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ADAPTIVE MODEL OF MUTUAL FINANCIAL INVESTMENT PROCEDURE CONTROL IN CYBERSECURITY SYSTEMS OF SITUATIONAL TRANSPORT CENTERS

Abstract. The article presents a model of searching investment control strategies in cybersecurity systems of situational transport centers. The solution of the problem was considered in the context of the development of the Unified State Information and Communication System of Transport of the Republic of Kazakhstan. The model is a component of the information component of intellectualized decision support systems in the tasks of analyzing various strategies for investing in cybersecurity systems of situational transport centers, in particular for the case of mutual investment in a large innovation project for the modernization of information security systems and cybersecurity systems by several states or companies. A characteristic feature of the model is the possibility of working out specific recommendations choosing their strategies for investment in information technology and cybersecurity systems of the situational transport center. It is based on the consideration of a bilinear dynamic quality game with several terminal surfaces. The difference of such a bilinear dynamic game, from previously considered ones, lies in the fact that the discrete equations, that define the dynamics, can be described with the help of arbitrary coefficients.

The solution of such a game is in the class of positional strategies at all relations of the parameters of the investment process. The constructive method of the solution allows to create an intellectualized decision support system. This makes it possible to optimize management decisions in the investment process for cybersecurity systems of situational transport centers.

There are described the results of computational experiments conducted with the help of the intellectualized decision support system (IDSS) "SSDMI". Considered various relationships between the parameters of the investment process in the cybersecurity systems of the situation center. During the simulation there was confirmed the performance of the model and IDSS SSDMI and its high efficiency.

Keywords: cybersecurity, situational transport center, differential game, optimal investment strategies, hacking and protection, intellectualized decision support system.

Introduction. It's no secret that nowadays one of the priority problems of any business, including transport, is the task of providing information (IS) and cybersecurity (CS) [1, 2]. However, even after setting up cyber protection contours, many transport companies subjectively feel a potential loss to the side of the attack. The constant shortage of temporary, financial and human resources, while ensuring reliable cyber protection, leads to the fact that the problems of IS do not lose their relevance with the time. And it is not a simple task to attract investors for projects in the field of CS [1, 2]. The procedure of investment in innovative projects, for example, in the field of information technology (IT), cybersecurity (CS), and others, is often characterized by a high degree of uncertainty and risk. Therefore, in particular, the landscape of cyberthreats on transport that changed over the past few years [1] had a profound impact on the attitude of many transport companies to the problems of the CS [1, 2]. First of all, this was due to the significant potential vulnerabilities and cyberthreats for information and communication systems (ICS) of the transport (ICTS), to the occurrence of new classes of cyberattacks, to the widespread use of wireless data transmission technologies, etc. Also in recent decades, there were actively developed navigation systems with the use of GPS, GLONASS, GALILEO, active and passive monitoring and video surveillance systems for vehicles and cargo, new GSM, GSM-R, VSAT technologies, dispatching, situational and logistic management systems, etc. In the conditions of the rapid implementation of digital technologies at the objects of informatization of the transport industry [1, 2] not all investors paid due attention to the problems of the CS of ICTS [1, 2]. However, as well as to the tasks related to the need to review investment strategies caused by the occurrence and timely recognition of cyberthreats for ICTS, which many experts consider to be components of critical information infrastructures of leading industrial states [1, 2].

In order to increase the effectiveness of evaluation various investment projects in the demanded cybersecurity systems (CSS) of various information objects, in particular, in situational transport centers (STC), and subsequent decision-making related to investment, it is necessary to use "intellectualized decision support systems" (IDSS) [3], and, in particular, with elements of self-learning, i.e. adaptivity of the used algorithms.

Filling the IDSS and their individual modules directly responsible for the analysis and solution of specific tasks is carried out by implementation blocks containing programmed algorithms for economic and mathematical models. However, not many IDSS allow to optimize the procedures related to the searching for different variants of strategies in the mutual financial investment of companies in CSS [3, 4]. In this regard, it is important to develop new economic and mathematical models for IDSS, which will adequately describe the real processes of CSS investment, due to the growing level of competition between various firms and corporations on this market.

Literature review and problem statement. In recent years, a large amount of works [4–6] have been devoted to the problem of choosing effective strategies for financial investment in IT and CSS of various information objects.

It should be noted that with the development of computerized systems and IT, there was occurred a separate direction of researches devoted to the application of expert systems [7-9] and decision support systems (DSS, hereinafter IDSS) [10-12] in the tasks of determining rational investment strategies in IT and CSS. Unfortunately, as the analysis of the mentioned publications [11, 12] has shown, the authors did not offer any real recommendations during the search for rational strategies of mutual financial investment in similar spheres of human activity.

Also, as follows from the conclusions [8, 9] and [11, 12], the use of ES and DSS in order to automate procedures for selecting rational strategies for investment control in CSS is not always accompanied by clear recommendations, as the models and algorithms proposed by the authors are affected by a large number of secondary factors and limitations. And besides, as the authors admit themselves [12, 13], the proposed models have no adaptability parameter [8. 11], i.e. require correction even in the case of a slight change in the list of initial parameters and boundary conditions.

The aforementioned caused the problem related to the need to develop new adaptive models for IDSS [13] in the tasks of determining rational strategies for mutual financial investment, especially in the IT and CSS of various information objects.

On the basis of the previous experience and approaches, outlined by the authors in earlier publications on this topic [1, 3, 12-14], and also close in methodology of research publications of external authors [4, 5, 9, 10, 15, 16], we can confirm that a fairly effective approach in solving this class of problems is the use of methods of the differential quality games theory with several terminal surfaces [14-17].

Therefore, the analysis of publications on this subject confirmed the relevance of the problems of further development of adaptive models and corresponding algorithms for IDSS in the tasks of continuous mutual investment in IT and CSS of various information objects. The last is especially important for cases when it is necessary to develop clear recommendations for investors without complex mathematical calculations, shifting most of the calculations to computer programs in IDSS.

Purpose and objectives of the research. The purpose of the work is a model for the module of the intellectualized decision support system during the continuous mutual investment in the cybersecurity systems of the information object, in particular in the IT and CSS of the situational transport center.

In order to achieve the research purpose it is necessary to solve such problems:

- to develop an adaptive model of searching for investment control strategies for various relationships of investment process parameters in information technologies and cybersecurity systems of the information object;

- to perform simulation for different investment strategies, in order to verify the adequacy of the model and to develop rational investment strategies in the CSS of the situational transport center (on the example of such a center in the Republic of Kazakhstan).

Methods and models.

1. Adaptive model of mutual financial investment procedure control in the cybersecurity of the information object. Many transport companies retain the traditional approach of the solution of the CS ICTS tasks. Most solutions are limited by the traditional investments in antivirus software and network protection. This is a fairly simple financial strategy in order to protect the ICTS. Even experienced administrators of information security services are not always ready for the worst scenario during the cyberattacks at ICTS. Nevertheless, nowadays many hackers have mastered sophisticated methods of camouflaging cyberattacks, which can have catastrophic consequences for companies' business. Consequently, the last ones should shift their focus to replacing traditional approaches of CSS financing by changing the financial component of investment strategies to cybersecurity in the direction of detecting and blocking ICTS security systems hacking [18, 19]. Probably, for the customer the financial strategy of investing in integrated systems of information security and cybersecurity will be more profitable. In this case, it will be difficult without foreign investment. Particularly, for large IT projects, for example, such a large-scale one as the creation of the Unified State Information and Communication Transport System of the Republic of Kazakhstan (USICTS RK), see figure 1.

Such a project is caused by the need to integrate the existing ICTS of Kazakhstan into the Eurasian transport network. At the same time, the socioeconomic, technical and technological aspects of the development of the Republic of Kazakhstan, within the concept of the formation of the digital market economy, will significantly affect the subsequent change of the principles of IT functioning in the entire transport industry. The success of such a large-scale project is connected with ensuring the cybersecurity of the USICTS. The basis of the USICTS of the Republic of Kazakhstan should be a single information resource, which is created on the principle of decentralized databases, integrated among themselves by a protected telecommunication environment [9, 20, 21]. Local, regional, as well as ICS of certain transport types will be available to all participants of the transport market, regardless of the transport type and forms of carriers ownership.

Let consider the following situation. An investor from a country where a stronger currency (Val_1) is in monetary circulation, having free capital, is trying to choose the most preferable variants for its investment. In order to do this, he chooses a counterparty, i.e. object for investment his funds, in a country with a weaker currency (Val_2) in use. This object can be, for example - the economy of another country, or the economic region, or, for example, information and communication systems, CS systems, etc. There is an interaction of the investor and his counterparty. During the interaction, they seek to achieve their goals, in particular, to increase their capital and to improve their financial and economic indicators. In the future, without the loss of generality, we assume that the counterparty also seeks to increase its capital. However, non-coinciding interests, non-optimal governance and the presence of uncertainty do not always allow to reach the interaction simultaneously for the both sides.

If this task arises regularly for an investor, then it is appropriate to use IDSS in the decision-making process related to investment. The formalization of the investment process is given under the assumption that the investor is an economic region in one country (REG_1), the counterparty is the economic region (REG_2) in another country.

We will describe the "basic" process – the process of interaction between REG_1 of one country and REG_2 of another country. REG_1, having some free resources (its investment capital), increases them by α_1 times (α_1 – the growth rate of REG_1 resources) and then decides how much of these resources it will invest in active operations. These operations consist in placing resources in the investment projects of REG_1 and debts repayment of REG_1 at that time. We will assume that the same produces are carried out by REG_2 in relation to REG_1. We should note that if REG_2 does not allocate its resources to REG_1, then, as it will follow from the below mentioned, this will be a special case of the variant with

REG_2 and will be performed under the following assumptions: a) REG_1 controls the financial resources x valued in Val_1; b) REG_2 controls the financial resources y valued in Val_2; c) during the interaction, the ratio Val_1 to Val_2 (exchange rate) k_d remains constant. If these assumptions are fulfilled, the interaction proceeds as follows.

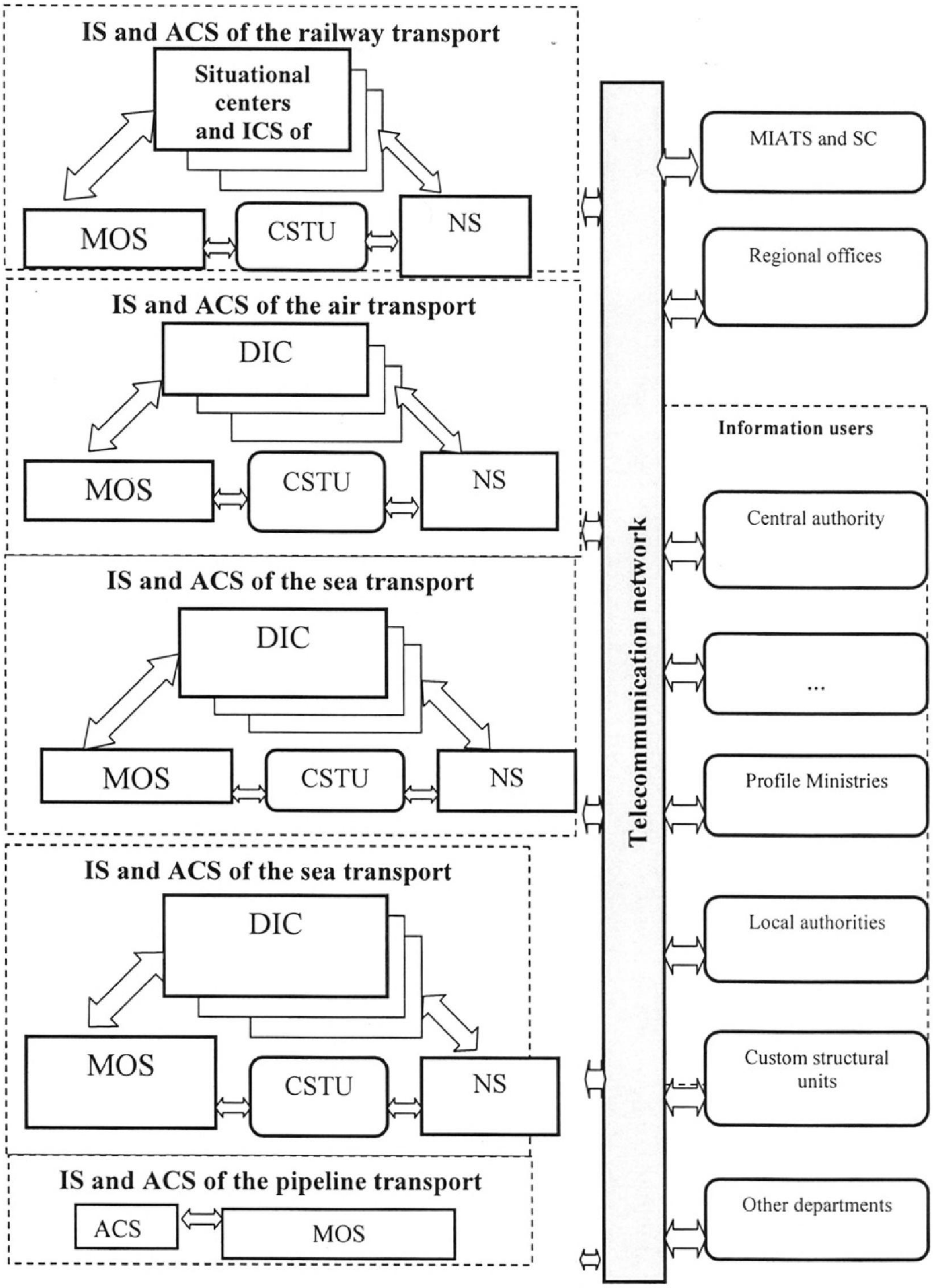

Figure 1 – Organizational and functional structure of the unified state information and communication transport system of the Republic of Kazakhstan:
ACS – an automated control systems; DIC – a departmental information center;
MIATS – the main information and analytical transport center; IS – information systems; CSTU – computerized systems of transport units; MOS – monitoring and observation systems; NS – navigation systems; SC - situational centers

After REG_1 and REG_2, which is a counterparty for REG_1, determined with the share of resources allocated for mutual active operations, mutual debts repayment, resource values, REG_1 and REG_2 will be determined by the following system of discrete equations:

$$x(t+1)=\alpha_1\cdot x(t)+\left[(1-\beta_1(t))\cdot(a_1(t)+r_1(t))-1\right]\cdot u(t)\cdot\alpha_1(t)\cdot x(t)+ \\ +\left[1-(a_2(t)+r_2(t))\cdot(1-\beta_2(t))\right]\cdot v(t)\cdot\alpha_2(t)\cdot\frac{y(t)}{k_d}; \tag{1}$$

$$y(t+1)=\alpha_2\cdot y(t)+\left[(1-\beta_2(t))\cdot(a_2(t)+r_2(t))-1\right]\cdot v(t)\cdot\alpha_2(t)\cdot y(t)+ \\ +\left[1-(a_1(t)+r_1(t))\cdot(1-\beta_1(t))\right]\cdot u(t)\cdot\alpha_1(t)\cdot x(t)\cdot k_d. \tag{2}$$

Therefore, at the moment of time t the value $x(t+1)$ REG_1 (in Val_1) will be equal to the sum of the following components

$\alpha_1(t)\cdot x(t),$ – interest value of $a_1(t)\cdot(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)$ for the invested financial resources of REG_1;

$(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ the value of the invested financial resources of REG_1;

$r_1(t)\cdot(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ the value characterizing the share of the "returned" investment resource of REG_1;

$(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ the investment resource of REG_1 on CSS;

$\left[\left\{(1-r_2(t))\cdot\left(1-\frac{\beta_2(t)}{k_d}\right)\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)\right]-$ the value of the "unreturned" asset (investment) of REG_2 (in Val_1);

$\left[\left\{\frac{\beta_2(t)}{k_d}\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)\right]-$ the resources for the debt repayment of REG_2 to REG_1;

$u(t)\cdot\beta_1(t)\cdot\alpha_1(t)\cdot x(t)-$ the resource for the debt repayment of REG_1 at the moment of time t to REG_2;

$u(t)\cdot(1-\beta_1(t))\cdot\alpha_1(t)\cdot x(t)-$ the resource of REG_1 for investment in the CSS at the moment of time t;

$\left\{a_2(t)\cdot\left(1-\frac{\beta_2(t)}{k_d}\right)\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ interest payment for investment resources of REG_2;

$\left\{\left(1-\frac{\beta_2(t)}{k_d}\right)\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ investment resource of REG_2.

Similar components will also be for the expression (2). Therefore, the value $y(t+1)$ (in Val_2) at the moment of time t will be equal to the sum of following components:

$\alpha_2(t)\cdot y(t),$ – interest value of $a_2(t)\cdot(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)$ for the invested financial resources of REG_2;

$(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the value of the invested financial resources of REG_2;

$r_2(t)\cdot(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the value characterizing the share of the "returned" investment resource of REG_1 in REG_2;

$(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the investment resource of REG_2 on CSS;

$(1-r_1(t))\cdot(1-\beta_1(t))\cdot u(t)\cdot k_d(t)\cdot\alpha_1(t)\cdot x(t)-$ the value of the "unreturned" asset (investment) of REG_1 in REG_2;

$u(t)\cdot\beta_1(t)\cdot k_d(t)\cdot\alpha_1(t)\cdot x(t)-$ the resource for the debt repayment of REG_1 to REG_2;

$v(t)\cdot\beta_2(t)\cdot\alpha_2(t)\cdot y(t)-$ the resource for the debt repayment of REG_2 to REG_1 at the moment of time t;

$(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the resource of REG_2 for investment in the CSS at the moment of time t;

$a_1(t)\cdot(1-\beta_1(t))\cdot k_d(t)\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ interest payment for investment resources of REG_1;

$(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ investment resource of REG_1.

Interaction ends when the variants of the conditions are fulfilled:

1) $x(t+1)\geq 0;\quad y(t+1)\prec 0;$ 2) $x(t+1)\prec 0;\quad y(t+1)\geq 0;$

3) $x(t+1)\prec 0;\quad y(t+1)\prec 0;$ 4) $x(t+1)\geq 0;\quad y(t+1)\geq 0.$

From an economic point of view, these variants are interpreted as follows.

Variant 1. The situation of investment resources (capital) loss of REG_2. REG_1 multiplied its capital by the amount of capital REG_2.

Variant 2. The situation of capital loss of REG_1. REG_2 increased its capital by the amount of capital REG_1.

Variant 3. The situation of capital loss of REG_1 and REG_2 (the default of both subjects of interaction).

Variant 4. The ability of subjects to continue interaction.

There is a question, how to determine the time of possible capital (investment resources) loss according to the information on the initial resources (capital), the exchange rate, the growth rates of REG_1 and REG_2 resources, the interest rates for the allocated capital, the levels of payables and receivables. The toolkit of the multi-step quality games theory [12, 14–17], which allows to determine the areas of possible initial states of resources (capitals) of interacting objects with the following property: if the interaction begins from these states, then at one moment of time the loss of capital is possible both by the one side of the interaction and by the other one, answers the posed question. In order to find such areas there is solved a multi-step quality game with two terminal surfaces, the solution of which is to determine the set of preferences, and also the strategies (control actions) of the parties, using of which make it possible to obtain the outcomes preferred for each side. In this approach, the set of preferences of one side are, in fact, a set of capital loss for the other party. Indeed, for any party of such interaction, the preferred outcome is the preservation of the capital, and undesirable one - its loss. However, it is quite possible that one of the party could act to the other in worst way, that ultimately led the other side to a capital loss. In this case, the set of initial states of the resources of the interacting parties possessing the property that there are strategies (control actions) of one side leading the other side to a state of capital loss, can be called as a set of capital loss for the other party.

We should note that the initial interaction is not limited by the multi-step game model. Similarly, it is possible to simulate interaction that reflects the functioning of several economic regions; it is possible to take into account the incompleteness of information among regions, etc. Therefore, it is possible to use the apparatus of multi-step games for group interaction and for interaction with incomplete information.

In the article, we shall limit ourselves by a simple interaction, which, despite all simplicity, nevertheless allows us to make qualitative conclusions about the financial state of the subjects, depending on the correlation of the parameters of this interaction, and on the possible capital loss of one or the other interaction subject.

The solution of the problem. For convenience of the presentation we will "identify" REG_1 with the player (I), and REG_2 – with the player (II). The above mentioned interaction will be considered within the framework of a multi-step positional game with complete information [12, 14–17]. Within the framework of this scheme, the interaction "generates" two tasks – from the point of view of the first player-ally and from the point of view of the second player-ally. Because of the symmetry it is sufficient to consider one of them, for example, from the point of view of the first player-ally. For this, we will define the pure strategies of the first player-ally. Denote by $T=\{0,1,\ldots\}-$ the discrete set characterizing the region of time parameter change.

Definition. The pure strategy of the first player-ally is the function $u : T \cdot [0,1] \cdot [0,1] \to [0,1]$, that puts the state of information (position) $(t, x(0), y(0))$ the value $u(t, x(0), y(0)) : 0 \le u(t, x(0), y(0)) \le 1$.

The pure strategy of the first player-ally is the function (rule) that puts the state of information at the moment of time t the value $u(t, x(0), y(0))$ that determines the value of the resource (capital) of the first player, which he allocated to "invest" the second player. With regard to the knowledge of the opponent player (within the framework of the positional game scheme), no assumptions are made, that is equivalent to the fact that the opponent player chooses his control action $u(t)$ based on any information. After defining the strategies in **task 1**, we need to determine the set of preferences for the first player. Considering that for the description of the proposed approach it is sufficient to confine ourselves with a qualitative description, the set of preferences W_1 of the first player will be given in this way.

W_1 – a set of such initial resources $(x(0), y(0))$ of players that possess such property.

Property: for initial states there is a strategy of the first player, which for any realizations of the strategy of the second player "leads" to one of the moments of time t, the state of the system $(x(t), y(t))$ in such, when the condition (3) will be satisfied. Moreover, the second player does not have a strategy that can "lead" to the fulfillment of the condition (4) at one of the preceding moments of time. The strategy of the first player, having this property, is called optimal. The solution of the **task 1** is to find the set of preferences of the first player and his optimal strategies. Similarly, the problem is posed from the point of view of the second player-ally. Because of the symmetry of the problems statement it is sufficient to confine ourselves with the solution of the **task 1**, because the solution of the **task 2** is exactly the same.

The solution of the **task 1** is found with the help of the tools of the multistep games theory with complete information [12, 14-17, 20, 21], which allows to find the solution of the game for various ratios of game parameters. We give the solution of the game, i.e. sets of preferences W_1 and optimal strategies for the first player.

Let assume that for any moment of time t the following conditions are satisfied: $\alpha_1(t) = \alpha_1$; $\alpha_2(t) = \alpha_2$; $\beta_1(t) = \beta_1$; $\beta_2(t) = \beta_2$; $r_1(t) = r_1$; $r_2(t) = r_2$.

Let denote through q_1 & q_1 the following values: $q_1 = (1 - \beta_1) \cdot (a_1 + r_1) - 1$; $q_2 = (1 - \beta_2) \cdot (a_2 + r_2) - 1$.

Four cases are possible:

a) $q_1 \ge 0$; $q_2 \ge 0$; *b*) $q_1 \prec 0$; $q_2 \prec 0$; *c*) $q_1 \succ 0$; $q_2 \le 0$; *d*) $q_1 \le 0$; $q_2 \succ 0$.

In addition, it is necessary to take into account that a different ratio of growth rates α_1, α_2 is possible, namely, it can be either $\alpha_1 \succ \alpha_2$ or $\alpha_1 \le \alpha_2$.

In **case a)** and $\alpha_1 \succ \alpha_2$ there are a finite number of set of preferences W_1^i for the first player-ally with the following property.

Property: if $(x(0), y(0)) \in W_1^i$, then the first player in i steps can get the condition (3), no matter how the second player acts. Moreover, the second player has a strategy that does not allow the first player to get the condition (3) in less number of steps. In this case, we write W_1^i in following way:

$$W_1^i = \{(x(0), y(0)) : k(i-1) \cdot x(0) \le y(0) \prec k(i) \cdot x(0)\}, \tag{3}$$

where $k(i) = \left(\dfrac{\alpha_1}{\alpha_2}\right) \cdot \left(\dfrac{q_1 + q_1 \cdot k(i-1) + k(i-1)}{1 + q_2 + q_2 \cdot k(i-1)}\right)$, $k(0) = 0$;

$i = 1, \ldots, k^* - 1$; $k^* : k(k^*) \succ \dfrac{q_1}{q_2}$, $k(k^* - 1) \le q_1 / q_2$,

(such k^* exists).

The set $W_1^i \quad (i = k^*)$:

$$W_1^i = \{(x(0), y(0)) : k \cdot (k^* - 1) \cdot x(0) \le y(0) \prec (q_1/q_2) \cdot x(0)\} \tag{4}$$

The combination of sets W_1^i will determine the set of preferences of the first player W_1 , i.e.:

$$W_1 = \{(x(0), y(0)) : y(0) \le (q_1/q_2) \cdot x(0)\}. \tag{5}$$

And from any state $(x(0), y(0))$ of this set the first player can reach the condition (3) in a finite number of steps (no more than k^*).

In **case a)** and $\alpha_1 \le \alpha_2$ there are countably number of set of preferences W_1^i of the first player-ally with the following property.

Property: if $(x(0), y(0)) \in W_1^i$, then the first player in i steps can get the condition (3), no matter how the second player acts. Moreover, the second player has a strategy that does not allow the first player to get the condition (3) in less number of steps.

We write the set W_1^i in following way:

$$W_1^i = \{(x(0), y(0)) : k(i-1) \cdot x(0) \le y(0) \prec k(i) \cdot x(0)\}, \tag{6}$$

where $k(i) = \left(\dfrac{\alpha_1}{\alpha_2}\right) \cdot \left(\dfrac{q_1 + q_1 \cdot k(i-1) + k(i-1)}{1 + q_2 + q_2 \cdot k(i-1)}\right), \quad k(0) = 0.$

In this case we will write W_1 as follows:

$$W_1 = \{(x(0), y(0)) : y(0) \le (q_*) \cdot x(0)\}, \tag{7}$$

where $q_* : q_* = \left(\dfrac{\alpha_1}{\alpha_2}\right) \cdot \left(\dfrac{q_1 + q_1 \cdot q_* + q_*}{1 + q_2 + q_2 \cdot q_*}\right).$

The optimal strategy of the first player in these cases is to "allocate" all of the capital to investments, if the resources $(x(0), y(0))$ belong to the first player's set of preferences.

Quite symmetrically, in these cases, there are found the set of preferences and the optimal strategy of the second player.

In **case b)** the whole set R_+^2 is preferable for both the first and second players. In any strategy, players will be able to continue the interaction.

In **case c)** and at the verity of the inequality $\left(\dfrac{\alpha_1}{\alpha_2}\right) \cdot (q_1 + 1) \ge 1$, , the set of preferences for the first player W_1 is all admissible initial resources, i.e. R_+^2. A set of preferences W_2 does not exist in this case. The optimal strategy for the first player is to invest all available resources in investments.

In **case c)** and at the verity of the inequality $\left(\dfrac{\alpha_1}{\alpha_2}\right) \cdot (q_1 + 1) \prec 1$, the set of preferences for the first player W_1 are determined in following way:

$$W_1 = \{(x(0), y(0)) : y(0) \le (q_*) \cdot x(0)\}, \tag{8}$$

where $q_* : q_* = \left(\dfrac{\alpha_1}{\alpha_2}\right) \cdot \left(\dfrac{q_1}{\left(1 - (q_1 + 1) \cdot \left(\alpha_1 / \alpha_2\right)\right)}\right).$

In this case, there is a countable amount of set of preferences W_1^i for the first player-ally with the property if $(x(0), y(0)) \in W_1^i$, then the first player in i steps can get the condition (3), no matter how the second player acts. Moreover, the second player has a strategy that does not allow the first player to get the condition (3) in less number of steps.

We write the set W_1^i in following way:

$$W_1^i = \{(x(0), y(0)) : k(i-1)\cdot x(0) \le y(0) \prec k(i)\cdot x(0)\}, \tag{9}$$

where $k(i) = \left(\frac{\alpha_1}{\alpha_2}\right)\cdot(q_1 + q_1\cdot k(i-1) + k(i-1)),\quad k(0) = \left(\frac{\alpha_1}{\alpha_2}\right)\cdot q_1.$

The optimal strategy for the first player is to invest all available resources in investments.

A set of preferences W_2 does not exist in this case.

In **case d)** the situation is symmetric to the **case c)**, i.e. a set of preferences W_1 does not exist. The set of preferences W_2 is determined in a symmetric manner with respect to the set of preferences W_1 for the **case c).**

All cases of correlation of interaction parameters are considered. Symmetrically solved the **task 2** from the point of view of the second player-ally.

As it was noted, the problem from the point of view of the second player-ally is solved similarly. And the areas of preferences from the point of view of the second player are "adjacent" to the areas of preference of the first player. These areas are divided among themselves by equilibrium beams (EQB) [12, 14, 17, 22]. The equilibrium beams have the following property: if a pair of states $(x(0), y(0))$ belongs to the EQB, then players have strategies that allow them to be on the EQB for all subsequent moments of time. Solving the tasks by the proposed game methods in the (x, y) variables space we can find EQB, that is, if the interaction starts from these states, then the players have strategies that allow them to stay on EQB. It means that, at the given $(x(0), y(0))$ it is possible to find the ratio of the interaction parameters for which the pair $(x(t), y(t))$ will be located on the EQB.

If the initial states (resources) are not on the beam of equilibrium interaction, then we can try to change the interaction parameters in such a way when the initial resources are on the EQB. This will allow the parties to continue their interaction for as long as they like.

It should be noted that there are possible situations where the interaction parameters have changed. Then, it is possible to carry out the above mentioned procedure with new parameters and to find new optimal strategies for interaction between the parties, that is, the proposed interaction control scheme is adaptive.

Remark 1. It is easy to see that a more "strong" currency influences the "increase" of preference zones (comparison by inclusion of sets) and the "decrease" of investor risk zones from an economy with a "stronger" currency, and vice versa. It means that an investor with a "weaker" currency should leave those areas of financial resources that become affected by the risk of capital loss due to the "weakening" of the currency of the investor's country.

Remark 2. The considered example of the simplest interaction allows to make the following conclusion that in the space of initial resources there are areas of preference for players. Therefore, if the resources are in the player's preference area, then it is disadvantageous for this player to avoid interaction with the other player, because the other player can change the resource ratio at the absence of interaction as a result of autonomous operation (for example, using the advantage of technology, i.e. in the case if its growth rate is greater) and thereby go to the set "preferred" for him. And then, having already entered into interaction, gain an advantage in this interaction and "lead" another player to a capital loss.

Experiment. The quantitative analysis of the parameters, obtained in the process of searching for rational financing strategies in the systems of cybersecurity of transport companies on the example of large investment projects in Kazakhstan and Ukraine, was carried out by simulation modeling in the Matlab/Simulink environment. For this purpose, there was constructed a corresponding simulation model that contains the blocks of equations (1) and (2) given in point 4, see figure 2. This simulation model was compiled on the basis of the standard blocks of the Matlab/Simulink environment. This made it possible to obtain the required parameters during the computational experiments, see figure 3 and 4.

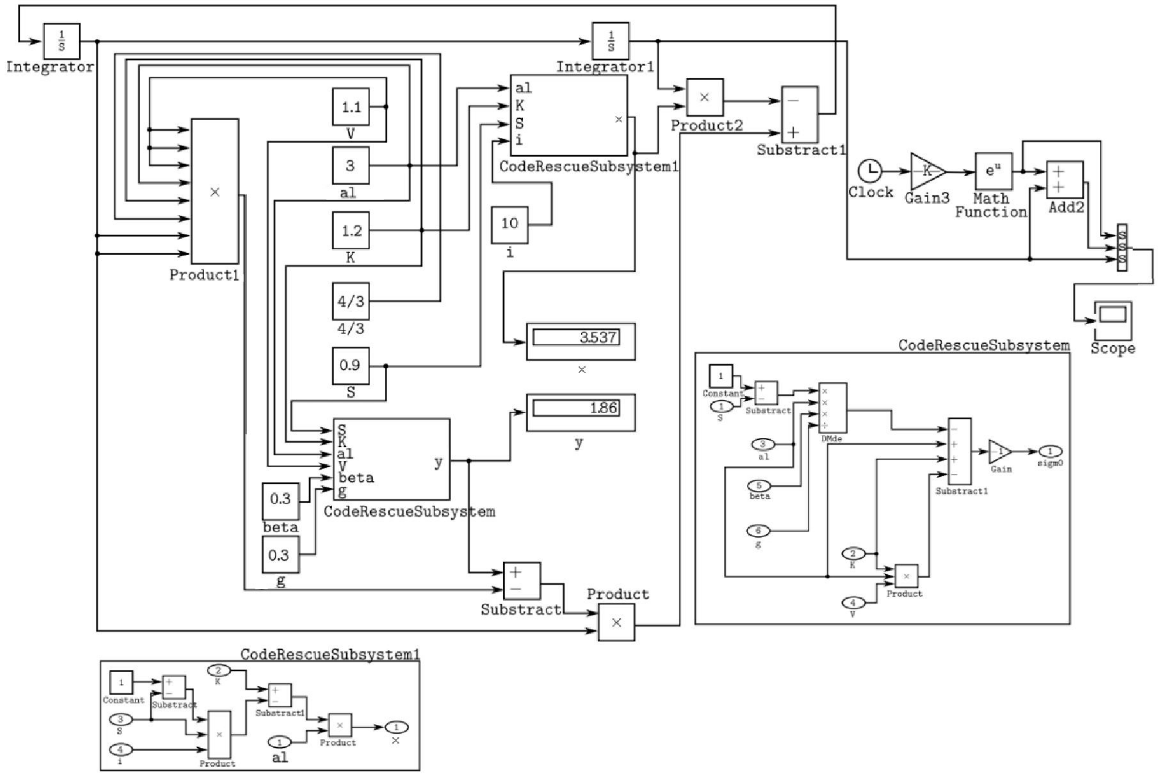

Figure 2 – Simulation model based on equations (1) and (2)

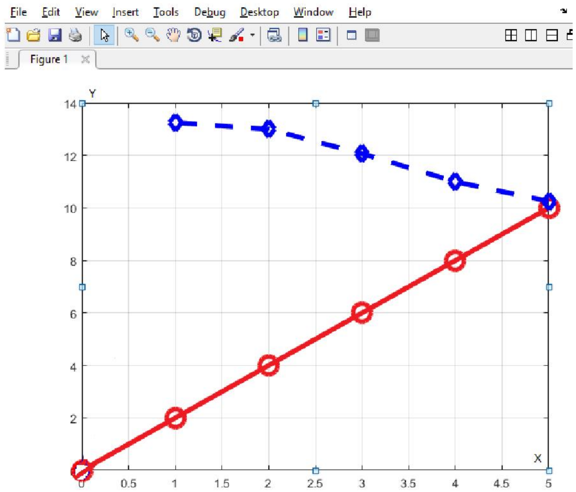

Figure 3 – Example 1 of the results of a computational experiment in the Matlab/Simulink environment

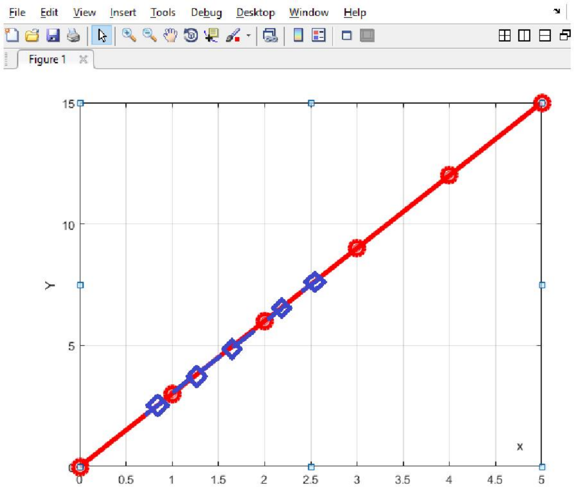

Figure 4 – Example 2 of the results of a computational experiment in the Matlab/Simulink environment

On the basis of the proposed model of continuous mutual investment, there was implemented the program module IDSS "SSDMI", see figure 5. The module is implemented in Delphi language.

During the analysis of the IDSS "SSDMI" module operation, the correctness of the algorithm execution was monitored.

The IDSS "SSDMI" module can be used as an independent software product, and as an auxiliary unit of the decision support system "DMSSCIS", which, in particular, allows to assess the risks of investment in information security systems of large enterprises [15, 16].

On the graphs of figures 3 and 4, the x-axis means “mln, $” (in our case Val_1). On figure 3 the tangent of the angle slope is "2". That is, the equilibrium beam is determined by the relation $y = q_* \cdot x$,

$q_* = 2.0$. On figure 4 the tangent of the angle slope is "3". The y-axis means "mln. hryvnia" (Val_2, for the case of the national currency of Ukraine). On figures 3 and 4, the investors' movement trajectory is shown by a blue dotted line with blue markers (rhombuses). The equilibrium beams are shown on figures 3 and 4 by a red solid line with red round markers. Similar calculations can be made for the case when tenge (Kazakhstan) is used as the currency.

On figure 5, the tangent of the angle slope is "3.5". That is, the equilibrium beam is determined by the relation $y = q_* \cdot x, \quad q_* = 3.5$. The area, highlighted in blue, corresponds to W_1. The area marked with a light yellow color, corresponds to W_2. The trajectory of investors' movement (shown by a red line with blue markers in the W_1 area), determined using the simulation model shown in figure 2, as well as using IDSS SSDMI, (x - financial resource of the first investor, y - financial resource of the second investor).

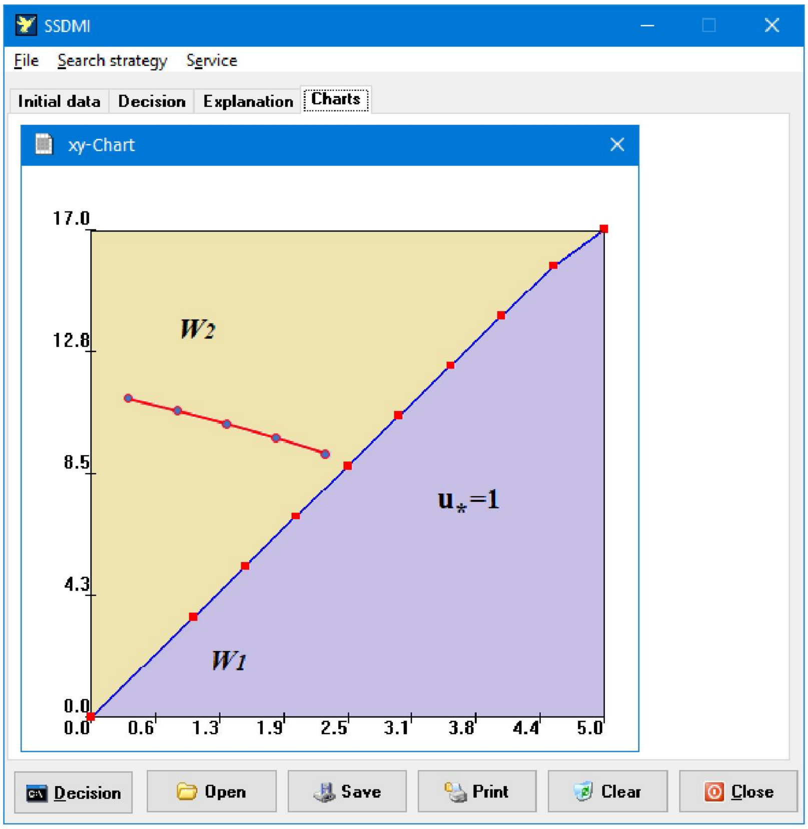

Figure 5 – The results of the operation of IDSS "SSDMI" for the selection of strategies for mutual investment in the cybersecurity systems of the situational transport center

The results obtained in the graph demonstrate the effectiveness of the proposed approach. During the testing of the program "SSDMI" there was established the correctness of the received results.

Discussion. The considered model for the interaction procedure, both at the micro and macro levels, is the process of prediction the results of investment in CSS of ICTS. The Figure 3 corresponds to an simulation experiment in which the second player, using the non-optimal behavior of the first player at the initial moment of time, achieves the case when he "brings" the state of the system to his "own" terminal surface. The Figure 4 corresponds to an simulation experiment in which the initial state of the system is on an equilibrium beam. And the players, applying their optimal strategies, "move" along this beam. This "satisfies" both players simultaneously. The Figure 4 illustrates the "stability" of the system. This corresponds to a situation where, at small deviations in choosing the implementation of the optimal strategy by the first player (see the dotted line), he will reach his goal, but somewhat later. The figure 5 shows the acceptable accuracy of the IDSS "SSDMI" program module in relation to the results of computational experiments in the Matlab/Simulink environment. The discrepancy does not exceed 3-7%. Unfortunately, the predicted data obtained not always using the IDSS "SSDMI" coincided with the actual data. At this stage of development of our model, this circumstance is a definite disadvantage of the proposed approach. By increasing the amount of variants for financial strategies by the protection side and the amount of computational experiments we can reduce discrepancies. In particular, due to wider use of information technologies for data mining and preliminary expert evaluation of financial protection strategies for ICTS and USITS RK. This will eventually allow us to improve the toolkit for prediction investment processes in CSS.

Comparison of the results of our computational experiments with the data of other authors [6-11, 15, 16] made it possible to conclude that the approach outlined in the article is acceptable. Therefore, the proposed toolkit will allow the participants of the investment process in CSS of ICTS to improve significantly the performance indicators of their activities. In addition, the joint use of software products such as IDSS "SSDMI" and an adaptive expert system for the recognition of cyberthreats (described in the works of the authors [20, 21, 23]) will allow investors not only at the stage of initial analysis of the project, but at the modernization of existing systems of cybersecurity, in particular, for critical computer infrastructures, to build effectively a forward-looking policy in the field of financing of cyber security systems, taking into account the trend towards increasing the amount of threats for their ICS.

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Conclusions. There is proposed a model of searching for investment control strategies in the cybersecurity systems of the situation transport centers in the conditions of active development of the Unified State Information and Communication Transport System of the Republic of Kazakhstan. There were considered different ratios of investment process parameters in CSS

The model is a component of the information component of intellectualized decision support systems in the tasks of analyzing various strategies for investment in cybersecurity systems for situational transport centers, in particular for the case of mutual investment in a major innovation project for the modernization of information security systems and cybersecurity systems by several states or companies. The model is based on the consideration of a bilinear dynamic quality game with several terminal surfaces. The peculiarity of the model lies in the fact that the discrete equations, governing the dynamics of the game, can be described with the help of random coefficients. This made it possible to extend the class of the solved problems. The constructive method of solution allowed to create a module of the intellectualized decision support system. This allows to optimize control decisions in the investment process for cybersecurity systems of situational transport centers.

There are described the results of computational experiments conducted in the Matlab/Simulink environment, as well as with the help of Intellectualized Decision Support System (IDSS) "SSDMI". There were considered various relationships between the parameters of the investment process in the cybersecurity systems of the situation center. The operability of the model and IDSS "SSDMI" and its high efficiency was confirmed.

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КӨЛІК ОРТАЛЫҚТАРЫ ЖАҒДАЙЫНЫҢ КИБЕРҚАУІПСІЗДІК ЖҮЙЕЛЕРІНЕ ӨЗАРА ҚАРЖЫ ИНВЕСТИЦИЯЛАРЫН РӘСІМДЕУДІҢ БЕЙІМДЕЛГЕН МОДЕЛІ

Аннотация. Мақалада көлік орталықтары жағдайының киберқауіпсіздік жүйелерінде инвестициялық басқару стратегиясын табудың үлгісі келтірілген. Мәселені шешу Қазақстан Республикасының тасымалдау Бірыңғай мемлекеттік ақпараттық-коммуникациялық жүйесін дамыту контексінде қаралды. Модель көлік орталықтары жағдайының киберқауіпсіздік жүйелеріне инвестициялаудың әртүрлі стратегияларын талдау міндеттерінде интеллектуалды шешімдерді қолдау жүйелерінің ақпараттық компонентінің құрамдас бөлігі болып табылады, атап айтқанда бірнеше мемлекет немесе компаниялардың ақпараттық қауіпсіздік жүйелерін және киберқауіпсіздік жүйелерін жаңғыртуға арналған ірі инновациялық жобаға өзара инвестициялау жағдайында. Моделдің тән ерекшелігі – ақпараттық-технологиялық және көлік орталығы жағдайының киберқауіпсіздік жүйелерін инвестициялау стратегиясын таңдау кезінде нақты ұсыныстар әзірлеу мүмкіндігі болып табылады. Ол бірнеше терминал беттерімен билинейлі динамикалық сапалық ойын қарауға негізделген. Бұрын қарастырылғандардан айырмашылығы мұндай билинейлі динамикалық ойын арасындағы динамиканы анықтайтын дискретті теңдеулер ерікті коэффициенттер көмегімен сипатталуы мүмкін.

Мұндай ойынның шешімі инвестициялық процестің параметрлерінің барлық қатынастары үшін позициялық стратегиялар класында орналасады. Шешімнің конструктивтік әдісі зияткерлік шешімдерді қолдау жүйесін жасауға мүмкіндік береді. Бұл көлік орталықтары жағдайының киберқауіпсіздік жүйесі үшін инвестициялық процесте басқару шешімдерін оңтайландыруға мүмкіндік береді.

«SSDMI» интеллектуалды шешімдерді қолдау жүйесінің (ИШҚЖ) көмегімен жүргізілген есептік эксперименттердің нәтижелері сипатталған. Оқиғалар орталығының киберқауіпсіздік жүйелеріндегі инвестициялық процестің параметрлері арасындағы түрлі қатынастар қарастырылады. Имитациялық модельдеу барысында ISPPR SSDMI моделінің жұмыс істеу мүмкіндігі және оның жоғары тиімділігі расталды.

Түйін сөздер: киберқауіпсіздік, көлік орталығы жағдайы, дифференциалды ойын, оңтайлы инвестициялық стратегия, бұзу және қорғаныс, зияткерлік шешімдерді қолдау жүйесі.

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АДАПТИВНАЯ МОДЕЛЬ УПРАВЛЕНИЯ ПРОЦЕДУРОЙ ВЗАИМНОГО ФИНАНСОВОГО ИНВЕСТИРОВАНИЯ В СИСТЕМЫ КИБЕРБЕЗОПАСНОСТИ СИТУАЦИОННЫХ ЦЕНТРОВ ТРАНСПОРТА

Аннотация. В статье представлена модель для нахождения стратегий управления инвестированием в системы кибербезопасности ситуационных центров транспорта. Решение задачи рассмотрено в контексте развития Единой государственной информационно-коммуникационной системы транспорта Республики Казахстан. Модель является компонентой информационной составляющей интеллектуализированных систем поддержки принятия решений в задачах анализа различных стратегий инвестирования в системы кибербезопасности ситуационных центров транспорта, в частности для случая взаимного инвестирования в крупный инновационный проект по модернизации систем защиты информационных систем и систем кибербезопасности со стороны нескольких государств или компаний. Характерной чертой модели является возможность наработки конкретных рекомендаций при выборе своих стратегий инвестирования в информационные технологии и системы кибербезопасности ситуационного центра транспорта. Она базируется на рассмотрении билинейной динамической игры качества с несколькими терминальными поверхностями. Отличие такой билинейной динамической игры, от ранее рассмотренных, заключается в том, что дискретные уравнения, задающие динамику, могут описываться с помощью произвольных коэффициентов.

Решение такой игры находится в классе позиционных стратегий при всех соотношениях параметров инвестиционного процесса. Конструктивный метод решения позволяет создать интеллектуализированную систему поддержки принятия решений. Это дает возможность оптимизировать управленческие решения в инвестиционном процессе для систем кибербезопасности ситуационных центров транспорта.

Описаны результаты вычислительных экспериментов, проведенных с помощью интеллектуализированной системы поддержки принятия решений (ИСППР) «SSDMI». Рассмотрены различные соотношения параметров инвестиционного процесса в системы кибербезопасности ситуационного центра. В ходе имитационного моделирования подтверждена работоспособность модели и ИСППР «SSDMI» и ее высокая эффективность.

Ключевые слова: кибербезопасность, ситуационный центр транспорта, дифференциальная игра, оптимальные стратегии инвестирования, взлом и защита, интеллектуализированная система поддержки решений.

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