denoted by X and Y, g_k^m – the cost of information at the object. The superscript is the information system number, the lower one is the object number. Since the system is homogeneous, $g_1^{(1)} = g_2^{(1)} = g^{(1)}, g_1^{(2)} = g_2^{(2)} = g^{(2)}$. The superscript characterises the relationship to the corresponding information system, the lower one is the object number. The target function $F(x,y)$ determines the total information baggage, which includes a decrease in the amount of damage caused by the implementation of threats to information $j(x,y)$ by making investments in the objects of protection and the cost of information $i(x,y)$, obtained from the opponent's objects (these values are relative). The objective functions for the first side $F_1(x,y)$ and for the second $F_2(x,y)$ have the form (Equations (1-2). Using the target function, the amount of damage from the implementation of information threats at the *k*-th object is presented as Equation (3):

$$F_1(x,y) = \sum_{k=1}^{2}\left[j_k^{(1)}(x,y) + i_k^{(2)}(x,y)\right] \tag{1}$$

$$F_2(x,y) = \sum_{k=1}^{2}\left[i_k^{(1)}(x,y) + j_k^{(2)}(x,y)\right] \tag{2}$$

$$i_k(x,y) = g_k p_k f_k(x_k, y_k) \tag{3}$$

where x and y – resources of the two parties allocated to the object; g_k – relative cost of information at the object; p_k – the probability of an attack on an object; $f_k(x_k, y_k)$ – object vulnerability.

Most of the values that are included in Equation (3) are relative: x, y, and $f_k(x,y)$ refer to the cost of information at the object; g_k and $i_k(x,y)$ refer to the information cost of the entire system. According to the developed model, it is believed that the variables *x* and *y* are included in the above expressions as a ratio, that is, the amount of damage caused by the implementation of information threats depends on the ratio of the attack and defence resources: for the first information system, it is $\frac{x}{y}$, for the second is $\frac{y}{x}$. In addition, it is assumed that in the absence of investment in defence, the attacker gains access to all information of the object, the cost of which is equal to one. The probability indicators are set at the level $p_k = 1$ (the attack has occurred). The distribution of resources among objects by the opposite side is also considered uniform, the amount of resources at each object is equal to one: thus, the transition from $\frac{x}{y}$ to x, and from $\frac{y}{x}$ – to y occurs. When using the specified conditions, the objective functions take the form Equations. (4-5):

$$F_1(x,y) = \sum_{k=1}^{2}\left[1 - g_k^{(1)} f_k^{(1)}(x) + g_k^{(2)} f_k^{(2)}(y)\right] \tag{4}$$

$$F_2(x,y) = \sum_{k=1}^{2}\left[1 - g_k^{(1)} f_k^{(1)}(x) - g_k^{(2)} f_k^{(2)}(y)\right] \quad (5)$$

To simplify formula of the functional dependences $f(x), f(y)$ the indices for the independent variable are not indicated, however *x* and *y* should be understood as relative resources on the objects of the corresponding systems. The main influence on the calculation results has the form of dependences $f(x), f(y)$, where x and y – unknown. $f(x), f(y)$ is the expression whose roots need to be found [94]. They are given as fractional power functions Equation (6):

$$f(x) = \frac{x^n}{x^n + c}; f(y) = \frac{1}{1 + cy^n} \quad (6)$$

where the parameters *n* and *c* express cost performance, that is, a decrease in dynamic vulnerability $f(y)$ or a corresponding increase in $f(x)$. In the following calculations, the following forms of functions are used (expressed in terms of the attack resources, since the defence resources are evenly distributed):
1) the first system Equation (7):

$$f_1^{(1)}(x) = \frac{x}{x+8}; f_2^{(1)}(x) = \frac{x}{x+16} \quad (7)$$

2) the second system Equation (8):

$$f_1^{(2)}(y) = \frac{x}{1+16y^2}; f_2^{(2)}(y) = \frac{x}{1+32y^3} \quad (8)$$

In expressions (4-5), the independent variables of the corresponding functions are used: in the functions $f_k^{(1)}(x) - x_k^1$, in the functions $f_k^{(2)}(x) - y_k^2$. Parameters *n* and *c* in (Eqs. 7-8) were chosen arbitrarily – in order to maximally expressive presentation of the results. The distribution of information over objects in each system is assumed to be uniform: $g_1^{(1)} = g_2^{(1)} = 0.5, g_1^{(2)} = g_1^{(2)} = 0.5. \sum_{k=1}^{2} g_k^{(s)} = 1, s = 1.2$. The feasibility of costs is determined by their efficiency for each of the objects. This indicator is numerically expressed by the performance of the costs, and graphically by the slope of the corresponding characteristic: $f^{(1)}(x)$ for information and $f^{(2)}(y)$ for protection. Since these characteristics have similar forms, the zones of expediency are located identically: with fractional linear dependences $f(x,y)$ – these are OA intervals in the initial ranges of values of *x* and, accordingly, *y*, with fractional nonlinear intervals, BC in the range of mean values x and y. Increasing *x* and *y* outside these ranges does not significantly increase $f^{(1)}(x)$ and $f^{(2)}(y)$.
Information confrontation occurs most often in conditions of uncertainty, when the opponent's actions are unknown and can only be predicted with a certain probability. This makes it difficult to optimise the distribution of resources between objects of protection and resource management in a dynamic mode (objects can have both physical and electronic forms). However, a situation is possible when changing the distribution of resources is unprofitable for either party. In game theory terminology, this situation reflects the saddle point of a matrix game. Determining the conditions for the existence of a saddle point is an important task of the economic management of information security. The search for a solution is complicated by its dependence on a significant number of parameters and characteristics of the information system. The existence of a saddle point is possible only in a certain range of values of the indicated parameters. In a number of studies, some aspects of the formulated problem were considered for the simplest form of confrontation, when the actions of one of the parties are aimed at obtaining information, and the other at protecting it. A similar problem was considered in the case where the search for the optimal set of protection mechanisms that minimises the risk of information loss is carried out using the example of the system of regional bank branches [95-100].
The amount of information in each department is proportional to the potential number of clients, that is, the number of residents of the district. The probability of implementation of individual threats, as well as the cost and effectiveness of each of the protection mechanisms, is determined by the method of expert assessment [101-108]. It is assumed that the probability of a threat against each object is the same and depends only on the type of threat. Considering various combinations of protection elements for each department, the total damage for the entire system (which characterises the degree of risk) and the optimal set of protection elements for each department are calculated, provided that a limit is imposed on the total cost of the protection

system. When calculating the total risk, the question remains about the size of the cross terms, expressing the amount of damage caused by the implementation of information threats (these events are compatible).

3. Results and discussion

In a competitive environment, each party strives to protect its information and obtain information from the rival. In this case, a multidirectional or complex opposition is considered. The possibility of the existence of a saddle point is influenced by the following factors: form of opposition – unidirectional or multidirectional; number of objects l; the degree of vulnerability of objects, that is, the form of functions $f_k(x, y)$; relative value $\{g_k\}$ of information at the objects. Taking these factors into account, the saddle point can exist at certain values – the total amount of resources of each party (Eqs. 9-11):

$$Z = \frac{X}{Y} \tag{9}$$

$$X = \sum_{k=1}^{l} x_k \tag{10}$$

$$Y = \sum_{k=1}^{l} y_k \tag{11}$$

The interval ΔZ of the existence of a saddle point is determined by the indicated factors. Using a mathematical model, according to which the objective function $i(x, y)$ determines the amount of damage caused by the implementation of information threats Equation (12):

$$i(x, y) = \sum_{k=1}^{l} i_k(x, y) = \sum_{k=1}^{l} g_k p_k q_k(x, y) f_k(x, y) \tag{12}$$

The main attention is paid to the influence of the values $\{g_k\}$ and dependences $f_k(x, y)$ on the interval ΔZ. For this purpose, set $p_k = 1$ and obtained Equation (13):

$$i(x, y) = \sum_{k=1}^{l} g_k f_k(x, y) \tag{13}$$

According to the model, the dependence $f_k(x, y)$ is refined in the form of fractional-power functions Equation (14):

$$f_k(x, y) = \frac{\left(\frac{x}{y}\right)^n}{\left(\frac{x}{y}\right)^n + c} \tag{14}$$

where the parameter *n* determines the curvature of the dependencies, and *c* is the height of rise above the abscissa axis. Physically, the values *n* and *c* express cost productivity.

The influence of individual factors on ΔZ is often established in a unidirectional confrontation. At this stage of research, it is necessary to establish how the revealed patterns change during the transition to a multidirectional confrontation. Party X seeks information, party Y defends it. Each party has one object of protection $g^{(1)}$. For the Y party, $g^{(2)}$ – for the X party and seeks to obtain information from the opponent's object. In the designations, the subscript is the object number in the system, the upper one is the system number. With unidirectional opposition and linear fractional form of vulnerability functions (14) (that is, for $n_1 = n_2 = n = 1$) a saddle point in a system containing two objects exists for all values of Z. With an increase in the number of l over objects, the interval ΔZ becomes limited, and its width decreases with increasing *l*. If in the system at least one of the dependences $f_k(x, y)$ becomes fractionally nonlinear, then the interval ΔZ also becomes bounded. With an increase in the vulnerability of growth due to the index *n* or a decrease in the parameter c, this interval narrows and shifts towards smaller Z.

In the transition to a multidirectional confrontation, even in a system of two objects with linear fractional vulnerability functions, the interval ΔZ becomes bounded to *c*. The dependence $\Delta Z(n)$ qualitatively retains its character: with increasing *n*, the value of *c* decreases. The results obtained with the same cost of information at the objects: $\frac{g_1}{g_2} = \frac{g^{(1)}}{g^{(2)}} = \frac{0,5}{0,5}$. Other calculated parameters had the following values:

$c_1 = c^{(1)} = 8, c_2 = c^{(2)} = 32$. Dependences $\Delta Z(n_1), Z(n_1)$ were calculated at $n_2 = 1, \Delta Z(n_2), Z(n_2)$ – at $n_1 = 1$, dependences $\Delta Z(n)$ – at $n^{(1)} = n^{(2)} = n = 1$. The results are obtained for a unidirectional opposition and allow to find the width of the interval Equation (15):

$$\Delta Z = Z_{max} - Z_{min} \tag{15}$$

For the system, similar dependences are not shown, since Equation (16)

$$Z_{min}\left(n^{(1)}\right) = Z_{min}\left(n^{(2)}\right) = 0 \tag{16}$$

and the top border where Z_{max} defines the width of the interval. The dependence $\Delta Z(c)$ is obtained for curves at $n_1 = n_2 = 2$, since in the system at $n_1 = n_2 = 1$ $\Delta Z \to \infty$□, the curves – at $n_1 = n_2 = 1$, due to the fact that in the system at $n_1 = n_2 > 1$ $\Delta Z \to 0$. In the functions $\Delta Z(c)$ the differences between the two forms of opposition are significantly manifested. The dependences $\Delta Z(c^{(1)}), \Delta Z(c^{(2)})$ have a qualitatively opposite character: the value $\Delta Z(c^{(1)})$ increases (curve 3), in the same way, as $\Delta Z(c)$ for the system (curves 1 and 2), while $\Delta Z(c^{(2)})$ falls off (curve 4). This can be explained by the fact that the contribution of resources to defence and attack has different effects: the defence system must be more effective than the attack system, that is, hacking the system requires more resources than invested in defence. Formally, this is due to the fact that in the expression of vulnerability (5) x is included in the numerators of fractions, and y is in the denominators, and a change in these values by Δx and, accordingly, Δy leads to a different change in Δf of vulnerability.

The lower limit of the $\Delta Z(c)$ interval for the system, as in the dependence $\Delta Z(n)$, coincides with the abscissa axis. Thus, the upper limit of the dependence $Z(c)$ simultaneously determines the width of the interval $\Delta Z(c)$. In addition to the width of the interval ΔZ , an important indicator is the value $i(Z)$ within this interval. With an increase in c, which reflects a decrease in the vulnerability of objects, the $i(Z)$ curves shift towards lower values of i (transition from 1 to curves 2, 3). With an increase in n, that is, an increase in vulnerability, the values *of* i in the system increase. In the system, the dependence $i(Z)$ at $n > 1$ does not exist, since $\Delta Z = 0$.

The dependence of the interval width ΔZ on the relative cost of information at the objects shows that with an increase in the ratio $\frac{g_1}{g_2}$ the value ΔZ in the system either grows or narrows. For both forms of confrontation, a change in the parameters of the system $\left(n, c, \frac{g_1}{g_2}\right)$ leads to a change in the main indicators – i and ΔZ, and these changes are of the opposite nature: the best indicators in $i(Z)$ are achieved with the worst indicators of ΔZ. For the system, the smallest amount of damage caused by the implementation of information threats, but with the narrowest width of the interval of existence of the saddle point, corresponds to the placement of information inversely proportional to the differences of objects: for the curve $\frac{g_1}{g_2} = \frac{0{,}7}{0{,}3}$ at $n_1 = 1$, $n_2 = 2$. A broad band ΔZ (at the highest values of i) occurs when information is “incorrectly” placed, when most of the information is located on more vulnerable objects: for the curve $\frac{g_1}{g_2} = \frac{0{,}6}{0{,}4}$ at $n_1 = 1, n_2 = 2$.

In a unidirectional confrontation, the complication of the information structure due to an increase in the number of objects and an increase in the degree of nonlinearity of dependencies of dynamic vulnerability of objects leads to a narrowing of the interval ΔZ of the saddle point. Placing information on objects inversely proportional to their vulnerabilities can reduce losses, however, also reduce ΔZ. The transition from unidirectional to multidirectional confrontation confirms the indicated tendencies, however, reveals some new patterns. The differences between the two forms of opposition are significantly manifested in the study of the dependences of the intervals ΔZ of the existence of a saddle point on the parameter, which is included in the vulnerability function as cost productivity. The performed calculations allow to establish the influence of individual factors on the optimal solution and develop recommendations for achieving the saddle point regime in a competitive environment.

In conditions of dynamic confrontation, an important indicator is the time dependence of the state of the information system. The dynamics of the state change is considered on the example of the system of a government institution. Attempts to obtain the opponent's information form a Poisson stream of events, or a

continuous Markov chain. The following designations have been introduced: λ_1, λ_2 – the number of unauthorised access attempts made by opponents per unit of time (in what follows, the first party will be the party with resources Y, which protects two objects of the first information system); p_1, p_2 – probabilities that the corresponding attempts will be successful [109; 110].
Rates of successful attempts by opponents Equation (17):

$$\Lambda_1 = p_1\lambda_1, \Lambda_2 = p_2\lambda_2 \tag{17}$$

Cumulative success rate Equation (18):

$$\Lambda = \Lambda_1 + \Lambda_2 \tag{18}$$

S_{ij} – the state of the system, in which *i* objects of the first of the opponents and *j* objects of the second rival remain unharmed $\left(i = \overline{1.2}, j = \overline{1.2}\right)$; p_{ij} – probability that the system is in the *ij*-th state.
The system of Kolmogorov differential equations according to the system graph has the form Equation (19):

$$\begin{array}{ll} \frac{dp_{22}}{dt} = -\Lambda p_{22} & \frac{dp_{11}}{dt} = \Lambda_1 p_{12} + \Lambda_2 p_{21} - \Lambda p_{11} \\ \frac{dp_{21}}{dt} = -\Lambda_1 p_{22} - \Lambda p_{21} & \frac{dp_{10}}{dt} = \Lambda_1 p_{11} + \Lambda_2 p_{20} - \Lambda_2 p_{10} \\ \frac{dp_{12}}{dt} = -\Lambda_2 p_{22} - \Lambda p_{12} & \frac{dp_{01}}{dt} = \Lambda_1 p_{02} + \Lambda_2 p_{11} - \Lambda_1 p_{01} \\ \frac{dp_{20}}{dt} = -\Lambda_1 p_{21} - \Lambda_2 p_{20} & \frac{dp_{00}}{dt} = -\Lambda_1 p_{01} + \Lambda_2 p_{10} \end{array} \tag{19}$$

By successively integrating the differential equations, expressions for $p_{ij}(t)$ are obtained Equation (20; 21; 22). These are the dependences for various values of Λ_1, Λ_2. The values $p_{ij}(t)$ are determined by the probabilities of the previous states, from which the transitions occur, and by the cases of the transition probabilities, which are determined by the values Λ_1, Λ_2. The course of $p_{ij}(t)$ dependences, in particular, the position of the maxima is shown by the example of the state S_{20}. The rate of change in $p_{20}(t)$ is expressed by equation Equation (20; 21; 22):

$p_{22}(t) = e^{-\Lambda t}$

$p_{10}(t) = \Lambda_2 t e^{-\Lambda_2 t} - (\Lambda_1 \Lambda_2 t^2 + \Lambda_2 t)e^{-\Lambda t}$

$$p_{11}(t) = \Lambda_1 \Lambda_2 t^2 e^{-\Lambda t} \tag{20}$$

$p_{12}(t) = \Lambda_{2t} e^{-\Lambda t}$

$p_{20}(t) = e^{-\Lambda_2 t} - (1 + \Lambda_1 t)e^{-\Lambda t}$

$$p_{02}(t) = e^{-\Lambda_1 t} - (1 + \Lambda_2 t)e^{-\Lambda t} \tag{21}$$

$p_{21}(t) = \Lambda_{1t} e^{-\Lambda t}$

$p_{01}(t) = \Lambda_1 t e^{-\Lambda_1 t} - (\Lambda_1 t + \Lambda_1 \Lambda_2 t^2)e^{-\Lambda t}$

$p_{01}(t) = \Lambda_1 t e^{-\Lambda_1 t} - [\Lambda_1 t + \Lambda_1 \Lambda_2 t^2]e^{-\Lambda t}$

$$\frac{dp_{20}}{dt} = \Lambda_1 p_{21} - \Lambda_{20} p_{20} \tag{22}$$

At the initial stage, $p_{20} \geq 0, p_{20} \approx 0, p_{21} > p_{20}, \frac{dp_{20}}{dt} > 0$. As a result, the flow of attempts p_{21} decreases over time, and p_{20} increases and eventually reaches its maximum at the point determined by Equation (23):

$$\frac{p_{20}^{0}(t_{20}^{0})}{p_{21}(t_{20}^{0})} = \frac{\Lambda_1}{\Lambda_2} \tag{23}$$

The moments t_{ij}^0, at which the probabilities of states reach their maximum values can be determined from the expressions for the derivatives $\frac{dp_{ij}^{'}}{dt}$. By equating the derivatives to zero, the values $t_{ij}^0[\ ]$ are found. Analytical expressions Equation (24) are obtained for the initial states. To find t_{20}^0 it is necessary to solve the transcendental equation Equation (25):

$$t_{22}^0 = 0; t_{12}^0 = \frac{1}{\Lambda} \tag{24}$$

$$t_{20}^0 = \frac{1}{\Lambda}\left(1 + \frac{\Lambda_2}{\Lambda_1} e^{\Lambda_1 t_{20}^0}\right) \tag{25}$$

The maximum values of p_{ij}^0 can be found by substituting the value t_{ij}^0 in the expressions $p_{ij}(t)$s. Another way is to express p_{ij}^0 in terms of the probabilities of previous states, for example, from Equation (26):

$$p_{20}^0 = \frac{\Lambda_1}{\Lambda_2} p_{21}(t_{20}^0) \tag{26}$$

The values t_{ij}^0 and p_{ij}^0 depend on both values – Λ_1 and Λ_2, since each of the states, except for the final ones, is in a dynamic bidirectional process: it is possible to go to the state S_{21} from the previous state S_{22} with a probability proportional to the value of Λ_1, and also pass from this state to the following ones – to the state S_{20} with the probability Λ_1 and to the state S_{11} with the probability Λ_2. Since $\Lambda = p\lambda$, the problem is reduced to determining the values p, λ. These values for various information systems can be estimated based on statistical data. The probabilities of successful attack attempts *p* can also be determined theoretically using a certain mathematical model [111-126]. Dynamic vulnerability is expressed by exponential functions Equation (27):

$$f(x,y) = \frac{\left(\frac{x}{y}\right)^n}{\left(\frac{x}{y}\right)^n + c} \tag{27}$$

where n and c – parameters expressing a productivity of expenses. The value $f(x,y)$ can be considered as the probability of a successful attack by an opponent. The specificity of its use as the p_k parameter for each of the objects is related to the fact that it is not a constant value, but depends on the ratio of resources x_k, y_k. The growth rate of *p* with increasing $\frac{x}{y}$ depends on the degree of nonlinearity of the function $f(x,y)$, that is, on the parameters *n* and *c*.

When $\frac{x_k}{y_k}$ changes between values, p_k can change qualitatively. So, at point A, the first object has the greatest value $p(x,y)$ (with a linear fractional dependence $f_1(x,y)$), and at point B, through the fractional nonlinear nature of the $f_3(x,y)$ dependence – the third object. For the first of the contenders, the most desirable state is S_{20}, which can be reached from the state S_{21}. In this case, the priority task is to achieve the highest value of p_{20}^0 with the lowest t_{20}^0. As the ratio $\frac{\Lambda_1}{\Lambda_2}$ increases, the value p_{20}^0 increases also. The influence of Λ_1, Λ_2 on t_{20}^0 is more complex. It is possible to increase the ratio $\frac{\Lambda_1}{\Lambda_2}$ by increasing the resources of the first of the rivals – in this case Λ_1 increases and Λ_2 decreases. If for the second opponent the probability of successful attempts is given by expression (26), then for the first it is Equation (28):

$$f^{(1)}(x,y) = \frac{\left(\frac{y}{x}\right)^n}{\left(\frac{y}{x}\right)^n + c} \tag{28}$$

The information system under consideration can be associated with a hydraulic structure that contains a set of reservoirs, each of which is equipped with two pipe systems: one of them fills the reservoir, the second

simultaneously releases it. The value p_{ij} has the value of the flow velocity from the *ij*-th reservoir, which is determined by the water pressure in it, Λ_1 and Λ_2 – the cross-sectional areas of the pipes. Leakage from the reservoir S_{ij} in $S_{i,j-1}$ occurs through a pipe with a cross section Λ, and from S_{ij} to $S_{i,j-1}$ – ith a cross section Λ_2. The rate of filling and then the release of the reservoir at given Λ_1, Λ_2 is determined by the time dependence of the $p_{ij}(t)$ values. For the reservoir S_{20} these are $p_{21}(t)$ and $p_{20}(t)$. Both functions first increase, reaching their maximum at certain points in time, and then decline. The time during which the maximum p^0_{20} value is reached, which depends both on the functions $p_{21}(t)$, $p_{20}(t)$, and on the values Λ_1, Λ_2. For the reservoir S_{20} the difference $\Lambda_1 p_{21} - \Lambda_2 p_{20}$ determines the volume of water that arrives (or leaves) per unit of time. Thus, the Kolmogorov differential equations describe the water balance of the corresponding reservoirs.
The use of an equivalent structure makes it easier to understand the obtained patterns. Further, the options for complicating the confrontation scheme are considered. An increase in the number of objects in a homogeneous system, where all objects of each party are the same, does not cause fundamental changes, only the opposition scheme becomes more cumbersome, since the number of possible states increases, and, accordingly, the number of calculations. The transition to a heterogeneous scheme can be carried out in several directions, determined by the parameters that distinguish individual objects. These parameters include: g_k – relative cost of information at the object; p_k – probability of a successful attack on an object, which depends on its vulnerability; λ_k – frequency of attacks on an object, which depends on the market conditions. Since the values p_k and λ_k are included in the calculation in the form of the product $p_k\lambda_k=\Lambda_k$, the problem is reduced to revealing the influence of two calculated parameters g_k and λ_k.
The superscripts in the designation of states express the numbers of intact objects, and in the designation of the frequency of successful attacks – the number of the object at which the attempt is directed. Thus, $S_{21}^{(2)}$ denotes a state in which two objects of the first party and one object of the second party remain intact, with the second object being the unharmed object of the second party. The value $\Lambda_1^{(1)}$ determines the frequency of successful attempts of the first party directed at the first object of the second party. With an uneven distribution of information over objects, when objects differ not only in susceptibility (that is, in p_k parameters), but also in the relative cost of information g_k, the system graph remains unchanged, but the states will now differ not only in the numbers of unharmed objects, but also in the proportion of protected and received information. As an example, consider the case with the formula Equation (29):

$$\frac{\Lambda_1}{\Lambda_2} = 2 \tag{29}$$

In this case, $\Lambda_1 = 0.1$, and $\Lambda_2 = 0.05$. If $\lambda_1 = \lambda_2$, then $p_1 = 2p_2$. After doing some calculations, $\frac{y}{x}$ was found on the first and second objects: $\left(\frac{y}{x}\right)_1 = 0.125$, $\left(\frac{y}{x}\right)_2 = 0.255$
Then Equation (30):

$$Y = y_1 + y_2 = \frac{x_2}{0,255} + 0,125x_1 \tag{30}$$

if $x_1 = x_2$, then the ratio of the total resources of the first party to the second can be calculated: $\frac{Y}{X} = 0.129$.

4. Conclusion

Achievement of project objectives in full may be hampered by time constraints, the inconsistency of management actions. In this case, the expected results of the implementation should be clearly recorded. To prevent negative consequences, it is necessary to consistently plan the implementation of management functions. It is recommended to start implementation with planning and time management, then master resource planning and finish with planning and cost control. The implementation of various functions of the PIMS can affect the work of individual departments of the organisation. It is worth connecting users to the new system department by department. In project management, theoretical research is needed in the direction of introducing information technologies to automate the effective management of multiple projects and control the implementation of projects. The above technique can be extended to a larger number of objects that differ in the relative cost of information, the frequency of attacks, and the probability of success. In this case, the calculated expressions become cumbersome, but the problem can be solved using software tools. The performed analysis can be considered as a step towards the creation of a method of dynamic adaptive resource management in the context of multilateral confrontation.

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