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MULTI AGENT SIMULATION OF SUSTAINABLE DEVELOPMENT SCENARIOS.

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INTRODUCTION

In this work we consider a new approach to the system dynamics modeling [1]. The work is aimed on fostering the implementation of a new Adaptive Balance of Causes (ABC) method for complex systems modeling, suggested in [2] and a new multi agent information technology for system management, developed in [7,8]. We introduce our methods in a form of brief general description with application to the natural resources management problem, which plays extremely important role in the sustainable development of socio-economic systems. There are no simple solutions to the associated practical tasks due to the complex interaction of huge amount of various factors: economic, social, ecological, political and others, influencing the decision making on natural resources use. One of them could be simulation and analysis of possible development scenarios by a proposed ABC method for complex systems modeling. Another ones could be intelligent agents-systems that can decide what to do and do it. Simulation ABC AGENT technology, discussed in this paper, was constructed on these tools and could be used for solving the problem of rational natural resources consumption. It enables the evaluation of an industry economic benefits taking into account the costs of common pool resources for their private use. In fact we have suggested a new system management approach which enable to solve any complex system management problem in three main steps:

1. Concept management model construction by the use of 6 general system concepts, derived from the system analysis method [3,5]
2. Concept model formalization by a new Adaptive Balance of Causes (or ABC) method. This method makes it possible to use a standard module equation to obtain a set of equations being stable by the definition for any complex system. Dynamic and stochastic methods for objective model coefficients determination were suggested also [2,3].
3. Creation of an information technology for decision making support by the use of the formal ABC case study model and a new standard “resources market-enterprise-goods market” model based on intelligent agents (ABC AGENT model) [2,7,8]

All these steps were developed in details, mathematically grounded and verificated in numerous simulation case studies, published in our reference works. We don’t give any other references because our approach differs significantly from other publications we are acquianted with. We believe that our approach is an advanced one because from the very beginning we have being searched for a simple but effective and robust technology of a complex system management.

1. CONCEPT MANAGEMENT MODEL CONSTRUCTION

Main concepts of the system analysis to be exploit in a concept management model construction could be derived from the general system approach theory [2,3]. We summarized them in Table I.

Table 1. Main concepts of system analysis and their applications.

System analysis concepts	**Applications**
1. Relativity of development goals	Adaptation of goals to the existing development resources
2. Integrity of controllable system	Introducing the state-variable vector and main elements (modules) of the system structure
3. Casuality	Definition of the system inner structure
4. Subordination	Definition of the system position in hierarchy of different time/space scales systems
5. Dynamic balance	Construction of the system development scenarios as the result of external influences on it
6. Information unity	Adaptation of development scenarios to the observed information about the system state.

One of the main system analysis conceptions about decomposition of a complex system on relatively independent modules could be accomplished with the use of intelligent agents [8]. We shall call them simply “agents” keeping in mind their abilities to receive and process information and to execute prescribed them actions. General diagram of simulation ABC AGENT technology is presented in fig.1.

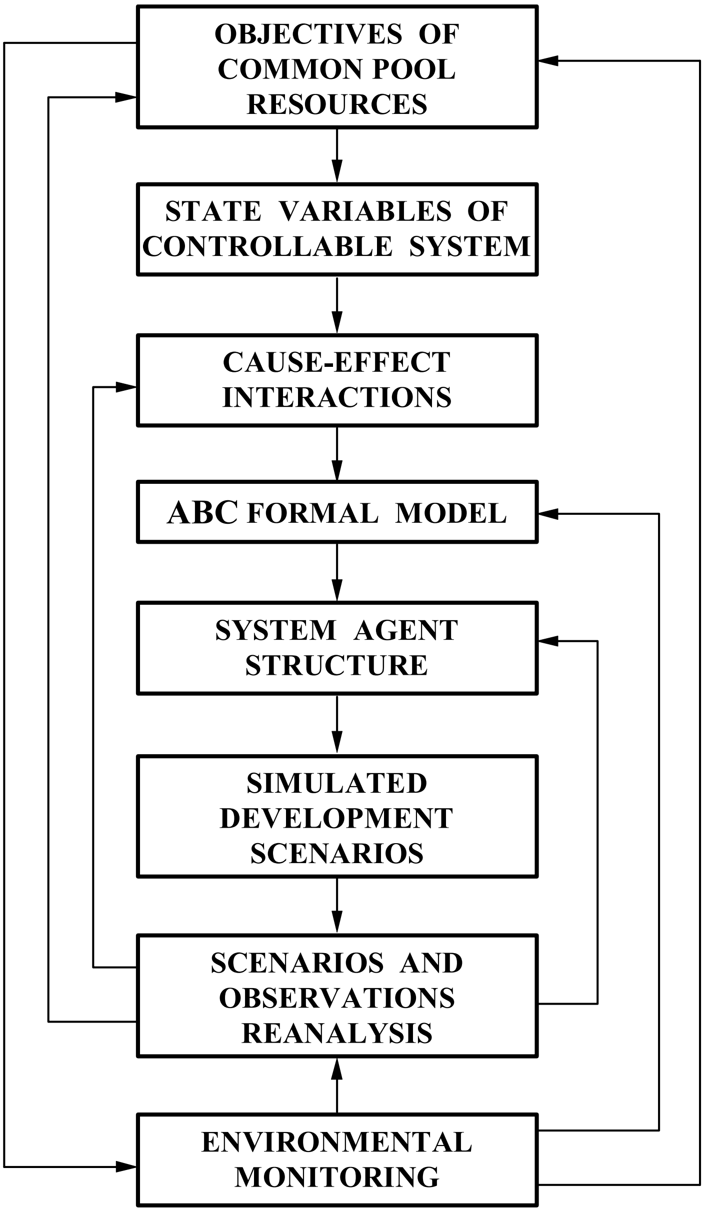

Fig. 1. General diagram of ABC agent simulation technology.

Objectives of common pool resources management generate a state variable vector of controllable system. This vector and cause-effect linkages between its components form the system model structure. Simulated development scenarios serve to make decisions about the ways of resources use and reanalysis procedure helps the model coefficients current identifications.

Simulation technology for natural resources management, that has to be constructed, forms several relatively separated multi agent models. The connection between them is shown in fig.2. and presents another one example of concept management model

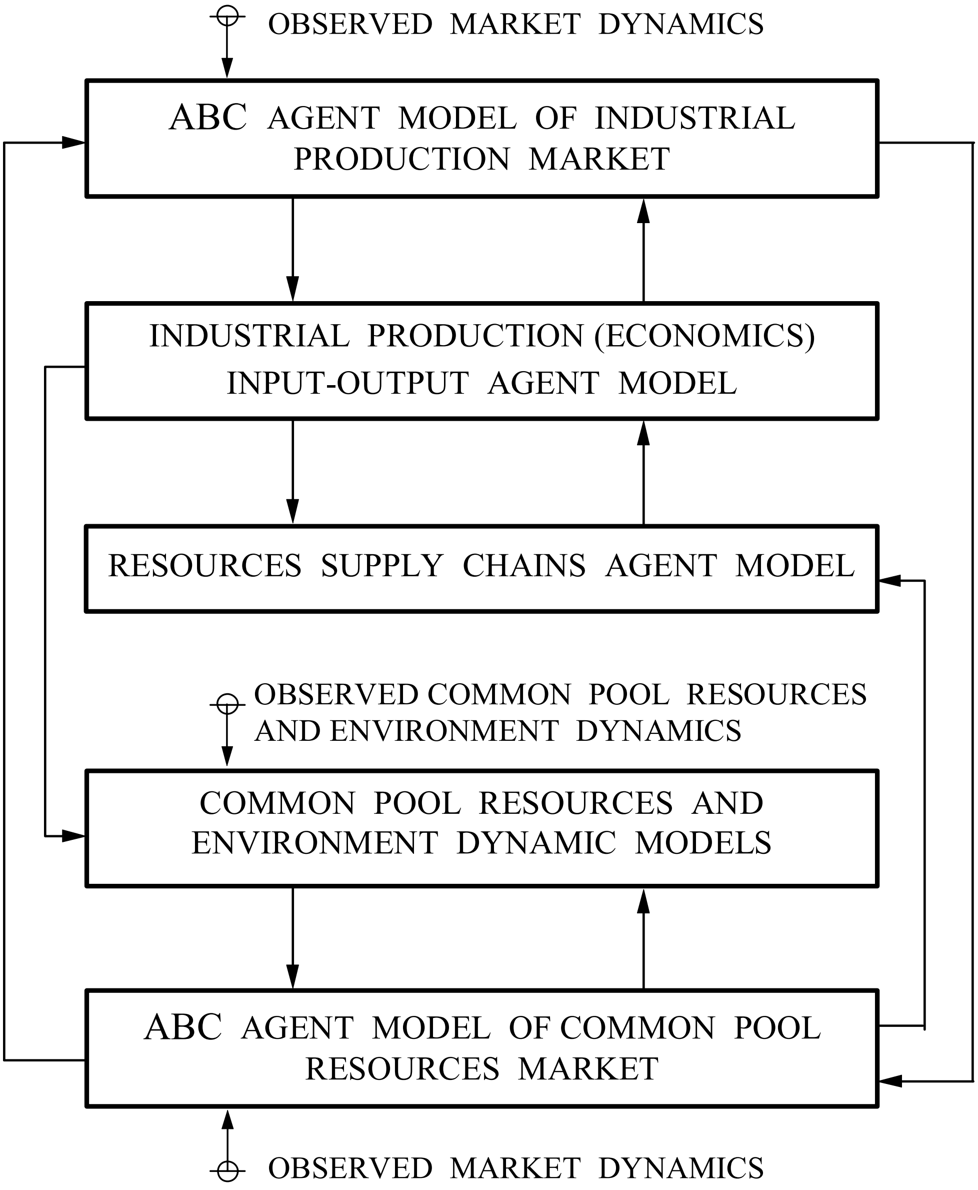

Fig. 2. Simulation models of ABC agent technology.

Two ABC agent models are used to be controlling the changing situations on production and resources markets. These market conditions define the profitability of an industrial production object, which input-output manufacturing agent model should be included in a general technology. Resources supply chains play an important role in industrial production and for all of them an agent model is to be presented also. Observations of common pool resources and environmental dynamics are necessary to ensure the environmental monitoring. If the information required is insufficient, appropriate dynamic models could be used to represent the possible environmental changes.

By the use of 6 system analysis concepts we have developed many different concept management models [2]. For instance, every ecological-economic system expresses general balance between economic profitability and ecological rationality of natural resources consumption.

An example of a concept model of ecological-economic system is shown in fig. 3

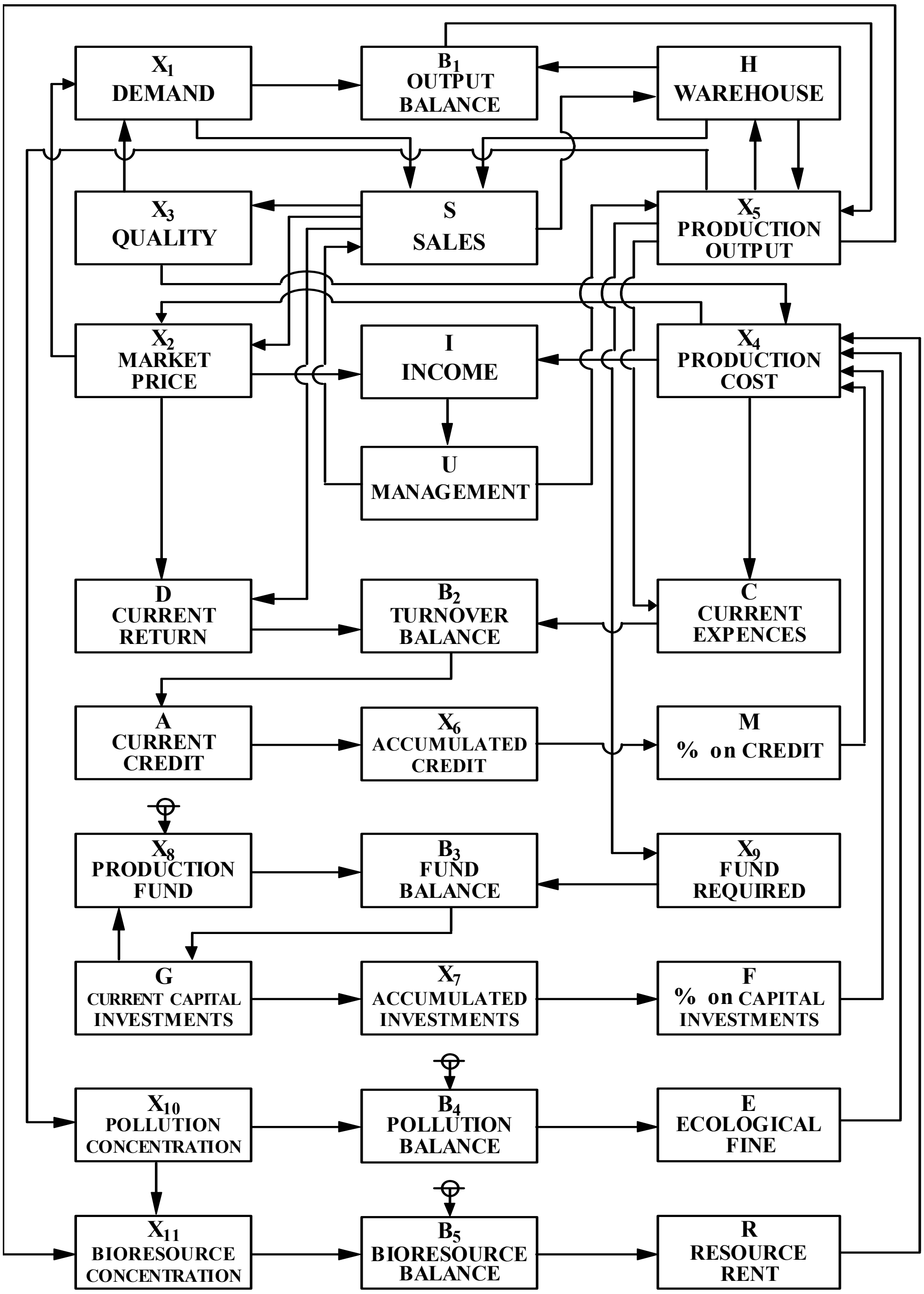

Fig. 3. Concept model of an ecological economics system.

Note, that in a contrast with the usial stocks and flows diagram used in traditional system dynamics approach [1] this scheme contains only system modules and influence linkages connecting them. That's enough for ABC modeling as it be explained in the next section.

2. ABC METHOD FOR COMPLEX SYSTEMS MODELLING.

2.1. ABC method's principles.

Consider a simple dynamic system with a scalar state variable x. Adaptive Balance of Causes (ABC) method declares that any system being in a balance condition has two equal and opposite directed development tendencies. Therefore its convergence to the stable balance state could be described by the following equation [2]

$$dx/dt = x F^{(-)}(x) - x F^{(+)}(x) \qquad (1)$$

Rate of value x change is under influences of two feed backs, controlling by functions: $F^{(-)}(x)$ and $F^{(+)}(x)$, which we shall call basic cause functions. Any influence on the system equally allocates to both of them, amplifying one and weakening another. It allows for to introduce condition (2) and to use equation (3) instead of (1)

$$F^{(-)}(x) + F^{(+)}(x) = 1. \qquad (2)$$

$$dx/dt = x\,[1 - 2F^{(+)}(x)]. \qquad (3)$$

Putting into operation finite difference $\Delta x = x_k - x_j$ on a small time interval $\tau = t_k - t_j$ (which one can always assume as $\tau = 1$), we came to the discrete form of main ABC model equation

$$x_k = 2x_j\,[1 - F^{(+)}(x_j)]. \qquad (4)$$

If we choose the most simple linear representation (5) and (6) for basic cause functions, equation (4) became (7)

$$F^{(-)}(x) = 1 - ax + b, \qquad (5)$$

$$F^{(+)}(x) = ax + b. \qquad (6)$$

$$x_k = 2x_j\,(1 - b - ax_j). \qquad (7)$$

Coefficients a and b are used to establish balance state x^* and to make an appropriate scaling.

ABC method assumes that any external influence on a module should be accounted for by an appropriate addition to the module basic cause function argument $F^{(+)}(x_j)$ [2]. To illustrate this notion let us consider a simple 3-elements system, which has applications in biological and economic systems modeling [8]. Cause-effect diagram of the system is shown in fig.4 and ABC model equations are

$$\begin{aligned} x_{1k} &= 2x_{1j}\,(1 - c_1(x_{1j} - a_{12}x_{2j} + a_{13}x_{3j} - f_{1j})),\\ x_{2k} &= 2x_{2j}\,(1 - c_2(x_{2j} - a_{21}x_{1j} + a_{23}x_{3j} - f_{2j})), \qquad (8)\\ x_{3k} &= 2x_{3j}\,(1 - c_3(x_{3j} + a_{31}x_{1j} + a_{32}x_{2j} - f_{3j})), \end{aligned}$$

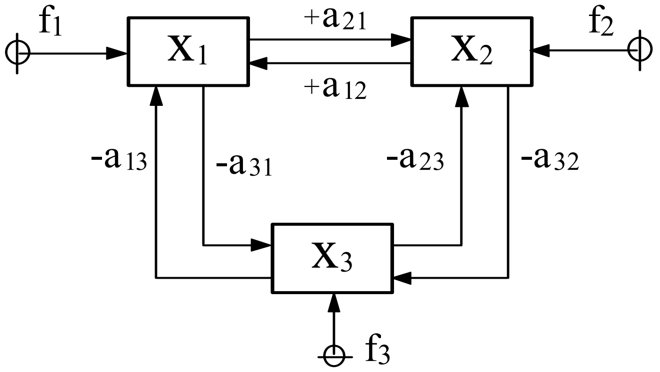

Fig. 4. Cause-effect diagram for simple ecosystem model.

2.2. Stochastic determination of ABC model's coefficients.

Monitoring the external forcing and watching the model response on it under some time interval, one can identify the ABC model coefficients. To accomplish this operation the Kolmogorov's optimal interpolation equations may be used [3]. This set of equations is based on a covariance matrix accounting statistical linkages between the model development scenarios and external forcing. Calculating of coefficients determines the model cause functions and ensures the minimal inclination of model scenarios from reality. Let us introduce correlation coefficients $D_{12}=M[x_1x_2]$ and $G_{12}=M[x_1f_2]$. Then from Kolmogorov's equations we obtain [2]

$$a_{12} = (D_{12} - G_{21} - D_{23} D_{13} + D_{23} G_{31}) / (1 - D_{23}^2), \qquad (9)$$

$$a_{13} = (D_{13} - G_{31} - D_{23} D_{12} + D_{23} G_{21}) / (1 - D_{23}^2).$$

The analogous formulae could be easily derived for other cause function coefficients in the model (8).

In order to study the procedure of coefficient's determination in this ABC model simulation experiments were made (see an examples in fig. 5)

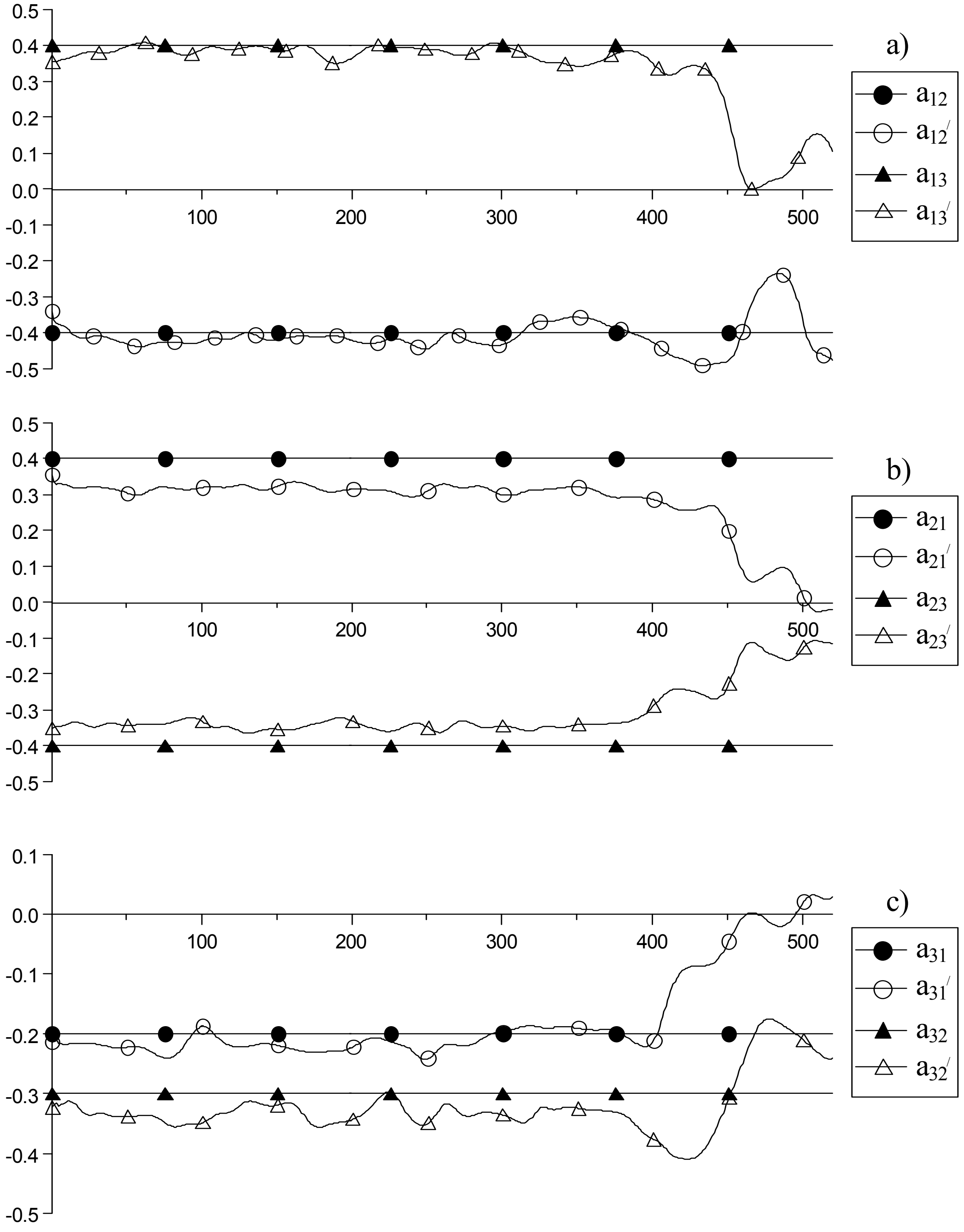

Fig. 5. Identification of influence coefficients for ecosystem model (8).

Coefficients were identified at each time step of simulation run. The results shown in fig.5 a,b,c could be compared with the real constant coefficients presented there also. Calculated coefficients were located very close to the real ones except the end areas of simulation runs, where the accuracy of evaluated covariance matrixes became insufficient. After identification the model was used to reconstruct each of x_i scenarios from equations (8). These results were presented in fig.6 a,b,c together with the known original scenarios. Reproduction accuracy was happen to be rather high during the almost all simulation time interval.

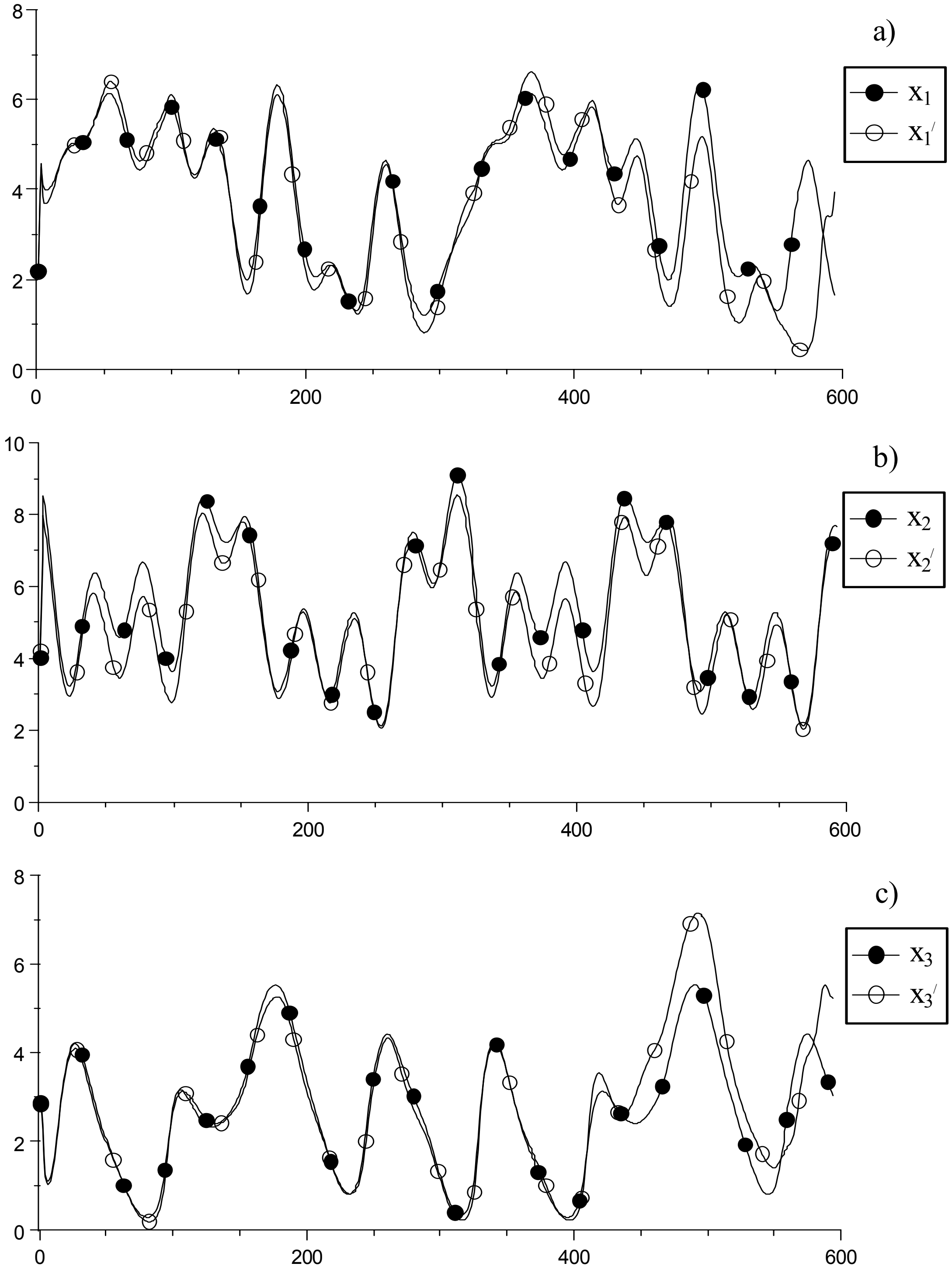

Fig.6. Reconstruction of development scenarios in the system: x_1, x_2, x_3 - under known influence coefficients; $x_1^{/}$, $x_2^{/}$, $x_3^{/}$ - under identified influence coefficients.

3.CREATION OF AN INFORMATION TECHNOLOGY FOR DECISION MAKING SUPPORT BY THE USE OF FORMAL ABC AGENT MODEL.

3.1 Agent model of industrial production.

Demand and sales rates drive the input of industrial production providing output positive profitability. Circulating capital is currently complimented (when it is necessary) with the current credit to support its value on certain level for baying all the various resources required. If the income grow is sufficient to avoid a total accumulated credit limitation, then the manufacture makes environmental and other resources consumption in an accordance with the current resources prices. If the accumulating credit reaches a definite threshold level, current credit is ceased and production output should be cancelled. Agents controlling industrial production model have functions of goods management, output volume planning, circulating capital distribution, accumulate credit evaluation and others. Formal algorithms for these agents could be introduced as follows.

Let us assume that one unit of industrial production (good) contains y_1 amount of economic resources (raw materials, energy, work force and others), y_2 – of natural resources (mineral or biological resources) and y_3 – of ecological resources (environmental ability to resist to the pollution contamination, to destroy them and others). Current circulating capital of an industrial object is used to be allocated to purchasing of each kind of the resources in the same proportion.

Let us designate as H_k – current volume of ready for sale production, $H_1{}^i{}_k$ - current amount of y_i resource spared in the object's warehouse, H_{2k} - current circulating capital and H_{3k} - current value of accumulated credit received by the object. All these values have a general dynamic equation of the same form as for goods spare at the sale floor

$$H_k = H_j + V_k - S_k, \tag{10}$$

where V_k - coming in and S_k – coming out amounts of goods at the time interval from moment j to moment k.

The agent making functions of a sales manager could be presented by equations

$$\begin{aligned} &S_k = \mathrm{IF}\ (N_k < 0;\ 0;\ R),\\ &R_k = \mathrm{IF}\ (D_k < H_j;\ D_k;\ H_j),\\ &N_k = x_{2k} - x_{4k}, \end{aligned} \tag{11}$$

where D_k – current demand on the good, x_{2k} - market price and x_{4k} – production cost of it. The agent which is controlling the production output will take the following actions

$$\begin{aligned} &V_k = \mathrm{IF}\ (D_k < H_j;\ 0;\ M_{1k}),\\ &M_{1k} = \mathrm{IF}\ (D_k - H_j < M_j;\ D_k - H_j;\ M_j),\\ &M_j = \min\ (m_{1j}{}^1;\ m_{1j}{}^2;\ m_{1j}{}^3),\\ &m_{1j}{}^i = H_1{}^i{}_j / y_i,\ \ i = 1, 2, 3. \end{aligned} \tag{12}$$

$$\begin{aligned} &I_k = \mathrm{IF}\ ((P_k - E_k) < 0;\ 0;\ P_k - E_k),\\ &P_k = x'_{2k}\, S_k,\\ &E_k = x'_{4k}\, V_k, \end{aligned} \tag{13}$$

where $m_{1j}{}^i$ - minimal resource spare limiting the production output.

3.2. Agent model of resources supply chain.

Resources spare, which has every industrial object, could be presented as balances between coming and spending amounts. Expenditures for each kind of them are proportional to the object's output. If the current resources amounts are sufficient to supply the planning output there is no need to bay them. In the opposite case some amounts of insufficient natural and economic resources should be purchased. The controlling functions on current circulating capital are used to be made by an agent

$$\begin{aligned} H_{2k} &= H_{2j} + I_{0k} - S_{3k}, \\ S_{3k} &= \mathrm{IF}\ (H_{3j}\,\theta < H_{2j};\ H_{3j}\,\theta;\ H_{2j}), \end{aligned}$$

where θ is the accumulated credit pay off interest.

Let it be$V_{1\,k}^{\,1}$, $V_{1\,k}^{\,2}$ и $V_{1\,k}^{\,3}$ – volumes of resources which are to be purchased for credits. Then total amount of current credit will be

$$V_{3k} = p'_{1k}\,V_{1\,k}^{\,1} + p'_{2k}\,V_{1\,k}^{\,2} + p'_{3k}\,V_{1\,k}^{\,3},$$

and for accumulated credit we shall have

$$H_{3k} = H_{3j} + V_{3k} - S_{3k}.$$

Analogous balance equation takes place for the object's resources spare

$$H_{1\,k}^{\,i} = H_{1\,j}^{\,i} + V_{1\,k}^{\,i} - S_{1\,k}^{\,i}.$$

Each kind of resources spending is proportional to the industrial output volume

$$S_{1\,k}^{\,i} = V_k\,y_i.$$

Supply chain agents determine which amount $F_{1\,k}^{\,i}$ of insufficient resource should be purchased

$$\begin{aligned} V_{1\,k}^{\,i} &= \mathrm{IF}\ ((D_k - Hj)y_i < H_{1\,j}^{\,i}\ ;\ 0\ ;\ F_{1\,k}^{\,i}), \\ F_{1\,k}^{\,i} &= \mathrm{IF}\ (p'^{\,i}_{j}\,(y_i\,D_k - H_{1\,j}^{\,i}) < \rho_i\,H_{2j};\ y_i\,D_k - H_{1\,j}^{\,i}\ ;\ R_{1\,k}^{\,i}), \\ \rho_{i\,k} &= p'_{ik}\,y_i\,[p'_{1k}\,y_1 + p'_{2k}\,y_2 + p'_{3k}\,y_3]^{-1},\quad i = 1,2,3, \end{aligned} \tag{14}$$

where p'_{ik} are prices on resources markets.

Another one agent $R_{1\,k}^{\,i}$ is watching for total amount of accumulated credit H_{3k} and rejecting the letting of a new credits after some limited level $\rho_i H_3^{*}$. The equations for $R_{1\,k}^{\,i}$ could be find in [8].

3.3. ABC-Agent models of resources and goods markets.

Let us consider a simplified ABC agent resource market model, which is analogous on the cause-effect interactions with those were shown in fig.4. Then ABC model equations may be written in form

$$\begin{aligned} p^i_k &= 2\,p^i_j\,(1 - c_1\,(p^i_j + a^i_{1t}\,t^i_j - a^i_{1q}\,q^i_j)), \\ t^i_k &= 2\,t^i_j\,(1 - c_2\,(t^i_j + a^i_{1q}\,q^i_j - a^i_{1p}\,p^i_j)), \\ q^i_k &= 2\,q^i_j\,(1 - c_3\,(q^i_j - a^i_{1t}\,t^i_j - a^i_{1q}\,p^i_j)). \end{aligned} \tag{15}$$

Here are p^i_k – prices on resources markets, t^i_k - volumes of resources supply, q^i_k - resources qualities.

ABC equations for goods market could be written as follows

$$\begin{aligned} D_k &= \mathrm{IF}\ (x_{3k} > x_3^{0}\ ;\ x_{1k}\ ;\ 0), \\ x_{1k} &= 2\,x_{1j}\,(1 - c_1\,(x_{1j} + a_{12}\,x_{2j} - a_{31}\,[1 - \exp \alpha_3\,x_{3j]})), \\ x_{2k} &= 2\,x_{2j}\,(1 - c_2\,(x_{2j} - a_{24}\,x_{4j} - a_{23}\,x_{3j})), \\ x_{3k} &= 2\,x_{3j}\,(1 - c_3\,(x_{3j} - a_{3\mu}\,\mu_j)), \\ x_{4k} &= 2\,x_{4j}\,(1 - c_4\,(x_{4j} - a_{4\eta}\,\eta_j)). \end{aligned} \tag{16}$$

$$\mu_o = \rho_1 q_{1j} + \rho_2 q_{2j} + \rho_3 q_{3j},$$

$$\eta_j = p_{1j}\, y_1 + p_{2j}\, y_2 + p_{3j}\, y_3.$$

where x_{1k} – demand on the production at the goods market, x_{2k} – price, x_{3k} – quality and x_{4k} – production cost of appropriate sale stuff. μ_o and η_j present integral estimates of resources quality and cost. Note that dimensional variables A' could be presented in non dimensional form A by the transform

$$A = 5\, A' \,(M\,[A'])^{-1} \qquad (17)$$

Both ABC market models are to be coupled with the AGENT models of industrial production and resources supply chain to form general ABC AGENT technology as it was shown in fig. 2

3.4. An example of ABC AGENT technology for ecological-economic system.

By the use of the ABC method presented above one can convert a concept model in the form of a set of dynamic equations. Any basic inlfuence functions meeting condition (2) could be used for this purpose. In reference work [2] exponential basic functions were used instead of linear ones. Formal equations of corresponding ABC dynamic model for concept model in fig. 3 were obtained as follows

$$\begin{aligned}
&X_{1j} = 2\, X_{1j} \exp(-a_{11} X_{1j} + a_{21} X_{2j} + a_{31} X_{3j});\\
&X_{2k} = 2\, X_{2j} \exp(-a_{22} X_{2j} + a_{42} X_{4j} + a_{s4} S_j);\\
&X_{3k} = 2\, X_{3j} \exp(-a_{33} X_{3j} + a_{s3} S_j);\\
&X_{4k} = 2\, X_{4j} \exp(-a_{44} X_{4j} + a_{64} X_{6j} + a_{74} X_{7j} +\\
&\qquad\qquad + a_{E4} E_j + a_{R4} R_j + a_{34} X_{3j}); \qquad (18)\\
&X_{5k} = 2\, X_{5j} \exp(-a_{55} X_{5j} + a_{U5} U_j X_{5j} + a_{B1\,5} B_{1j});\\
&X_{6k} = M_{06} X_{6j} + A_j;\\
&X_{7k} = F_{07} X_{7j} + G_j;\\
&X_{8k} = 2\, X_{8j} \exp(-a_{88} X_{8j} + a_{78} X_{7j} + a_{08} \exp(-c_{08}\, n\tau));\\
&X_{9k} = 2\, X_{9j} \exp(-a_{99} X_{9j} + a_{59} X_{5j});\\
&X_{10k} = 2\, X_{10j} \exp(-a_{10\,10} X_{10j} + a_{5\,10} X_{5j});\\
&X_{11k} = 2\, X_{11j} \exp(-a_{11\,11} X_{11j} + a_{5\,11} X_{5j} + a_{10\,11} X_{10j});\\
&B_{1j} = \mathrm{IF}((X_{1j} - H_j) \le 0;\, 0;\, X_{1j} - H_j);\\
&B_{2j} = D_j - C_j;\\
&B_{3j} = X_{8j} - X_{9j};\\
&B_{4j} = X_{10}^{*} - X_{10j};\\
&B_{5j} = X_{11}^{*} - X_{11j};\\
&S = \mathrm{IF}(I > 0;\, \mathrm{IF}(X_1 \le H;\, X_1;\, H);\, 0);\\
&A = \mathrm{IF}(B_2 > 0;\, 0;\, B_2);\\
&G = \mathrm{IF}(B_3 > 0;\, 0;\, B_3);\\
&E = \mathrm{IF}(B_4 > 0;\, 0;\, -B_4);\\
&R = \mathrm{IF}(B_5 > 0;\, r_0 X_5;\, r_1 X_5);\\
&H_k = H_j + X_{5k} - S_k;\\
&I_k = X_{2k} - X_{4k};\\
&D_k = X_{2k} S_k;\\
&C_k = X_{4k} X_{5k};\\
&AD_k = AD_j + S_k X_{2k};\\
&AC_k = AC_j + X_{4k} X_{5k};\\
&T_k = AD_k / AC_k - 1.
\end{aligned}$$

Dynamics of this ecological-economic system is presented by 11 scenarios:

X_1 – demand on industrial production of an interprise,
X_2 – market price of the production unit (good),
X_3 – index of the good's quality,
X_4 – industrial cost of good,
X_5 – production output,
X_6 – accumulated credit,
X_7 – debts on capital investments,
X_8 – current capital investments,
X_9 – necessary capital investments,
X_{10} – pollutant concentration in environment,
X_{11} – bioresource concentration in environment.

Other variables of the model were

H – ready for sale goods amount at a sale floor,
S – sales rate (agent),
I – unit income,
U – agent management of output and sales,
D – current benefits,
C – current production costs,
A – current credit of circulating capital (agent),
M – credit interest,
G – current investment (agent),
F – investment interest,
E – share of ecological fine in the production cost (agent),
R – share of resource rental in the production cost (agent),
AD – accumulated benefits,
AC – accumulated costs,
AI – accumulated return,
T – production efficiency,
B_1 – output balance (agent),
B_2 – circulating capital balance,
B_3 – investment balance,
B_4 – pollutant concentration balance,
B_5 – bioresource concentration balance.

3.5. Simulation runs with the ecological economic model.

Various simulation runs with the ecological-economic model were made. Their results are presented in [2,8]. Here we could give only very brief description of a few of them. For instance, simulation runs with the model made it possible to choose the most effective scenario of economic resources use. Designating accumulative costs for some time period as AC and accumulative benefits as AD we can introduce an efficiency estimate T

$$T = (AD - AC) / AC, \tag{19}$$

$$X_{7k} = F_{07} X_{7j} + G_j (1 - EXP(- c_{07} t_j)). \tag{20}$$

$$AD_k = D_j + S_j X_{2j}; \qquad (21)$$
$$AC_k = AC_j + X_{4j} X_{5j} + G_j (1 - EXP(-c_{07} t_j));$$

were time delay c_{07} in practical using of capital investments were taken into account. Some results of simulation runs were shown in fig.7 and 8.

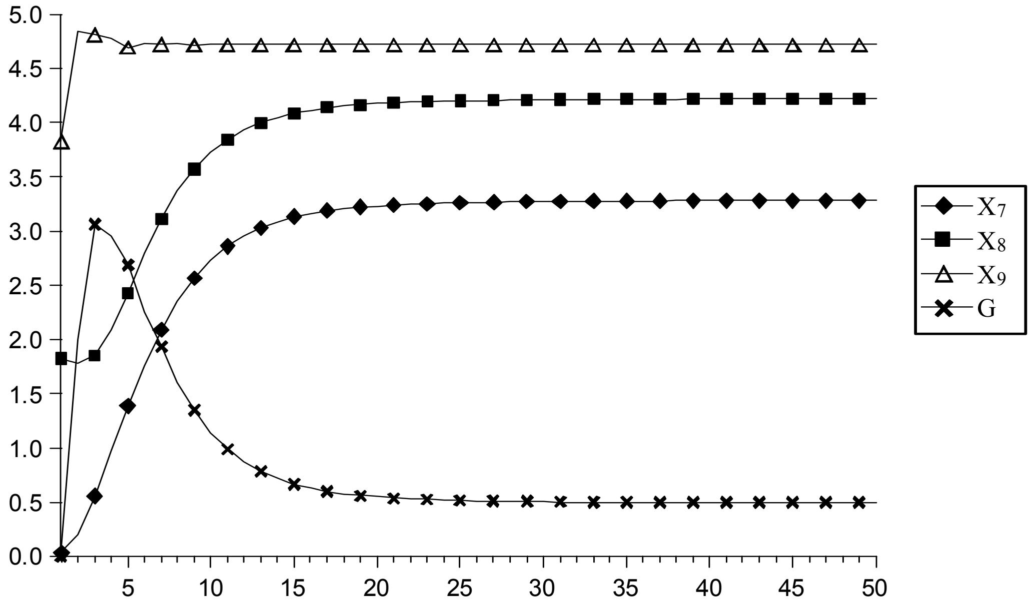

Fig. 7. Capital investments dynamics.

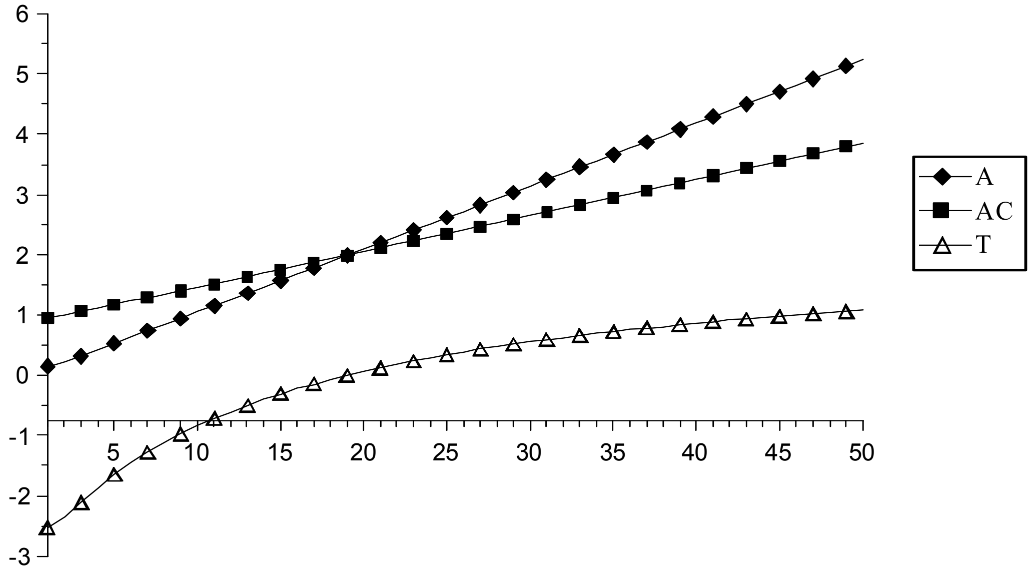

Fig. 8. Profitability dynamics.

These results show the grow of profitability and help in planning of industrial output.

4.4. Resource rental and ecological fines.

These two mechanisms for natural resources management were considered in another simulation runs with the model, considered in section 3.4. Special agents were watching the changing situation with natural resources use and pollutant contaminant concentrations in environment. They “switched on” 10 times higher rental and used ecological fines, applying them to an industrial unit, if the later was causing dangerous environmental situation. Results of the management were shown in fig.9.

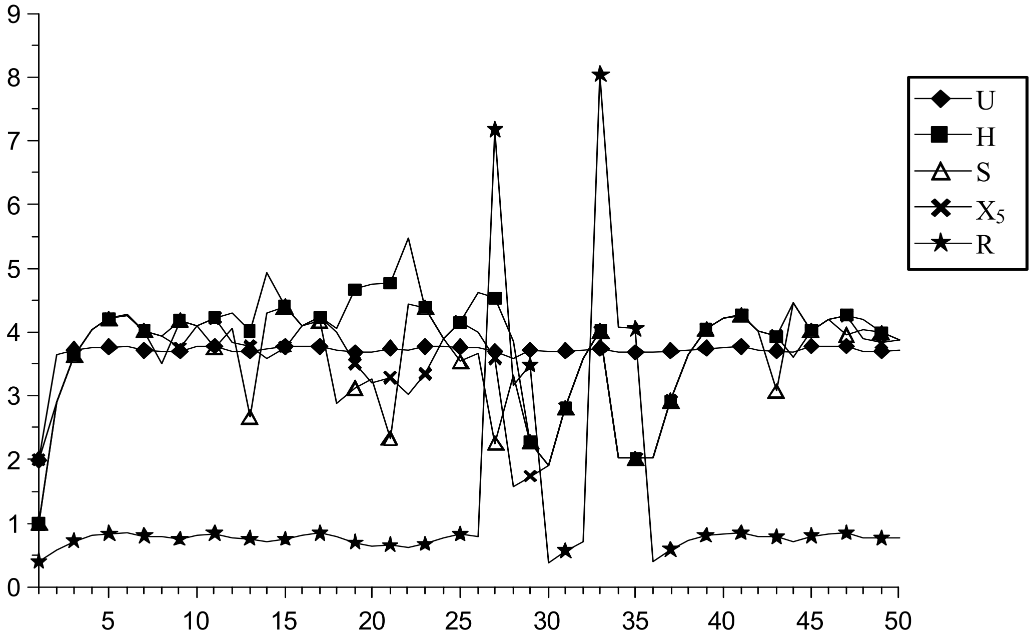

Fig. 9. Resource rent influence on production output and sales rate.

Current management of natural resources consumption have being provided their concentration and the pollutant contaminant amounts in environment at prescribed levels.

4.5. Control for common pool environmental resources private use.

Let us define mineral and biological properties of the soil or the sea environment in some region as the common pool resources to be used by some industrial object. Another one common pool environmental resource of the region, (which we shall call “assimilative capacity”) is its ability to accept, contain and possibly destroy the industrial wastes produced by the object. This ecological resource can be estimated as the difference between current specific contents of unhealthy substances in the air, soil or sea and their total admissible concentrations in the natural environment. We shall assume that the less assimilative capacity of the environment, the high must be the cost of the environmental common pool resource and hence the high will be the price on a resource market, which has to be paid for its consumption.

In simulation runs with the ABC AGENT information technology, presented in the reference works [7,8], various situations were examined under changing conditions on production and common pool resources markets. Some of the results were presented in fig.10 and 11. Thus, for example, suppose that an industrial object could spend up to 40% of its current circulating capital for purchasing necessary common pool resources. After monitoring the common pool resources states in the region social (state) advisory or managerial board fixed the total amount of accumulated credit admissible to this particular object for its environmental resources use at the 1100 non dimensional units level. ABC AGENT technology allowed for to obtain possible scenarios of cost-benefit dynamics for the object meeting the environmental protection conditions.

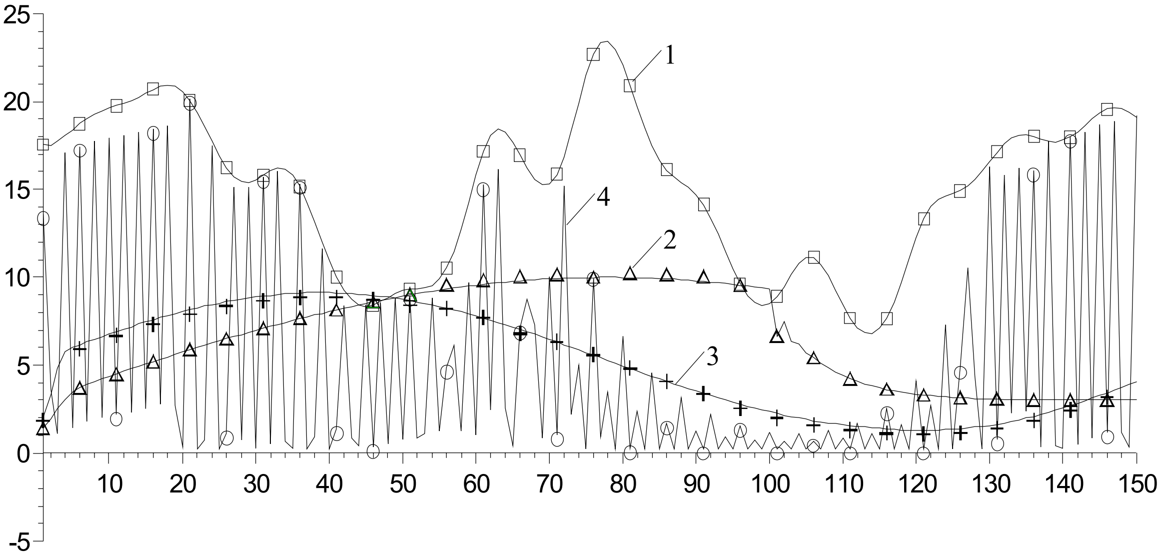

Fig. 10. Simulated dynamics of the system "resources-production-market" (1- demand on production, 2- changes in environmental recovering capacity, 3- seasonal change of bioresource concentrations, 4- daily production output).

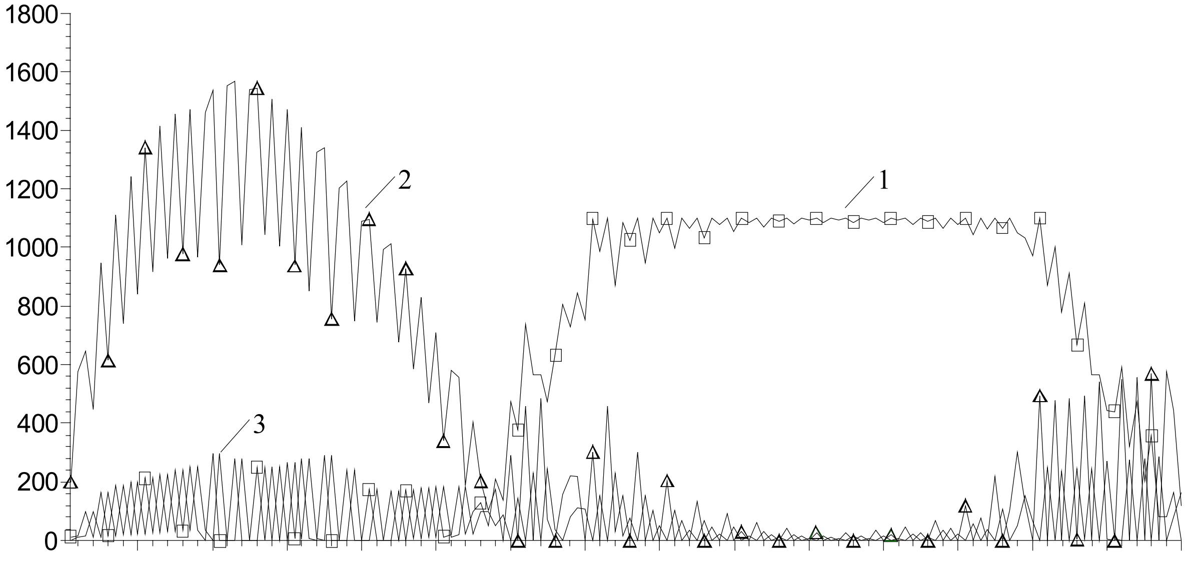

Fig. 11. Rental for resources use dynamics and accumulated credit under conditions shown in fig. 10 (1- daily accumulated credit, 2-daily income, 3- current rental payment).

As the external influences on industrial economic system, there were simulated random fluctuations of demand on the production market, seasonal variations of natural bioresource price and environmental assimilative capacity (ecological resource price) on the resources markets, which were shown in fig.10.

Under these conditions agent distributor of circulating capital, supply chains agents, agent manager of manufacturing and others agents ensured production output on the market demand level at the beginning of simulation run (up to 55th time step) and close to the end of it (after 130th time step).

Dynamics of the industrial capital return to the society in a form of its payment for common pool resources use is exhibited in fig.11. At the start of the run time interval industrial object settled his accounts with the society completely and accumulated credit was absent. After 60th time step production profitability started fall down and to support the production output the object was made to ask current credits. Industrial debts to the society began to rise rapidly and at 70th time step the accumulated credit of the object had reached the total admissible level in 1100 units. Further consumption of common pool resources would be dangerous for environmental health. Therefore current credits letting were ceased and production output was made to stop practically between 80th and 120th time steps. But after 130th time step general situation had improved significantly due to the rise of demand on industrial production market. Following income grow allowed for to return accumulated credit to the society. Production output was set at the demand level and the society began once again to receipt industrial payment for common pool resources use.

CONCLUSION.

ABC AGENT technology suggested in reference works [2,7,8] may be used as a practical tool for common pool resources management. In contrast with the usial system dynamics approach there is no need to use traditional stocks and flows diagram at the step of concept management model construction. Signs and directions of influences between a system's modules self-acting create all the necessary loops of feedbacks in the system structure. A new Adaptive Balance of Causes (ABC) method has an advantage of a standard module equation, which simplifies the construction of formal dynamic model taking into account positive and negative influences from neighboring modules and external forces. Current identification of the model coefficients is possible, based on stochastic reanalysis of external forcings and model development scenarios. Suggested agent based information technology of the system "markets-industrial unit" could be considered as a standard agent structure and allows for the various developments and applications. It makes it possible the simulation of development scenarios in complex socio-ecological economic systems under various paths of their resources use. Simulation is enable to ensure the important information about rational ways of natural resources consumption and conservation. Therefore ABC AGENT informational technology could be utilized in the construction of practical decision making support systems for sustainable development management.

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