ІНФОРМАЦІЙНЕ ТА МАТЕМАТИЧНЕ ЗАБЕЗПЕЧЕННЯ ЕКОНОМІЧНИХ ПРОЦЕСІВ

INFORMATION AND MATHEMATICAL SUPPORT OF ECONOMIC PROCESSES

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THE USE OF SIMULATIVE MODELING APPROACHES AT THE ECONOMIC SYSTEMS' RESEARCH PRACTICE

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Соколовська З.М., Маковей І.В. Використання підходів імітаційного моделювання в практиці досліджень економічних систем.

Наведено огляд сучасних напрямків імітаційного моделювання. Обгрунтовано доцільність використання методів системної динаміки для дослідження економічних систем. Представлено можливості програмного продукту Ithink як платформи для проведення експериментів та визначення ефективної політики типового комерційного банку.

Ключові слова: системна динаміка, імітаційне моделювання, Ithink, дослідження економічних систем, функціонування комерційного банку

Соколовская З.Н., Маковей И.В. Использование подходов имитационного моделирования в практике исследований экономических систем.

Приведен обзор современных направлений имитационного моделирования. Обоснована целесообразность использования методов системной динамики для исследования экономических систем. Представлены возможности программного продукта Ithink как платформы для проведения экспериментов и определения эффективной политики типичного коммерческого банка.

Ключевые слова: системная динамика, имитационное моделирование, Ithink, исследование экономических систем, функционирование коммерческого банка

Sokolovskaya Z.M., Makovey I.V. The use of simulation modeling approaches in the practice of research of economic systems.

An overview of current trends simulation. The expediency of the use methods of system dynamics for the study of economic systems. Possibilities software Ithink as a platform for experimentation and determining effective policies of typical commercial bank.

Keywords: system dynamics, simulation, Ithink, study of economic systems, the commercial bank

Analyzing the commercial banks' management models demonstrates that their operation efficiency increase essentially depends on the modern information technologies and special mathematical apparatus introduction. Transition to the business processes' management paradigm proves the necessity to use the original technological solutions. The instrumental basis should be flexible enough to implement appropriate prognosis at different time horizons, as well as able for fast reacting and easily implementable at daily practice. Required are the methods allowing to take into account the various factors' impact onto the object's dynamics, to evaluate the banking system stability in respect of both external and internal influences. One of that problem's possible solutions consist in engaging the simulative (computer-aided) modeling auxiliaries.

Analysis of recent researches and publications

In recent years observed is a considerable development of both theoretical and applied principles of simulative models shaping, reflected at numerous the works of national and foreign researchers [1-5].

Evident is a significant enrichment of simulation systems' methodological possibilities by creating multi-media simulation. Such environments do typically integrate a variety of mathematical methods and system analysis' traditional model using special apparatus of simulation languages. Increase in simulation systems technological level is facilitated with the use of visualization tools, CASE-technologies, Internet-technologies. Further developed are the opportunities for research and design of complex systems based on virtual reality models (Virtual Reality – VR).

The contemporary simulation includes and widely uses the three main methodological approaches – discrete-type modeling (DTM), system dynamics (SD), and agent-based modeling (AM). In mathematical sense, the SD operates with processes continuous in time, while the DTM and AM are related to mostly discrete ones. The system dynamics replaces individual objects with their units and provides the highest level of abstraction. The DTM operates at the low and middle levels of abstraction. The AM is used independently of level and scale.

The DTM approach is based onto the concept of orders (transacts, entities), resources and flow diagram (flowcharts), determining the flow of orders and resources' use. The most widely used are the software-based support approach platforms: GPSS / PC, GPSS / H, GPSS World, Object GPSS, Arena, SimProcess, Enterprise, Dynamics, Auto-Mod. The complexity of patterns describing in terms of business processes is partially compensated by the use of products such as Object GPSS or ISS 2000.

The SD approach is used when the simulated object's dynamics is defined as evolutionary change, without displaying several elementary events. At that the real objects models are presented as different nature flows' interaction. The flow approach here is based onto system dynamics method, proposed by J. Forrester in the 20th century early 60s [6].

Software platforms used for SD include: DYNAMO, Stella, Vensim, PowerSim, Ithink, ModelMaker etc.

The agent/multi-agent modeling (agent-based modeling) represents a relatively new simulation approach. The agent-bases simulations' purpose is to get a glimpse of these global rules and the system general behavior departing from the assumption on its individual active objects' individual, private behavior and those objects' interaction at the system.

Today there is no single definition of «agent». One of quite comprehensive definitions is given at [4], asserting that an agent refers to some entity specific with its own activity, autonomous behavior and ability to make decisions in accordance with some rules, therefore capable to interact with the environment and other agents, and to vary (evolve).

The agent-based models are used for researching the decentralized systems, whose dynamic operation is not determined by global rules and laws, but rather these global rules and laws embody the result of the group members' individual activity. The agent-based simulation is also called as "upwards modeling" because, first of all determined is the individual level behavior and the global behavior represents a result of numerous (dozens, hundreds, thousands) agents, each following its own rules, existing in a shared environment, interacting with both that environment and other agents.

The most common software platforms for the approach support are: SWARM, RePast, AScape, AnyLogic.

The use of a specific methodological approach when modeling depends on the study object specificity, as well as of the goals set by the experimenter. This is a very difficult problem associated with determining the model optimal complexity and its adequacy to the real studied processes etc. In this regard, we should emphasize that economics field operates with not perfectly adequate models of stable equilibrium regimes.

More appropriate are the models allowing to analyze the formation of rules and trends of the object's global behavior as integral characteristics of numerous many active participants' behavior. So, to ensure the efficient results of experimental simulation when constructing an economic object's adequate model, we must use a symbiosis of several approaches.

However, some problems do respond well to the simulation particular approaches. In these cases, the «overcomplicated» model does not mean more accurate experimental results.

Unsolved aspects of the general problem

Today the simulation is widely used at various sectors of the economy: manufacturing, business, warehouse, logistics, transportation, engineering and business re-engineering, etc.

Despite of significant international experience in the field of simulation there are still many unresolved issues regarding the selection of particular methodological approaches, theories of simulation experiments planning and their implementation software platforms [1-3, 7-10]. In particular, of topical actuality is to find solution for the use of optimizing simulation methodology in the practical studying of complex economic systems [8]. Necessary is to develop the methodological and technological standards for applied solutions' creation and implementation at integrated simulation environments [7].

More essential importance for users is attributed to the simulation systems' quality and efficiency requirements. Under the national market conditions all that involves a rather limited use of simulation systems that is also related to credit and finance business entities.

According to the outlined problems, this article *aim* is to reveal the applied aspects of the use of system-dynamic approach to a typical commercial bank' branch credit-deposit activity modeling.

Main part

Suggested is a developed simulation model of a typical commercial Bank's branch. The research object embraces processes associated with the loan and deposit activity of the bank.

When simulation, the system dynamics method has been applied. Software platform chosen for simulation experiments: Ithink pack. The Ithink is a simulation pack, which tools are optimally suited to solving a variety of economic problems. In favor of Ithink platform use at economic researches the following arguments do evidence:

- The system implements one of the system-dynamic approach main principles;

— The system simulates the feedback mechanism, so it becomes possible to model the management complex system' non-trivial behavior;
— Due to numerous tools of stochastic effects imitation, the Ithink is easily simulating the variability and uncertainty of the environment where the investigated objects' business processes are running;
— The created with Ithink model do actually serve is a training facility for managers due to an objective focus at various aspects of management processes' behavior;
— The Ithink pack positive features are also related to its technical specifications.

The chosen method's fundamental concepts include the concepts of assets (storage, reservoir) and flows. The object modeled within the accepted concept is presented as a dynamic system consisting of assets interrelated with flows. The assets' content is measured with their level and the flows intensity is determined by flow rate or velocity of assets' content transition.

These concepts are very versatile and easily interpreted in terms of a particular economic system. For example, the assets (storage) may be represented with the enterprise's bank account, the number of bank clients having received loans, the number of lost customers etc. The assets levels are determined by the values of continuous cipher range, but discrete in time. They actually represent the system state variables whose values are derived from the accumulation of differences between input and output flows.

The flows may reflect different processes: physical, financial, information, processes related with human resources etc. Their rate is determined with managerial decisions, formed on the basis of level condition information. The rate equations represent some formalized rules determining how the information about levels allows the selection of flow rate current values.

The flow-type models include the time delay elements, as the real system are characterized with given processes length. The system dynamics models represent these feedback-including, where the processes occur over time. The latter is achieved by the presence of specific discrete variable, the "time". The user can set the imitation term as the total simulation time and/or the imitation step as the simulation time step (basic time period).

At the mathematical level the system dynamics models represent a system of finite-difference equations solved on the basis of numerical integration algorithm (according to the Euler or Runge-Kutt scheme) with constant step and chosen initial values. The model shaping by system dynamics method uses the causal relationship diagrams. The diagrams determine the pattern of variables' interconnection, representing charts with marked graphs.

Thus, to study the development dynamics of the bank as a whole system needed are some especially flexible mathematical methods taking into account the operational environment uncertainty and dynamics. Such specificity involves the choice in quality of methodological platform the system dynamics methods of model construction.

The commercial bank operation is dynamic, being constantly changed over time. In addition, the bank activity performance indexes are impacted with many factors of stochastic nature.

The strategies of natural and legal persons crediting by commercial banks are constantly changing due to situation changes at the financial market. That thus assigns the bank activity priorities.

The bank's resources are constantly circulating, representing in the time aspect the financial flows. Due to the activities' diversity the bank money circulation embodies an interaction of several relatively independent cash flows.

The commercial bank's cash flows can be divided into two sectors by business areas:

The credit activity, that include loans, interest income, and information flows required for crediting.

The deposit activity, that includes deposits received, the interest costs, and information flows necessary for the issuance of deposits.

The sections «Credit activity» and «Deposit Activity» represent the current financial activities of commercial banks in the given areas. The «Credit activity» and «Deposit Activity» sections have a common field uniting them. This is the central part of the commercial Bank of embracing the income and expenses from operations and the equity value.

A fragment of model at flow chart level is shown at Fig. 1.

The basic legend used at the model is listed at Table 1.

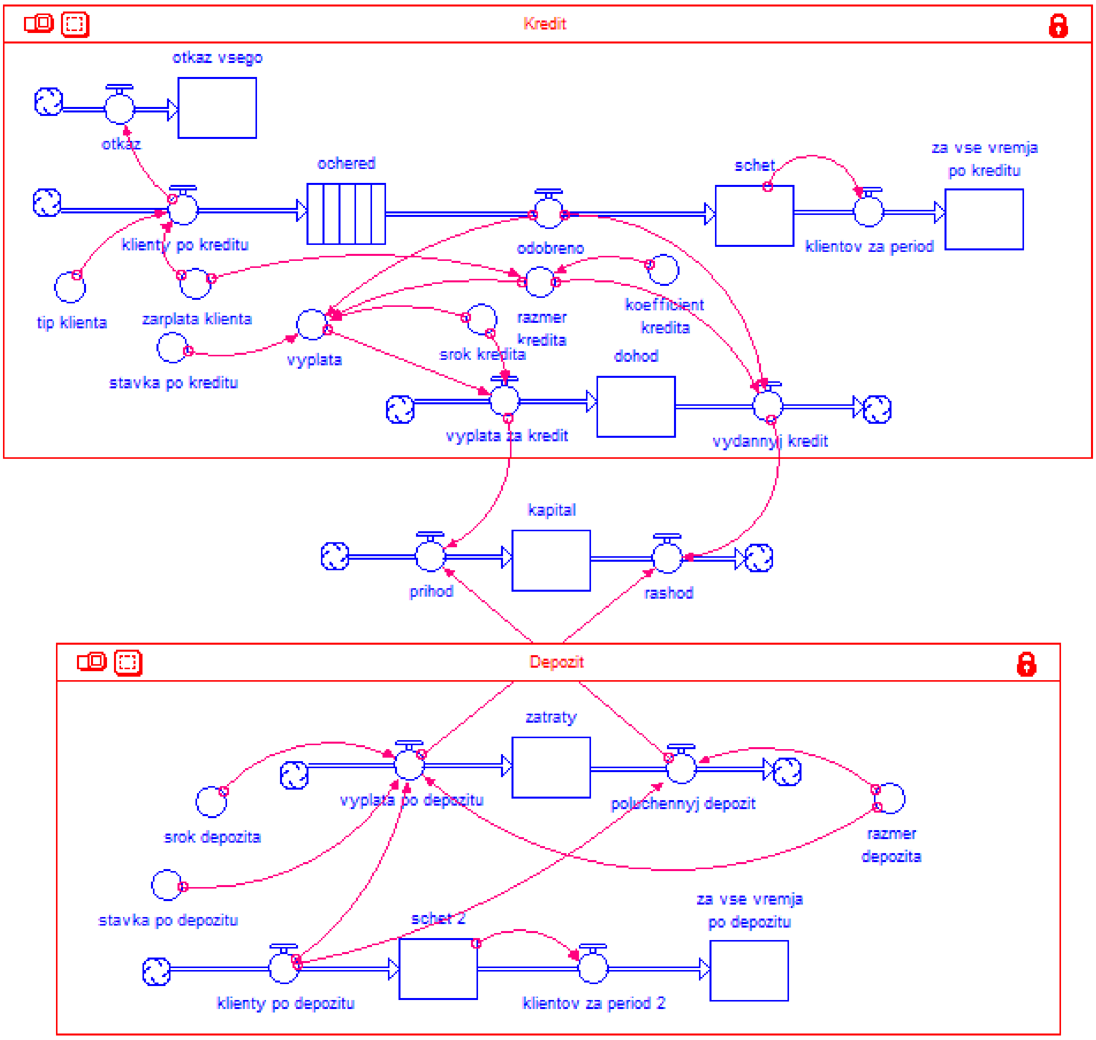

Fig. 1. Model of commercial bank money flows circulation (fragment)

Table 1. Simulating model variable components

Variable's name within model	Variable's representation	Variable value either calculation algorithm	Purpose
Section «Credit activity»			
klienty po kreditu	Flow	if tip_klienta=1 and zarplata_klienta >=2200 then pulse(1,0,10) else 0	Clients' arrival to bank, potential borrowers selection with respect to criteria
tip klienta	Converter	montecarlo(35)	Indicator of client's payroll account availability
zarplata klienta	Converter	random(1000,5000)	Random-value generated client's salary cipher
otkaz	Flow	if klienty_po_kreditu=0 then pulse(1,0,10) else 0	Collecting data on clients in default for crediting
otkaz vsego	Reservoir	0	Total number of clients in default for crediting
ochered	Конвейєр	0	Forming the clients' queue
odobreno	Flow	1	Collecting data on clients confirmed able for crediting
koefficient kredita	Converter	round(random(3,10))	{Multiplying coefficient * salary} characterising the scale of the requested credit sum exceeding the salary

Table 1 Continuation

razmer kredita	Converter	random(3500,zarplata_klienta *koefficient_kredita)	Defining the requested credit amount
stavka po kreditu	Converter	0.02	Credit interest rate established by the bank
srok kredita	Converter	24	Credit payment term established by the bank
vyplata	Converter	-pmt(stavka_po_kreditu, srok_kredita,razmer_kredita,0)*odobreno	Calculating monthly repayments to the bank
schet	Reservoir	0	Summarising the clients number serviced within one model-assigned time period
klientov za period	Flow	if mod(time(),24)=0 then schet else 0	Summarising the clients number serviced within a selected time period
za vse vremja po kreditu	Reservoir	0	Summarising the clients number serviced over whole system operation period
vyplata za kredit	Flow	vyplata*srok_kredita	Sum payable by the client during whole credited period
vydannyj kredit	Flow	odobreno*razmer_kredita	Amount credited to the client
dohod	Reservoir	0	Amount of bank income from the credited sum
Section «Deposit activity»			
klienty po depozitu	Flow	pulse(1,24,120)	Clients' arrival to bank, proceeding to deposit formalities
schet 2	Reservoir	0	Collecting data on clients having effected the deposit
klientov za period 2	Flow	if mod(time(),24)=0 then schet_2 else 0	Random-value generated client's salary cipher
za vse vremja po depozitu	Reservoir	0	Summarising the clients number serviced over whole system operation period
razmer depozita	Converter	random(1000,70000)	Amount deposited by the client
srok depozita	Converter	12	Deposit term
stavka po depozitu	Converter	0.015	Deposit interest rate
vyplata po depozitu	Flow	klienty_po_depozitu*razmer_ depozita*(1+srok_depozita*st avka_po_depozitu)	Sum payable by the bank during whole deposit period
poluchennyj depozit	Flow	klienty_po_depozitu*razmer_ depozita	Deposited amount
zatraty	Reservoir	0	Bank expenses during the deposit term
Section «Cash flows»			
prihod	Flow	vyplata_za_kredit+ poluchennyj_depozit	Clients' arrival to bank, proceeding to deposit formalities
rashod	Flow	vydannyj_kredit+ vyplata_po_depozitu	Collecting data on clients having effected the deposit
kapital	Reservoir	50000	Bank's initial capital

The use of models for the commercial bank activity analysis is aimed onto familiarizing with the activities of commercial banks from the comprehensive analysis viewpoint that allows studying the core business areas of its operation on the basis of key economic indicators.

Departing from a comprehensive analysis we can evaluate the bank capital dependence from such variable values as the interest rates on loans / deposit, the credit / deposit term, amount of credit / deposit etc.

The simulation model can be considered in the dynamics of parameters («kapital», «dohod» and «zatraty»), as the commercial banks' CEO and managers need to be acknowledged with «dynamics shot» and comparative dynamics of income and expenses affecting the overall capital level. The model includes main indicators of a typical commercial bank activity:

— Credit monthly rates 2%;
— Credit term: 24 months;
— Deposit monthly rate 1,5%;

— Deposit term: 12 months;
— Initial capital amount: 50000 UAH.

Further we shall consider some of the simulation experiments results using the model.

Fig. 2 and Table 2 are presenting the bank basic cash flows' dynamics.

Selected simulation term: one month, selected simulation step: one day.

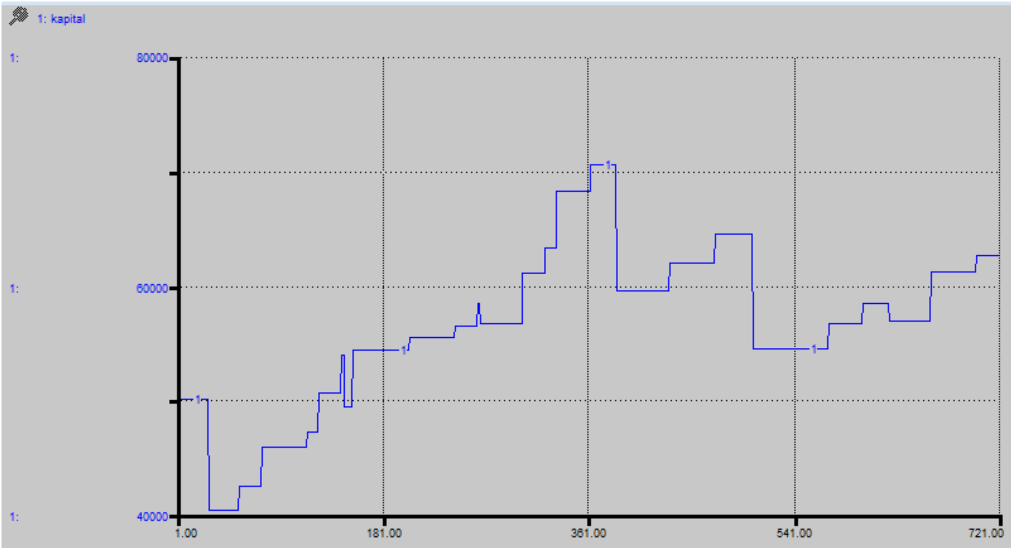

Fig. 2. Commercial bank capital dynamics

Table 2. Dynamics of the bank basic cash flows

Hours	vydannyj kredit	vyplata za kredit	dohod	vyplata po depoz	poluchennyj depo	zatraty	prihod	rashod	kapital
Initial			0,00			0,00			50†000,00
24	0,00	0,00	0,00	63†808,65	54†075,12	9†733,52	54†075,12	63†808,65	40†266,48
48	0,00	0,00	0,00	0,00	0,00	9†733,52	0,00	0,00	40†266,48
72	20†762,92	26†346,20	5†583,28	0,00	0,00	9†733,52	26†346,20	20†762,92	45†849,76
96	0,00	0,00	5†583,28	0,00	0,00	9†733,52	0,00	0,00	45†849,76
120	4†608,23	5†847,41	6†822,46	0,00	0,00	9†733,52	5†847,41	4†608,23	47†088,94
144	25†238,43	32†025,20	13†609,23	29†499,55	24†999,62	14†233,45	57†024,81	54†737,97	49†375,78
168	18†454,35	23†416,84	18†571,72	0,00	0,00	14†233,45	23†416,84	18†454,35	54†338,27
192	0,00	0,00	18†571,72	0,00	0,00	14†233,45	0,00	0,00	54†338,27
216	4†197,23	5†325,89	19†700,39	0,00	0,00	14†233,45	5†325,89	4†197,23	55†466,93
240	0,00	0,00	19†700,39	0,00	0,00	14†233,45	0,00	0,00	55†466,93
264	10†878,76	13†804,12	22†625,75	11†295,84	9†572,74	15†956,55	23†376,87	22†174,59	56†669,21
288	0,00	0,00	22†625,75	0,00	0,00	15†956,55	0,00	0,00	56†669,21
312	16†384,65	20†790,59	27†031,69	0,00	0,00	15†956,55	20†790,59	16†384,65	61†075,14
336	26†732,84	33†921,47	34†220,32	0,00	0,00	15†956,55	33†921,47	26†732,84	68†263,77
360	0,00	0,00	34†220,32	0,00	0,00	15†956,55	0,00	0,00	68†263,77
384	8†618,32	10†935,84	36†537,84	72†429,00	61†380,51	27†005,04	72†316,35	81†047,32	59†532,80
408	0,00	0,00	36†537,84	0,00	0,00	27†005,04	0,00	0,00	59†532,80
432	9†076,67	11†517,44	38†978,61	0,00	0,00	27†005,04	11†517,44	9†076,67	61†973,57
456	0,00	0,00	38†978,61	0,00	0,00	27†005,04	0,00	0,00	61†973,57
480	9†498,28	12†052,43	41†532,76	0,00	0,00	27†005,04	12†052,43	9†498,28	64†527,72
504	0,00	0,00	41†532,76	65†962,11	55†900,09	37†067,06	55†900,09	65†962,11	54†465,71
528	0,00	0,00	41†532,76	0,00	0,00	37†067,06	0,00	0,00	54†465,71
552	0,00	0,00	41†532,76	0,00	0,00	37†067,06	0,00	0,00	54†465,71
576	7†941,21	10†076,66	43†668,20	0,00	0,00	37†067,06	10†076,66	7†941,21	56†601,15
600	0,00	0,00	43†668,20	0,00	0,00	37†067,06	0,00	0,00	56†601,15
624	6†647,31	8†434,81	45†455,71	9†589,95	8†127,08	38†529,93	16†561,88	16†237,26	56†925,78
648	0,00	0,00	45†455,71	0,00	0,00	38†529,93	0,00	0,00	56†925,78
672	15†832,74	20†090,27	49†713,23	0,00	0,00	38†529,93	20†090,27	15†832,74	61†183,30
696	0,00	0,00	49†713,23	0,00	0,00	38†529,93	0,00	0,00	61†183,30
720	5†373,29	6†818,20	51†158,14	0,00	0,00	38†529,93	6†818,20	5†373,29	62†628,21

Here we shall illustrate the analytical conclusions that can be determined using system dynamics model, at the example of Raiffeisen Bank Aval commercial bank's branch.

Investigated are the processes of natural persons' credit and deposit filing as well as the impact of these processes' economic constants onto the income and expenses levels. The economic constants applied are: the credit monthly rate, the credit term, the deposit monthly rate, the deposit term, the borrowers' arrival intensity, the investors' arrival intensity. Variations of experiments' conditions are exposed at Table 3.

Table 3. Experimental conditions

Constant	Experiment I	Experiment II	Experiment III	Experiment IV
Credit monthly rate	2%	2,5%	3%	3,5%
Credit term	12	24	36	48
Deposit monthly rate	1%	1,25%	1,5%	1,75%
Deposit term	24	12	9	6
Borrowers' arrival intensity	2 persons daily	1 person daily	1 person per 2 days	1 person per 3 days
Investors' arrival intensity	1 person per 9 days	1 person per 6 days	1 person per 4 days	1 person per 3 days

The imitation term: one year, the simulation step: one month.

Fig. 3 represents the dynamics of the bank branch capital amount and the experiment conditions.

As shown at Fig. 3, the conditions of the experiment are worsening the commercial bank situation, periodically completely exhausting its capital level. The income from credit interests is insufficient even for costs overriding, and sure the profit is negative. Thus, under such conditions the bank goes bankrupt.

Fig. 4 represents the dynamics of the bank branch capital amount under conditions of experiment II.

As shown at Fig. 4, the second experiment condition are more favorable that these of I experiment, but they also decrease the situation of commercial banks and nearly exhaust its capital level. The income from credit interests does not cover costs, the bank is incurring losses.

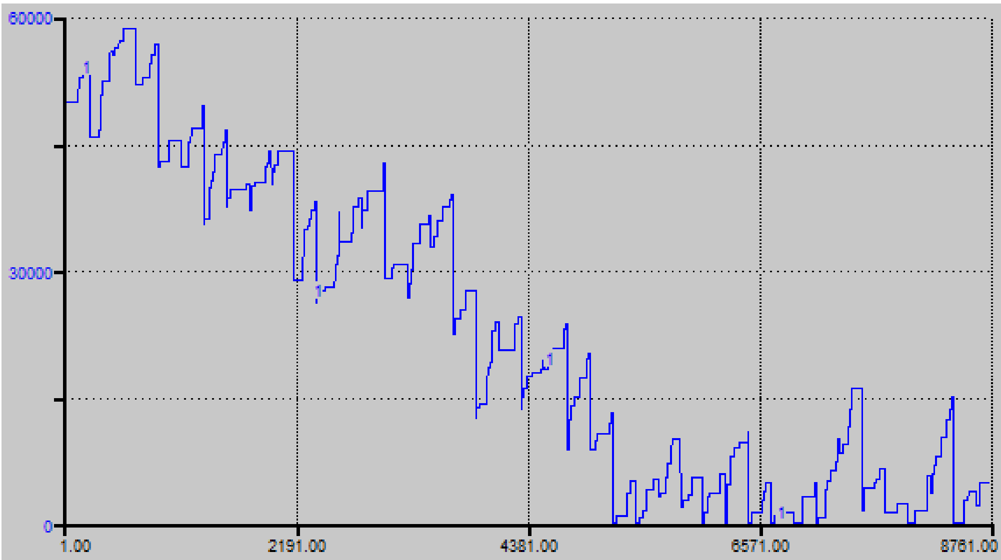

Fig. 3. Experiment I

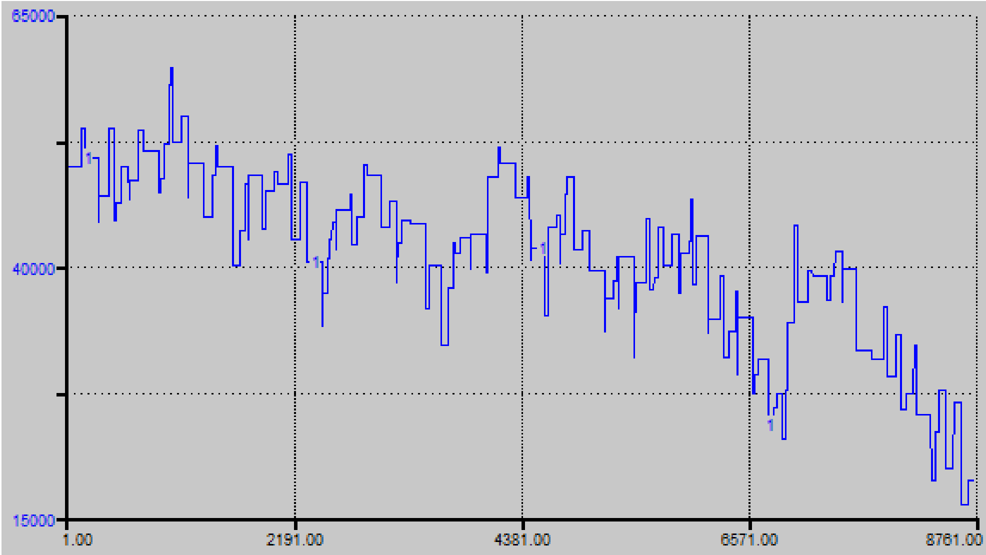

Fig. 4. Experiment II

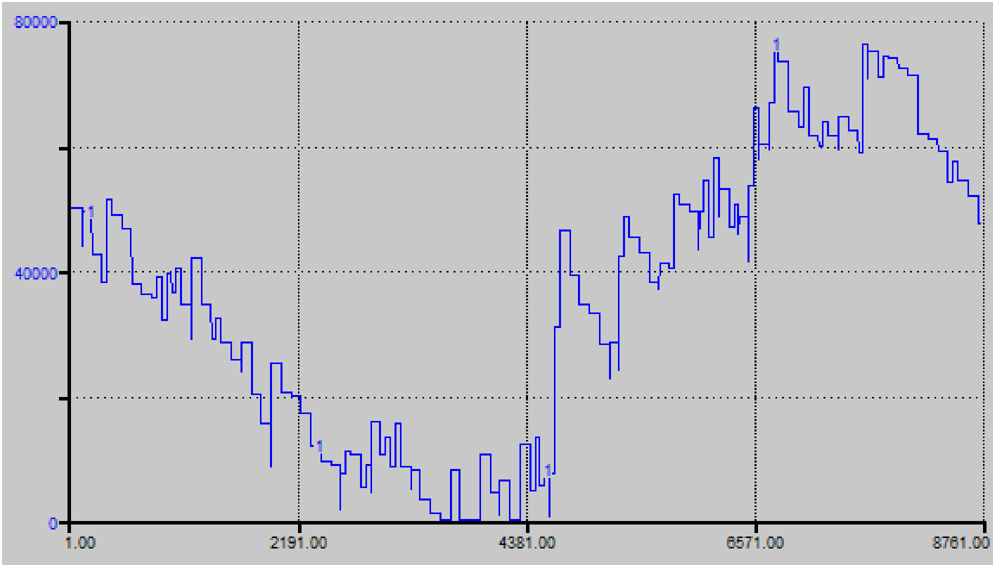

Fig. 5. Experiment III

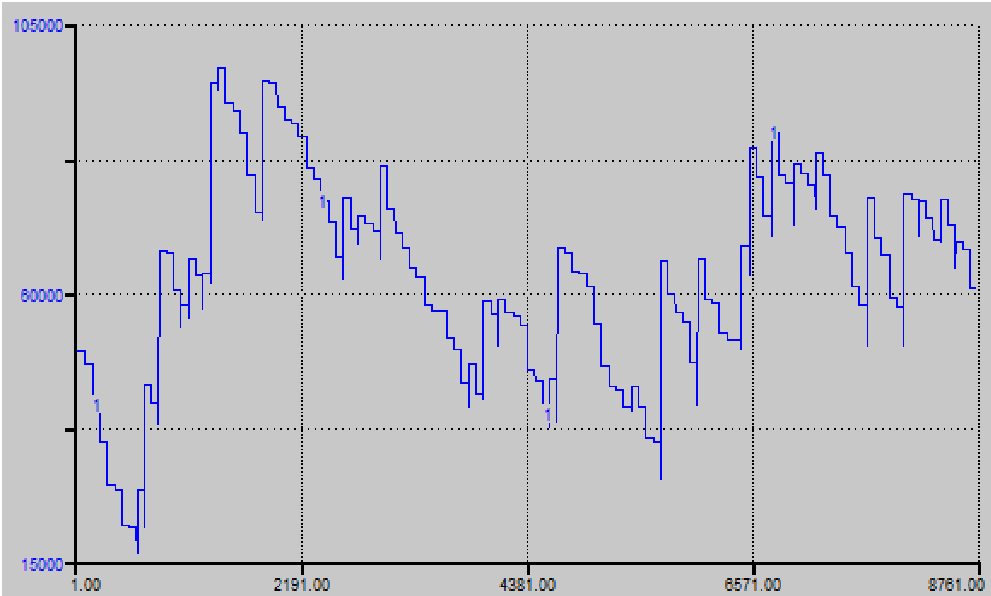

Fig. 6. Experiment IV

Table 4. Bank cashflows

Hours	dohod	vyplata po depoz	poluchennyj depo	zatraty	prihod	rashod	kapital
Initial	0,00			0,00			50†000,00
720	34†727,40	455†305,51	412†041,18	43†264,32	478†962,04	487†498,96	41†463,08
1440	120†893,65	377†302,04	341†449,81	79†116,55	507†495,04	457†181,02	91†777,10
2160	144†336,33	304†475,79	275†543,70	108†048,64	320†718,51	326†207,92	86†287,68
2880	162†560,43	357†792,99	323†794,56	142†047,07	358†913,02	374†687,34	70†513,36
3600	178†033,31	353†502,93	319†912,15	175†637,85	349†728,90	367†846,80	52†395,46
4320	209†735,50	313†172,85	283†414,35	205†396,35	344†505,53	342†561,84	54†339,15
5040	247†378,73	391†151,87	353†983,59	242†564,63	426†523,33	426†048,39	54†814,09
5760	288†083,54	377†280,64	341†430,44	278†414,83	419†869,96	415†015,35	59†668,71
6480	312†737,48	356†016,05	322†186,47	312†244,41	369†695,45	378†871,08	50†493,08
7200	379†141,93	451†691,33	408†770,44	355†165,30	536†734,01	513†250,46	73†976,63
7920	413†727,41	519†520,71	470†154,49	404†531,52	536†801,85	551†582,60	59†195,88
8640	457†130,22	372†240,23	336†868,99	439†902,77	420†507,66	412†476,08	67†227,45

Fig. 5 shows the dynamics of the bank branch capital amount under the conditions of experiment III.

As we reveal from Fig. 5, the position of the bank, third experiment running, has been improved at the year end, the level of capital having raised. However, we must pay attention to the rapid decline and depletion of capital in the middle of the year. That does mean the unstable overall position of the bank, so we can expect high expenses and low incomes. Thus, the third experiment conditions are quite unreliable and controversial.

Fig. 6 shows the dynamics of the bank branch capital amount under the conditions of experiment IV.

As Figure 6, demonstrates, the fourth experiment conditions improve the bank's situation and regularly raise the level of capital. The Income from credit interest are enough to reach a profit. The model includes periodical decrease of capital, but that effect does not interfere with profitability. Under such conditions, the bank will reach prosperity.

The scheme of the bank's total cash flow under the IV experiment is presented at the Table 4.

Conclusions and perspectives

The methods of simulation, implemented with Ithink, allow assessment of the bank's activity directed at improving the quality and increasing the loan portfolio size. A simulative model provides possibility to predict the bank operation dynamics at any time perspective, drawing conclusions about its efficiency. Accordingly, it becomes possible to evaluate the effectiveness of the entered values for interest rates on credits and deposits, term of credits and deposits repayment and other variables used. The main advantage here is this model's training character, its openness and modular structure that allows every commercial bank to adjust the simulative modeling process to its own circumstances.

The developed experimental basis proved significant opportunities for decision-makers in the field of crediting and credit policy general elaboration, through preliminary «running-in» the possible situations, with prediction of the managerial decisions' implementation consequences.

The article exposes only some of the computer-aided simulation possibilities to assess the overall credit and deposit policy of the banks. The chosen system dynamics method specificity is aimed at creating models for the considered object's future strategic development as well as at studying various financial market situations. The next step supposed in that field relates to using the agent-based simulation on modern platforms like, e.g. the Anylogic [4, 11, 12].

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