Artificial societies

(The quarterly journal)

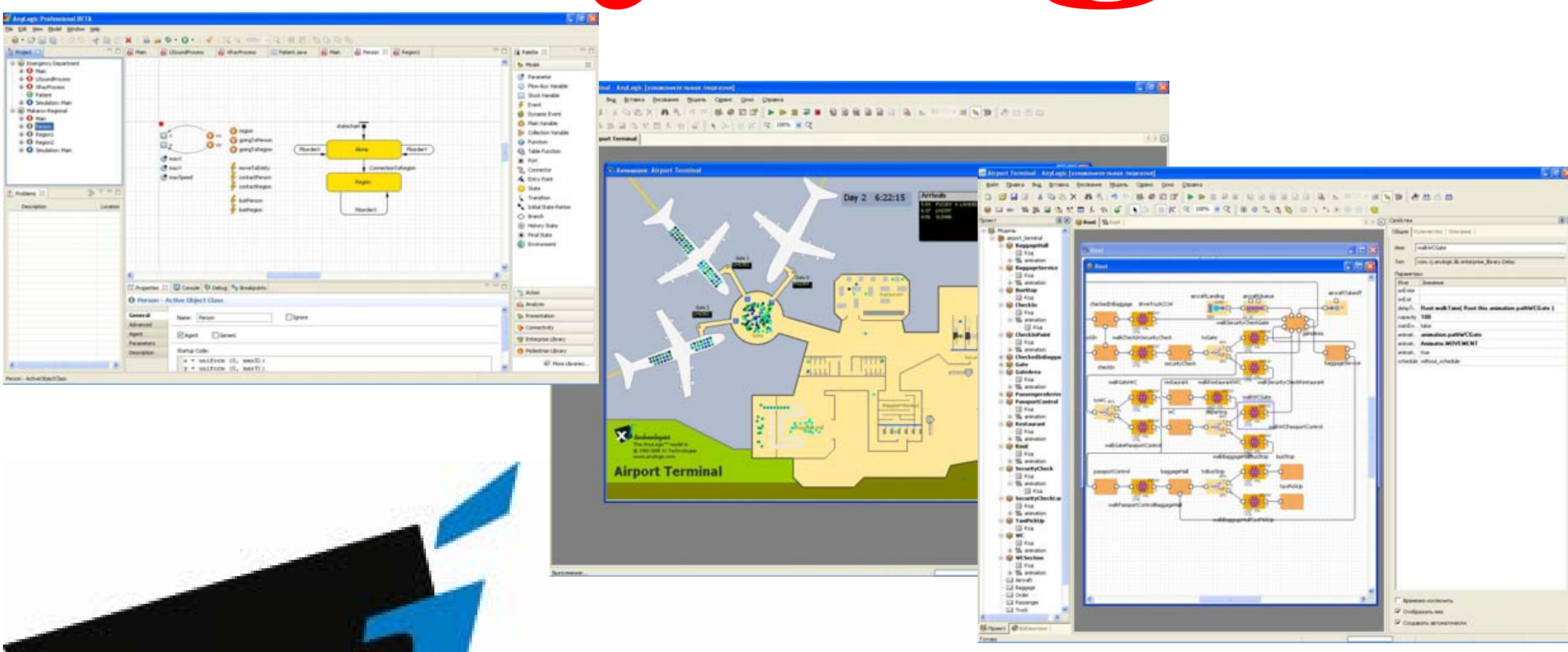
Vol 2, No 3-4
Quarters III-IV
2007

• scientific articles • discussions • models
• artificial intelligence• scientific software • digest

IN THIS ISSUE:

we present the simulation modeling package

AnyLogic



xj technologies

in the article by Doctor of technical sciences S.I.Parinov

«New Possibilities for Simulation Modelling of Socio-economic Systems»

Central Economics and Mathematics Institute
of the Russian Academy of Sciences

(Laboratory for experimental economics)
Laboratory for artificial societies

Artificial societies

The quarterly Internet-journal
Volume 2, No 3-4, 2007

ISBN 5-8211-0393-2

The journal is issued since October, 2006, 4 times per one year.

Address:

47 Nakhimovsky prospect, 117418, Moscow, Russia

Phone (7) (495) 129 07 44

Fax (7) (495) 129 14 00

E-mail: albert@artsoc.ru

Web: www.artsoc.ru

CONTENTS

Volume 2, issues 3-4, 2007

Scientific articles

Artificial Societies: A powerful Tool to study Economics and Related Systems

© *V.L. Makarov (Moscow)*

Abstract

The methodology of artificial societies, coming from sophisticated development of so called agent based models, is going to be a breakthrough in social sciences. In this paper I try to demonstrate it on the examples of mathematical economics and related topics. The growing complexity of mathematical models can be overcome by construction of artificial worlds and computer experiments. The first non trivial results are on the basis of this methodology are already in place. We may also formulate a number of intriguing issues, the answer to which one can expect under further application of the new methodology.

Where mathematical modeling faces a limit.

Mathematical modeling of a real world is a practically universal methodology. One considers theory serious or modern if it based on mathematical model. It is easy to list numerous examples of these theories in any field of research. Economic science is not an exception. Let me mention for example widely used general economic equilibrium theory, which one can consider to be a part of theory of games. One can see a lot of mathematics in leading economic journals as well.

But it is clear that mathematical modeling has its limits. Reality is too complicated to be modeled as precisely as one wants. Making more realistic mathematical models we produce monsters, which it is impossible to analyze by standard methods of logics.

Economic science is developing to the direction of getting closer to natural sciences. Now it is possible to make experiments in the sphere of economics, that was difficult to imagine a century ago. The first breakthrough was done when laboratory economics appeared after Vernon Smith's methodology and related activity. The next crucial step is connected with the quick development of virtual worlds and artificial societies. One can raise much broader set of questions, which are impossible to formulate in mathematical terms.

Let me illustrate the thesis by mathematical model of an economy, which is a combination of well-known economic models.

In the modern economic literature one uses a notion of an (economic) agent. The agent is autonomous to make its decisions. The standard classification of the decisions is the following.

1d. An agent chooses a so-called consumption basket of all types of goods and services.

2d. An agent chooses a jurisdiction to live.

3d. An agent chooses profession and a firm to work.

4d. An agent votes for (a) a political party, (b) economic policy, (c) provision of a certain bundle of public goods, (d) creation or modification of jurisdictions.

5d. An agent decides to participate in clubs, including such club as family.

6d. An agent chooses investment portfolio.

The listed decisions of all agents define the total demand in the society.

The total supply of the society one can define by the following actions and mechanisms.

1s. Production of goods and services by institutions.

2s. A mechanism of jurisdiction's creation and modification.

3s. Professions and jobs.

4s. Political system, type of democracy.

5s. Clubs' formation.

6s. Investment policy.

The basic approach of main stream's theory consists of defining equilibrium and finding properties of the equilibrium. The economics literature is full of brilliant models equalizing demand and supply for every point, outlined in the above list.

For example, points (1d – 1s) give the very famous Arrow – Debreu model of general equilibrium, which is classic. The theorem of an equilibrium existence is based on Kakutani fixed point's theorem. Optimality of the equilibrium yields from Kuhn – Tacker separation theorem, the proof of finite number of equilibrium states uses some facts of algebraic geometry. The point (2d – 2s) leads to the Tiebout model, (Tiebout Ch., 1956), which is so popular now and came to the top of topics in terms of citations. The technique to prove equilibrium's existence of theorem is very sophisticated, see Caplin and Neilbuff. The point (4d – 4s) generates a number of relatively simple graceful models, most of them the reader can find in Person and G. Tabellini.

The same situation one sees in the other points.

But if you try to combine all these points into one model you create a monster from the mathematical point of view. It is absolutely impossible to prove something putting all the notions into one wrap. There are a number of attempts to combine just some of the listed points, two or three, to obtain substantial results. Yet, there are no results to be mentioned as visible.

What is an artificial society?

Computers offer a natural way to overcome complexity of mathematical models. A computer model can be as complex as possible. There are nearly no limits, except for computer's memory and human efforts. One calls computer model of real society as artificial society.

An artificial society consists of *agents,* which act in *an environment*, following given *rules*. According to the standard terminology the artificial society is a particular case of, so-called, *agent – based models*. Agent – based models are widely used in a number of fields for analysis of such problems as, for example, transportation flows, city design, mass services, etc. Hence, agent – based model should not necessarily be considered as artificial society.

Agents in an artificial society behave relatively autonomously. They *make decisions, act* and *interact* with other agents. Agents make decisions as a reaction on the environment and actions of other agents. The key word is an *interaction* between agents. One calls it social ability of agents and therefore we can talk about an artificial society, as a particular case of agent – based models.

Historically the first example of artificial society was Neumann's cellular automates. The simplest society of cellular automates was proposed by Conway (see Conway J., 1970), called "Life". The game "Life" looks very simple according to the rules of behavior of agents (black cells). Nevertheless, the cellular automata shed new light on the problems, which are difficult to understand by other methods. See, for example, Hu Bin and Debing Zhang (2006). To the paper we will return below.

I do not aim at describing the history in detail. One can find it in the seminal book of Epstein Joshua M. and Axtell Robert (1996) "Growing Artificial Societies". The authors develop the methodology of Artificial Societies, based on relatively simple SugarScape model, which became very popular thanks to the book. The SugarScape model is really very simple, even in comparison with a set of finite automata of von Neumann or Cetlin type (see Цетлин М.Л., 1969). Nevertheless one can see the variety of questions and problems to be raised, discussed and experimented in terms of the SugarScape model.

It should be noted that Epstein and Axtell compare cellular automata with environment or space in their SugarScape model. Under this vision the SugarScape model is the agents traveling among cellular automata.

The SugarScape model.

Let me start with the original version of the model. At any moment t there is finite number of agents located in the space. Space is a two dimensional lattice of equal cells.

At any moment *t* each cell *(x,y)* has: (1) an agent *a* $(a_t(x,y) = a)$, if agent *a* is located in the cell (x,y), or no agents otherwise $(a_t(x,y) = \text{empty set})$. (2) quantity $r_t(x,y)$ of "sugar".

An agent is born with two parameters: vision (number of cells in the lattice to look around) and level of metabolism (quantity of sugar to eat per unit of time to survive). An agent can carry any amount of sugar. An agent dies if it has not enough sugar to eat. The authors explore a number of rules how an agent can be born. For example, simultaneously with its death a new agent is born with randomly chosen parameters and location. So the total population of agents stays constant in this case.

Rules for agents.

- Look out in the four (eight) lattice directions and identify the unoccupied site, having the most quantity of sugar.
- Move to this site and collect all the sugar at this new position.

Based on the simple version of the SugarScape model authors produced a number of experimental calculations and received results, which are consistent with common understanding of human society's features. The model looks wonderful, because in this version there are no interactions between agents, which one treats as a basic property of human society.

For example, there is a fundamental problem, which challenged many thinkers of all times. It is distribution of wealth among members of society. The distribution is always quite uneven in any existent society. And the urgent issue nowadays is growing inequality both among people and among countries. The authors of the book find that "under a great variety of conditions the distribution of wealth on the SugarScape is highly skewed, with most agents having little wealth."

The agents compete with each other for the sugar. The macro structural result is concentration of population in sugar – rich arias. Even in this simple version of the

SugarScape model without interactions between agents, authors explore a way, how to avoid the concentration of population, particularly with phenomena of pollution.

Pollution can be introduced as an impact of collection and eating of sugar. So each cell contains sugar and the level of pollution. An agent moves to a free sell with maximum sugar to pollution ratio. The rule changes the picture dramatically. First, the number of deaths increases and second, distribution of population across territory becomes more even.

In advanced versions of the SugarScape model different types of interaction between agents and some complexities are introduced. It allows analyzing a great variety of phenomena, taking place in human societies. Sex, Culture, Conflicts, Decease, Heritage and a number of others properties of human society can be investigated in terms of the SugarScape model.

One can see especially interesting findings coming from the SugarScape model in the sphere of economics. The authors make the model more complicated introducing the second good "Spice".

In the SugarScape model with two commodities the agents' rules of behavior are getting more complicated. An agent moves to the neighboring empty cell, where augmented welfare is maximal. The welfare function of an agent is defined on the basis of two goods. So, in this respect the behavior of agents looks similar to their behavior in the case of one good. But an agent has new possibility to exchange commodities with another agent, if it is beneficial for both.

Under condition of finite time horizon one can formulate the SugarScape model as a standard Arrow – Debreu model, basic one in the general equilibrium theory. Namely, an agent a has the initial endowment $w_{a,t}(x, y)$, where for every t and given (x, y) pair $w_{a,t}(x, y)$ shows a quantity of sugar and spice, (x, y) is the cell of its location at the moment 1, $t = 1,2,\ldots,T$. Then it is possible to compare an equilibrium state of the Arrow – Debreu model and the results of calculations for the SugarScape model. The authors of the book made a lot of calculations, starting from different initial locations of agents. Mean price of exchanges of sugar and spice between agents always moves to the equilibrium price value. But final position of agents depends on their initial location. In particular it means that the two absolutely identical agents with the same initial endowment can turn out to be in different positions in the end. It confirms once again the unevenness of distribution of wealth, irrespective of the variety of initial conditions and variety of genetic characteristics of agents.

In this connection the remark of the authors about principal difference between the equilibrium in the sense of general equilibrium theory and the equilibrium (called statistical equilibrium) of the SugarScape model looks a little bit strange. They mention that according to the general equilibrium theory, identical agents with equal endowment have equal behavior and equal meaning of the utility function in an equilibrium state. It is correct. But after that they state that in the SugarScape model identical agents with the same endowment finally come to very different positions. To be exact, in the SugarScape model agents have different endowment, because it is necessary to include its location into definition of the endowment.

Collective goods' economics.

Methodology of "Artificial Societies" perfectly fits in the economics of collective goods. Collective goods are by definition products of interactions or mutual actions of agents. The notion of collective goods appeared relatively recently. Pioneering works in the field belong to the two Nobel prize winners in Economics – Samuelson and Buchanan. See, Samuelson, P. A. (1954), Buchanan, J. M. (1965).

The process of production, distribution and consumption of collective goods is collective by definition. It is not regulated by market, although for production it is necessary to use private goods operated on a standard market. The volume of tangible and intangible collective goods, which appeared in the modern economics, is rapidly growing. It is now more then one third of GDP in most countries. Needless to say, that these estimations are very conditional because collective goods are not measured in market terms. Sometimes the cost of production of collective goods is huge, like in the case of infrastructure, sometimes – close to zero, like in the case of marriage.

One of the basic problems in the economics of collective goods is group formation. Below I show the formation of pairs to produce and consume collective good, which one can call “sharing time”. Details see in Макаров В. Л. (2007).

Let us consider an artificial society of agents where the problem of every agent is to split its time onto two parts. The first part is used to produce private good and the rest of time is spent with a partner, who it is necessary to find. The partner should agree to spend exactly the same piece of time, which the agent wants to.

Notations.

N – total number of agents;

i – number of an agent;

w_i – total reserve of time, the agent has;

$(w_i - c_i)$ – quantity of private good, produced by the agent;

x_i – quantity of private good, consumed by the agent;

c_i – time of the agent, which it spends together with a partner;

a_i – level on propensity to be alone;

$u_i(x_i, c_i) = a_i{*}\, x_i + x_i{*}\, c_i$ – utility function og the agent;

$d(i, j)$ – characteristics function defined on pairs (i, j) with additional condition that if $d(i, j)=1$, then $d(i, k)=0$, $d(k, j)=0$ for all others k.

Social planner’s problem.

As usual it makes sense to take understandable criteria of optimality, to have possibility to compare different approaches and calculations. Here the criterion is the sun of all individual utility functions. After that one can formulate the optimization problem to find maximum this sum of utility functions of all agents.

Namely,

To find: $\{(x_i, c_i)\}$, $i = 1,2,\ldots,N$; $d(i, j)$, $i = 1,2,\ldots,N$, $j = 1,2,\ldots,N$, $i = j$, such, that

$x_i = w_i - c_i$,

$c_i = c_j$, if $d(i, j) = 1$,

$c_i = c_j = 0$, if $d(i, j) = 0$,

$\text{sum}_i(u_i(x_i, c_i))$ achieves maximal value.

Every agent tries to choose the partner, who agrees for interaction with minimal deviation (measured by the value of utility function) from optimal c. Thus the agent makes an order to all other agents according to the parameter. The real interaction (deal) happens, when both participants agree.

Rules of interactions between agents.

Every agent calculates the best period of time to be together with another agent. Namely s/he solves the problem of the function $a_i{*}\, x_i + x_i{*}\, c_i$ maximization over variable c_i, where $x_i = w_i - c_i$. The first order conditions give $c_i = (w_i - a_i)/2$. Consider the value c_i as desirable.

After that, given (for example, randomly chosen) agent looks at all agents in her neighborhood. The neighborhood is defined as the objects an agent can see (length of horizon). The given agent makes a proposal to the agent, whose desirable value is maximally close to her desirable value. The chosen agent accepts the proposal if there are no other more desirable ones in her neighborhood. The period of time, which agents agreed to spend together, is equal to arithmetic mean of the two desirable periods. In the case when the deal is not made, the second agent makes a proposal to her desirable agent. The process is finished when there are no agents who want to make a proposal. The natural question appears: does the described process lead to optimal solution of the social planner's problem or not?

The answer to the question one can receive by making calculations according to the methodology of "artificial societies". We made a number of the calculations, where the space was two - dimensional lattice. It is clear that in principle the process does not lead to the maximum (to the solution of the social planner problem). But it is interesting to know the dependence of the value of the criteria on the parameters, initial conditions and random details.

We limited ourselves by the case where all agents have the same sequence of time and different propensities to be alone. No essential surprises were discovered. The results were consistent with intuition. For example, longer horizon to look around – the solution is closer to maximum, all other conditions equal. The longer the horizon – the weaker is the dependence on the initial location of agents. In fact, maximum was never reached. It is also understandable, because the arithmetical average is not the ideal solution of the deal between two agents. The other more sophisticated rule consists of maximization of the sum of the two individual values, which does not concede with arithmetical average.

Collective behavior of agents (continued).

There is a big variety of collective behavior types. Keeping to the language of simple cellular automata, it is possible to study the relatively complex group behavior. The paper by Hu Bin and Debing Zhang (2007) brilliantly demonstrate, how the world of cellular automata can be used for explanation of group behavior focused on the loyalty to a group (firm) of its members. The member of the group can have different orientations, for example with motivation to earn money (Economic Being) or motivation to feel comfortable within the group Social Being).

There is the lattice of the finite number of cells in this case. Each cell represents one member of the group. The loyalty is measured by the three levels: “high”, “normal” and “low”.

From here a group can be divided further according to two generalized sets of characteristics, which result in different motivations. One group becomes "economic", and the other - "social". According to the theory of “employee behavior", Economic Beings are motivated by material and monetary gains. Social Beings are motivated by social status and respect of their colleagues.

Competition between political parties.

As was above mentioned, the attempts to take into consideration many factors come to a model, which is difficult to study by mathematical methods. In this section I illustrate the thesis by an important example of the very famous Tiebout model. See, Tiebout Ch. (1956).

The Tiebout model deals with people located in a finite number of jurisdictions (regions, towns, etc). Every citizen makes a decision to stay in the jurisdiction where he/she lives or to move to another jurisdiction to maximize her utility function's value. The decision is based on the following information about jurisdictions: a package of local public goods, provided by the jurisdiction, and level of taxes in it. In the wide literature dedicated to the Tiebout model one can find numerous results about existence of equilibrium and optimal properties of the equilibrium states.

The situation gets much more complicated when one incorporates into the model political process of elections. Every political party wants to win elections, and hence to attract as many votes as possible. A formalization of the political process leads to modification of the Tiebout model, which looks like an artificial society. In the modification agents make the following actions. They move from one jurisdiction to another and they vote for one or another political party, or for an offered issue in the case of direct democracy.

Let me formulate the modification based on the papers Collman, Ken, John H. Miller and Scott E. Page (1997) and Данков А. Н. и Макаров В. Л. (2002).

There are N inhabitances, each lives in one of the jurisdictions $j = 1,2,\ldots,G$.

The political process is represented by n political parties, which operate in all jurisdictions. Each party k ($k = 1,2,\ldots,n$) works out and offers voters its platform $p_k = (p_{ki})_{i=1,2,\ldots,I}$. The platform does not depend on the jurisdiction and formally is *i*-

dimensional Boolean vector, where $p_{ki} = 1$, if the party stays for an issue i and $p_{ki} = 0$, if the party agitates against the issue. The contents of the issue in the list may be quite different, like a war in Chechnya, property taxes or ban on producing human clones.

Every person has her own opinion on all the issues. The opinion is expressed by a number, which may be positive or negative. Let $v_{ai.}$ be this number. The opinions v_{ai} are uniformly distributed on the interval [-1, +1].

Knowing v_{ai}, one can calculate the utility of an agent a, if the platform p_k comes true. Namely, $U_a(p_k) = \text{sum}_i (p_{ki} * v_{ai})$.

An agent votes under various political systems. She votes for the party, which offers a platform with maximal utility for her. Alternatively, she votes for the issue, which her gives maximal utility.

The world political practice shows different ways of converting individual votes into political decisions. Simplest way is called *referendum* and direct democracy. The result of referendum is a policy (platform) $p= (p_i)$, where quantity of people with $v_{ai}>0$ is greater then quantity of people with $v_{ai}<0$ for all i. So, in the case of direct democracy there is no room for political party. People vote not for a party but for issues.

Another form of representative democracy called *direct competition*. In practice direct competition creates *presidential power* under the rule "the winner receive everything". Formally in our terms it means that people vote for parties and the party with maximum votes takes an office.

The third one, we take into consideration, is proportional representation. It is another form of representative democracy called *parliamentary power*. Every political party, which took part in the election, receives the influence proportional to the number of votes for the party.

Questions, to which we want to receive the answers.

1. What regime is better (in terms of the aggregate welfare function) and under what conditions?
2. What influence of number of political parties on the value of the welfare function?
3. What influence of number of jurisdictions on the value of the welfare function?
4. What type of party's behavior is better in terms of welfare function and in terms of probability to win or to pick up greater number of votes?

Of course, the number of questions to be raised is much greater. Nevertheless one can suppose, that purely mathematical approach would fail to answer the mentioned questions.

The behavior of agents is described as above. They vote and move if necessary. The behavior of political parties is more complicated. A political party has its platform, which lies in the base of the party. But a party can change its platform to attract more voters. So it is necessary to define the neighborhood of the platform, inside which the party keeps its base. There are more flexible parties than others, depending on the size the neighborhood of its platforms.

It is clear, that one can organize the process of simulations in different ways. One of the ways is the following.

1. One starts by defining the initial conditions: a realization of random distribution of agents between jurisdictions and random distribution of opinions (v_{ai}) among agents.
2. The platforms of all political parties are given.
3. Every party tries to find corrections to its platform, which would bring more votes. For that the party chooses so called focus group (randomly chosen given number of people). The focus group shows, which policy in the neighborhood gives maximal number of votes.

4. The population votes for the presented programs.
5. Points 3 and 4 can be repeated several times.
6. The results of the election are presented to the population. It means that in the case of referendum, indicated are the winning issues in each jurisdiction. Presidential election gives policies of wining party in each jurisdiction. And in case of parliamentary elections, each jurisdiction calculates the policy, which should be realized.
7. The agents move to preferred jurisdictions, knowing situation in all jurisdictions.
8. The process begins again from the point 3 and is repeated a given number of times.

The final distribution of the population between jurisdictions and the value of the welfare function are compared with the solution to the social planner's problem.

Detailed results of the simulations one can find in Данков А. Н. и Макаров В. Л. (2002). Here I mention the two most interesting ones. The calculations show that in case of one jurisdiction presidential regime gives better results in terms of welfare function when the number of parties is lower. If the number of parties is greater than two, parliamentary regime is better. In case of multiple jurisdictions both regimes give better results under several jurisdictions in comparison with one.

Needless to say, that the results are rather qualitative. One can calculate more precise outcome trying to obtain optimal number of parties and jurisdictions under different regimes.

Artificial Societies and Virtual Worlds.

One can find the evident connection between Artificial Societies and Virtual Worlds. In some sense we can consider an artificial society as a certain type of a virtual world. So virtual world is a broader concept with less definite boundaries.

Principal feature of the virtual world is involvement of one or more participants in the experiments. One may object this statement by giving the famous example of the "Star Wars", where there is no involvement of a spectacular. But here we have rather an exception than the rule. Nevertheless the example "Star Wars" shows, that it is possible to obtain new scientific results by this instrument. Namely, we can mention the power – law distribution of wealth (in Star Wars and other related games) as the final outcome of the whole procedure. Indeed it was checked that practically in every case the end of the war takes place when the distribution of power coincides with the distribution of wealth. Under this condition there is no incentive to continue the war.

As one can see, Virtual Worlds are not created only for scientific purposes. Moreover they are basically aimed at other purposes.

What is the purpose of Virtual Worlds?

- Commercial Games.
- Socializing / on line community building.
- Education.
- Political Expression Instrument for political debate
- Military Training
- And finally, research tool for better understanding of natural worlds.

It may be concluded that we are currently on the eve of mixture of natural world and virtual one. The virtual world is going to be a part of natural one. For a human being it will be difficult to distinguish between natural reality and virtual one. See, for example, the popular movie "Matrix". It can be a source and cause for mental diseases. So, we come to the analogous logical circle: construction of the virtual world, containing the virtual world of the, so called, second order. Recall, that the first logical circle, one receives in terms of the artificial societies is the following:

a perfect artificial society, an exact copy of the natural society, must include itself as a proper part.

An ambitious agenda for the future research.

In terms of artificial societies one faces the opportunity to formulate the problems, the answers to which the mankind has been waiting for centuries. Why formulation in the terms of artificial societies is more promising, than in standard terms?

Let us prove this statement by a number of examples.

1. One of the puzzling and difficult questions is related to the problem of finite duration of agents' life. Why agent does not live forever? Why it is more efficient to have the process of birth of new agents, their education, and absorption of knowledge from other agents, instead of accumulation of knowledge in one agent? So, we are talking about an evolution between agents versus the evolution within an agent.

2. The same question one can ask about the groups of agents. Why there is big diversity in duration of life of different types of groups? Some groups live during on generation, like gangs, classmates, busyness' alliances. The others exist for centuries, like empires, nations, religions, etc.

3. In terms of artificial societies one can easily formulate the question: what happens to the society, if reincarnation takes place. It means that one agent can live number of times, keeping his/her identity. It looks like a mixture of finite and infinite agents' life cases.

4. Why a human being must change a kind of activity during a day, year and life? In this respect the human (animal) society differs from a society of robots.

5. It is easy to imagine a population of agents, where there are no sexes or number of sexes is more then two. What happened then? Is it efficient in some sense in comparison with the traditional population? What are possible advantages?

6. Who knows, may be the instrument of artificial societies will produce better way of future human development, new models of society and so on. Remember, Leonardo da Vinci used to say that he did not copy the reality but constructed it.

7. Other sciences like psychology and philosophy find new arguments for understanding how emotions, conscience and consciousness evolve. Neuroscientists recognize six basic emotions: anger, disgust, fear, joy, sadness, and surprise. And the instrument of artificial societies gives more adequate language for definitions of the concepts. An interesting problem is to expand these concepts from individuals to groups. What is memory of the group, what is its consciousness, where is the memory of the group located, and so on?

8. At the end I would like to discuss the urgent problem, which is coming, first of all, to the community of economists as a sound challenge nowadays. It is the problem of happiness and its measurement. The journal "Economist" raised the issue in its publications in the last issue of year 2006. There is a common statement that a rich country in terms of GDP is not necessarily happiest one. Standard macroeconomic indices like per capita GDP, personal income, individual consumption, general wealth per capita etc. can not serve anymore as basic parameters for measuring prosperity of a country its general success or its superiority over other countries. People want to make life happier rather than richer. A person feels happy if he/she belongs to the top part of the group, he or she considers as very important. It means that the society should be organized in such a way that creates a sufficient number of such groups. As is mentioned in the journal "Economist", in USA there are more then 3000 Halls of Fame. I wrote in Макаров В. Л. (2007) about production of collective goods, which are not included into GDP. One can count it as a first step in the direction of the correction of the standard macroeconomic indices.

References.

1. Epstein Joshua M. and Axtell Robert (1996) "Growing Artificial Societies: Social Science from the Bottom Up" *Brooking Institution Press and MIT Press, Washington DC*.

2. Bewley, Truman, 1981, A Critique of Tiebout's Theory of Local Expenditure. Econometrica. 49: 713-741.

3. Buchanan, J. M. (1965) An Economic Theory of Clubs. *Economica, 32, 125, pp.1 - 14.*

4. Collman, Ken, John H. Miller and Scott E. Page (1997) "Political Institutions and Sorting in a Tiebout model." *American Economic Review 87: 977-992.*

5. Conway J. (1970) "The Game of Life". *Journal "Scientific American"*.

6. Hu Bin and Debing Zhang (2007) Cellular – Automata Based Qualitative Simulation for Nonprofit Group Behavior. *JASSS vol.10, #1*.

7. Persson T., Roland G. and G. Tabellini, (1999), Comparative Politics and Public Finance. *Quarterly Journal of Economics*,

8. Samuelson, P. A. (1954) The Pure Theory of Public Expenditure. *Review of Economics and Statistics, 37, 4.*

9. Tiebout, Ch. M. (1956) "A Pure Theory of Local Expenditures", *Journal of Political Economy*, **64**, 5, pp. 416-424.

10. Данков А. Н. и Макаров В. Л. (2002) «Межтерриториальная и межпартийная конкуренция: сравнительный анализ влияния политических институтов» *Препринт Российской экономической школы*, 2002.

11. Макаров В. Л. (2007) «Коллективные блага в АОМ» *ж. Искусственные общества*, т.2, №1, 2007.

12. Цетлин М. Л. (1969) «Исследования по теории автоматов и моделированию биологических систем» М. «Наука» 1969.

New possibilities for simulations of socio-economic systems

© S.I. Parinov (Moscow)

Introduction

Simulations in computer modeling, including modern ABM approach, attract instantaneous attention and become popular in applications, searching for improving existing socio-economic models and developing the new ones. This may be attributed to particular importance of such an action as predicting outcomes of certain situations in mental experiments. Development of computer simulations is aimed at enhancing efficiency of this very type of activity.

All groups of people, who are involved in interactions with others (managers, businessmen etc.) spend considerable efforts and time in order to forecast outcomes of certain events. One of the consequences of the progress in the society is the increase in the complexity of socio-economic processes. This implies that the tasks on human interactions to be solved by managers become more and more complex. One could predict emergence of mass interest to the tools, enhancing this type of managers' activity, as soon as the costs of developing and using corresponding hard- and software for these instruments become affordable for most of the users.

Recent decades saw considerable development in the methods for simulation modeling. Agent-based modeling is the most current approach in this field. Researchers acquired the tool for describing socio-economic interactions and emerging processes in most realistic way almost without any simplifications. This was accompanied by crucial changes in producing computer imitation software (including ABM software) for general users. These developments may be argued to have increased the accessibility of computer simulations. Therefore, the limit, separating it from mass applications, will soon disappear.

This implies particular importance and necessity of obtaining methodological knowledge about simulation modeling, along with applied skills for its computer realization. The package **AnyLogic** may be viewed as one of the modern and especially powerful tools for various types of computer simulation modeling (including agent-based modeling).

Modern understanding of the tasks for simulation modeling

Major aim of simulation computer modeling of human behavior is the search for the ways of improving the functioning of socio-economic systems. These types of research set the goal of perfecting currently existing organizational mechanisms with long experience of working, as well as the aim at searching for new approaches for organizing and managing joint human activity. This also includes construction of organizational or business systems with pre-set properties. In the last case, simulation modeling helps developing scientific understanding about the features and possibilities of socio-economic systems.

Computer simulations give the best result in the spheres where participants of socio-economic activity spent considerable effort and enough time on thinking and analyzing possible outcomes of various developments. The more complicated the situation is, the more objects, factors and possible scenarios are taken into consideration in their different combinations. Therefore, the expected effects of employing simulation model in order to analyze situation and search for optimal solution would be greater.

One of the consequences of progress in the society is the growth of interconnections between different spheres of human behavior. It is also accompanied by increase in the types of technologies, local application of which might have global outcomes and therefore, fast growth of complexity of human socio-economic environment. Hence, the task for computer modeling becomes giving those taking decisions, as well researchers of socio-economic systems, efficient tools, responding to modern challenges.

With increase in interconnections between such processes and different spheres of human behavior, that previously were not related to each other, another important task of computer simulation modeling is creation of instruments and mechanisms for keeping human activity coordinated. Non-trivial character of this coordination is determined by the following two important factors:

- Large number of participants and/or a rapid growth of interacting participants.
- Increase in intensity of changes in participants' abilities/intentions and in general conditions for their activity, which have to be coordinated in real time.

To obtain full and systematic understanding of the forms and methods (approaches) of modern simulation modeling in socio-economics one can refer to Karpov (2006) and publications in the Journal of Artificial Societies and Social Simulation (JASSS) (http://jasss.soc.surrey.ac.uk).

Agent-based modeling occupies the central place in modern simulations of socio-economic systems. The appearance of ABM may be regarded as the result of evolution in modeling methodology – the change from mono models (one model – one algorithm) to multi models (one model – a variety of independent algorithms). Agent-based modeling incorporates other existing approaches of simulation modeling, since the latter may be applied "inside" agent-based model in formalizing its certain active objects or agents.

Diagrams 1 and 2 represent the schemes, proposed by AnyLogic developers as combination of the three most popular recent methods of simulation modeling (on the graphs "SD" means "system dynamics" approach, and "DS" – "discrete event approach"). The approaches of system dynamics or discreet event modeling allow constructing only mono models, since they do not provide for integration of various simulation methods inside one model.

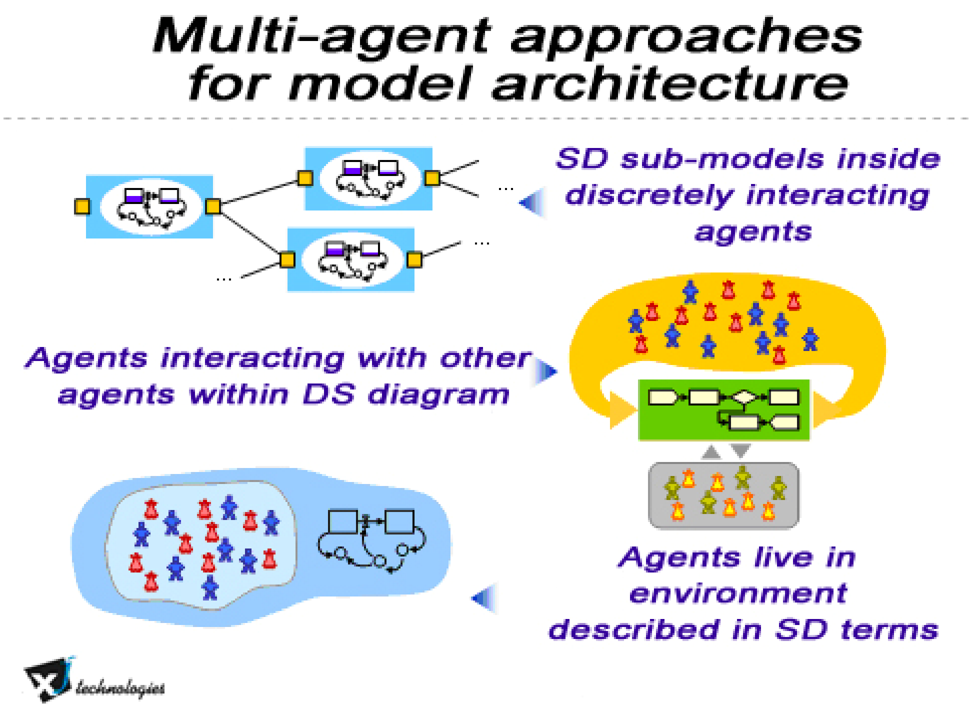


Diagram 1. The algorithm for combing three simulation modeling methods inside one agent-based model

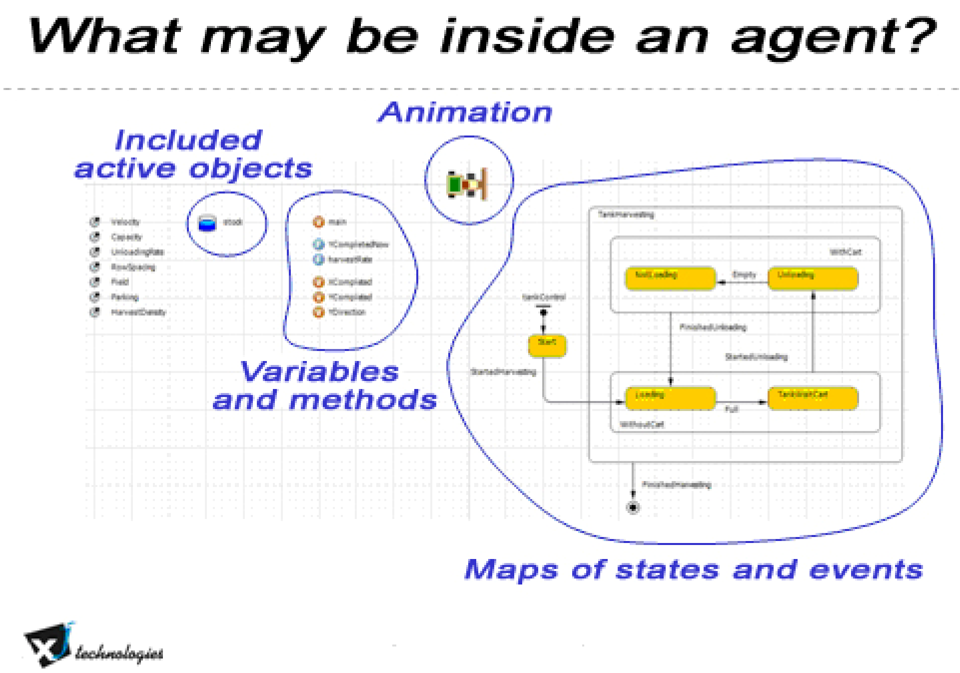


Diagram 2. The scheme for possible condition of agent in AnyLogic

Applied simulation modeling

Applying simulation modeling for existing technological, business and managing systems gives good results in operational and strategic governing of enterprise, in production, logistics, and in chain of supplies. This is particularly useful in situations with large number of elements, complex links and unpredictable development of events. Modern instruments of simulation modeling allow, for example, the following (see examples on graphs 1-5 and explanations to them):

1. Compact and visual (animated) representation of information about the state and behavior of complex system of any type for quick analysis of situation and making decisions. Functioning of large/complex business systems may be shown as visual/realistic picture of the change in elements condition and links between them. The leader may grasp and assess the amount of information, which would require a lot of time and effort to be analyzed in traditional form (tables and graphs).

2. Analysis of various scenarios and the search for the best solutions (including solving optimization problems) for functioning of complex technologic and business systems/processes of any type. Setting scenarios and viewing results may be done through Internet.

3. Keeping coordination and searching for coordinated decisions between territorially distributed leaders of inter-linked business systems. Leaders may formulate their proposals as scenarios for the model, imitating their inter-linked production system; and then collectively simulate the consequences of the totality of the proposed actions. The model may be installed in the Internet and be opened both for viewing the results of its work and for changing input data according to strictly regulated access rules.

4. Comparing results of actual processes with their model etalon in order to determine the reasons and the sources for disturbances in normal functioning of business systems. High precision of model reproduction of the work of technologic, organizational and mixed systems, which is possible in the current simulation

modeling, enables the leaders reproduce situations, describing, which inner or outer factors have led to disturbances of normal behavior.

5. Animated presentations with realistic/visual presentation of complex situations and processes. This includes possibility of simulating different scenarios of behavior of demonstrated object in the process of presentation.

The above links outline only certain ways of applying simulation modeling for improving the existing organizational mechanisms and systems. Other possibilities of using simulation modeling in business see in http://www.xjtek.com/consulting/solutions.

Below we mention the examples of actual models, illustrating possibilities of modern simulation modeling. All these models were developed by the company **XJ Technologies** (http://www.xjtek.com). The full list of demonstrated models can be found at http://www.xjtek.com/anylogic/demo_models (to run the models from the site one needs to open corresponding section in the left column and click the picture with description of the model).

The enlisted examples of models are realized in the model complex **AnyLogic**, also developed by **XJ Technologies**. The following sections will deal with capabilities of **AnyLogic** in detail.

Model "Mineral water and tonic production"

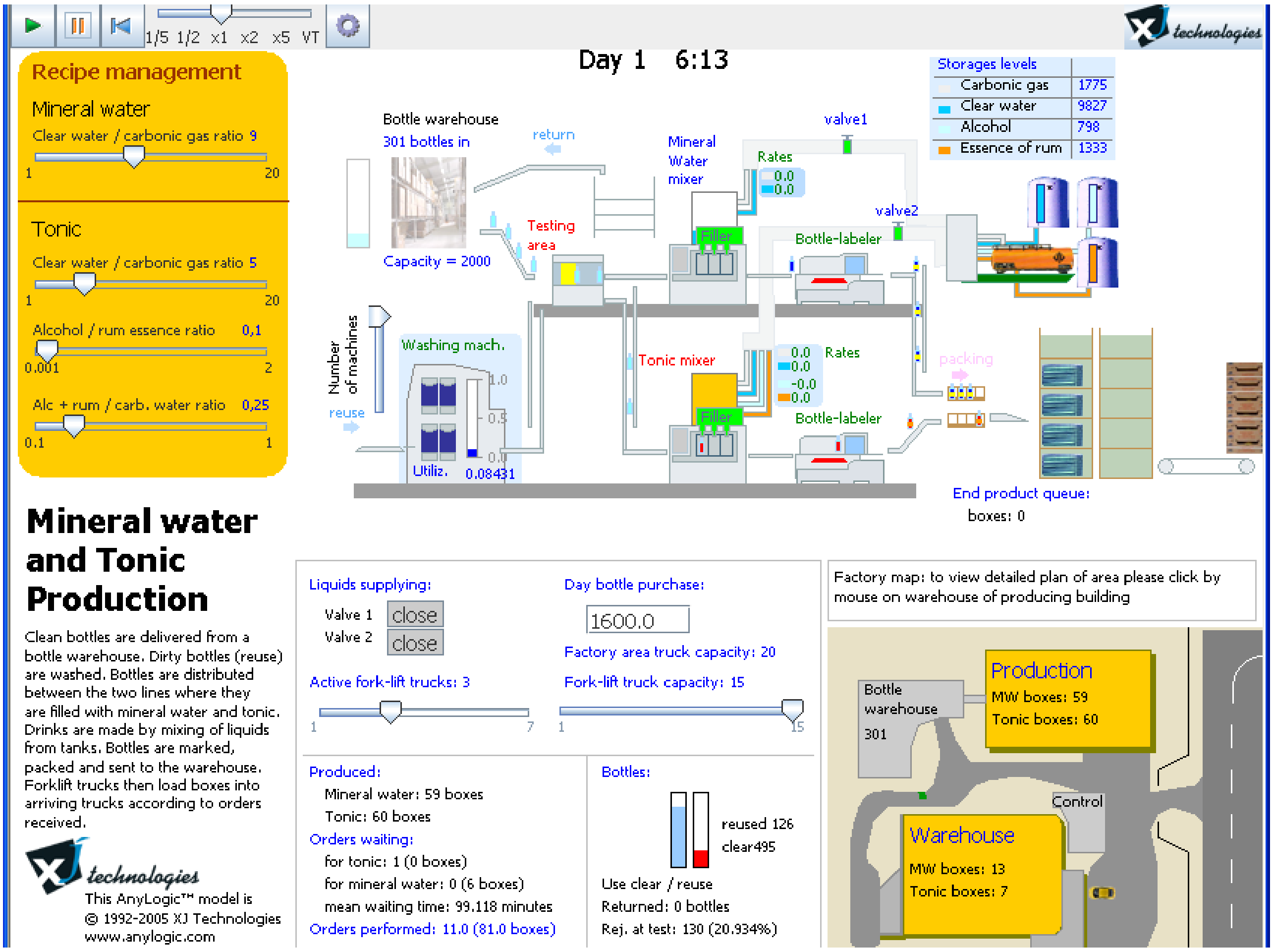
Graph 1 demonstrates examples of the work of the model, imitating technological line for production of mineral water and tonic, including storage and supplies of final product. The link for the working version of this model may be found at http://www.xjtek.com/anylogic/demo_models/manufacturing_logistics, the name of the model is **Beverage Production** (one can also find here the algorithms for running the model). The complete code of the model is included in distributive AnyLogic 5 (in "Examples" section, sub-section "Manufacturing and Logistics").

The working version of the model contains the following major elements (see graph 1a and graph 1b):

- Animated representation of all elements of technologic process for mineral water and tonic production, including indicator of the current condition for each of the elements;
- Menu of the model, including seven changeable parameters, allowing for variation of certain conditions of the work for the given technological process (recipe of mineral water and tonic, the amount of washing machines, the amount of lifting and unloading machines and containers, they can transport);
- Text explanations for output information as well as description how to shift animated presentation of production either to the technological line or to the warehouse of the products (graph 1a demonstrates technological line and the graph 1b – warehouse).

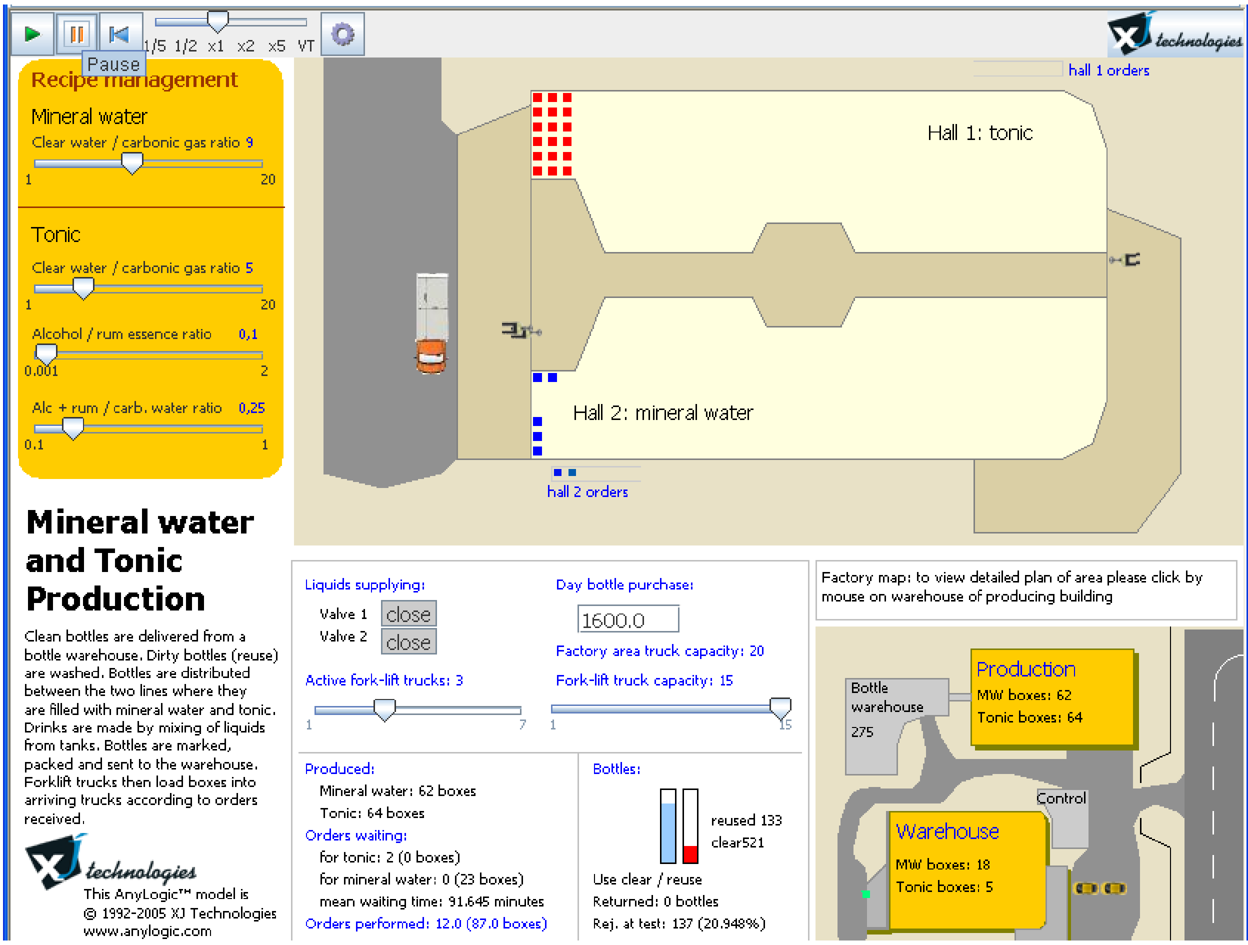
In running the model animated scheme of technologic process moves from left to right. Empty bottles come from the two sources: the new and previously used ones. Previously used bottles first go to the washing machines (the number of washing machines can be set). Then the bottles from the two sources undergo checking procedure and then distributed into two streams for the line of preparing mineral water and tonic. The beverages are produced from the ingredients, the stock of which is set in the model: water, carbon dioxide, alcohol and rum essence, mixed in set proportions (proportions may be changed by "recipe" parameters). The filled bottles are gone through two apparatus of attaching stickers, and then stored into boxes. As soon as five boxes of beverages appear at the end of technological line (graph 1a), the car arrives and takes them to the warehouse in container.

At the warehouse (graph 1b) the cars are unloaded on the left of animated scheme by two lifting and unloading machines. Containers with mineral water are stored in the lower part of warehouse, and with tonic – in the upper part. Another lifting and unloading machine transports containers to the right part of warehouse, where they are taken by cars of consumers. The amount of bottles bought per day is preset in the model (1600 bottles).



Graph 1a. The example of work of the model "Mineral water and Tonic Production" (technological line)

The model is a perfect animated presentation of the corresponding production. It offers its managers simple for understanding and compact information about the condition of all the processes/elements of technological cycle in the set periods of time. Creating similar level of information acknowledgement with the help of tables and graphs would require much more effort both from managers and from analysts. Adjusted parameters of the model allow analyzing the consequences of certain factor change during the very work of the model. These changes could be, for example, the damage of transporting machines, changes in the recipe of beverages etc. the amount of such adjusted parameters of the model may be increased, if necessary.



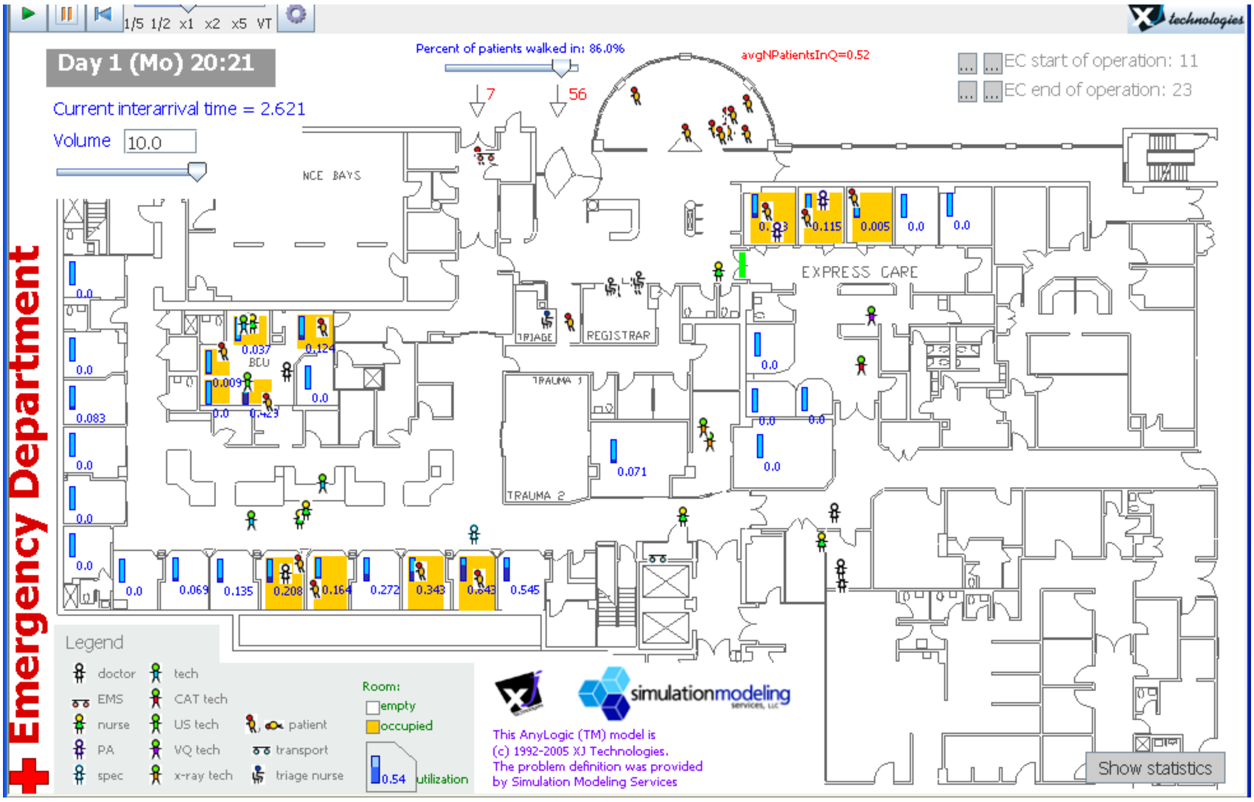
Graph 1b. The example of work of the model “Mineral water and Tonic Production” (warehouse)

Model “Emergency Department”

Graph 2 shows the work of the model, imitating functioning of emergency department of a large hospital, including detailed statistics of the usage of departmental resources. The link to the working version of the model may be found at http://www.xjtek.com/anylogic/demo_models/healthcare under the name **Emergency Department**. The full code of this model is included in distributive AnyLogic 5 (is placed in “Examples” section in “Healthcare” subsection). Karpov (2006) provides detailed description of the work of the simplified version of the model (page 280), as well as of the history for creating the full version of the model (page 354).

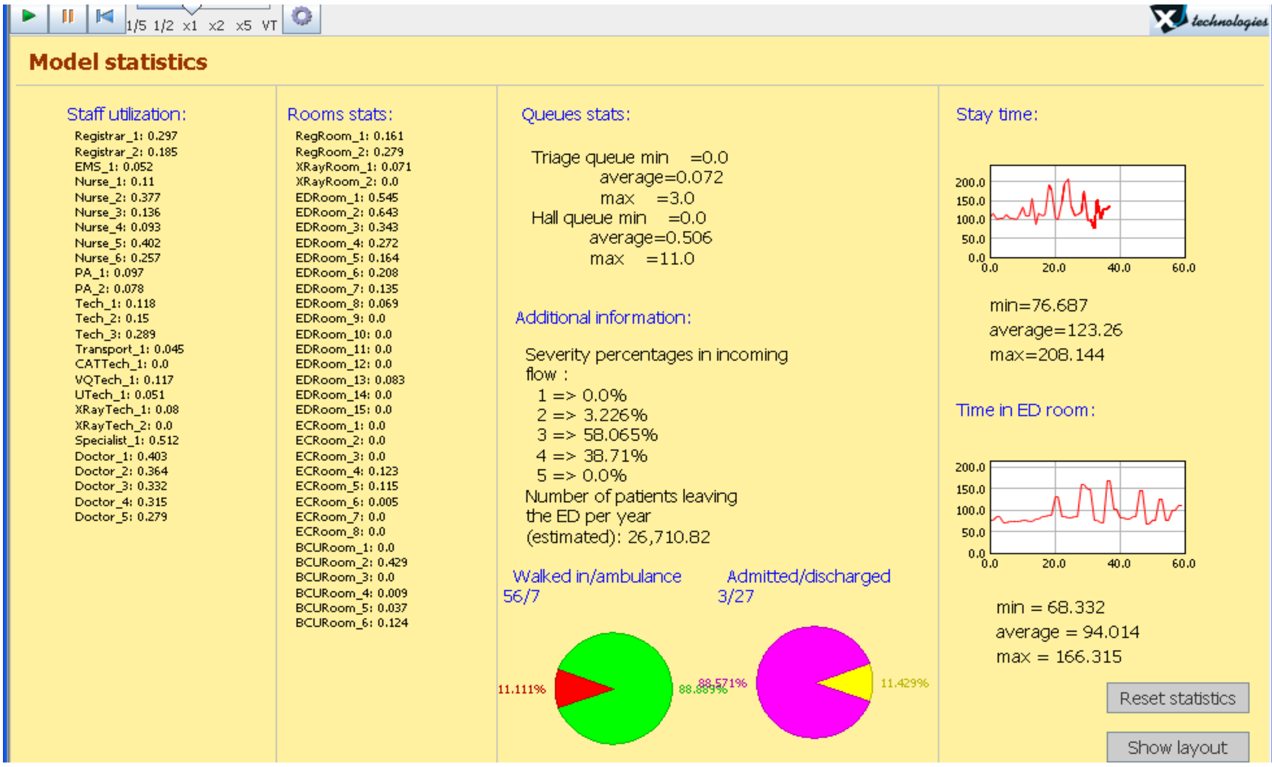
In the working form the model contains the same major elements, as the previous model. However, here there are only two adjusted parameters: 1) a number of patients, coming to the department in the moment of model time (in the example it equals to 10); 2) percentage of patients, who can walk in, among all the patients coming to the department.

The Emergence Department model imitates care offered by department to incoming flow of patients with random distribution of their traumas and illnesses. Departmental resources consist of a set number of specialists of various categories (see graph 2b, the list in the column **Staff utilization**), a number of specialized facilities and working time of specialists.



Graph 2a. The example of the work of the model "Emergency Department" (main scheme)

Additional limitation is organization of the space in department, since movements of patients and personnel in this space require time, may cause delays in serving the patients, and may create additional queues etc. Each coming patient receives a special scheme of treatment, depending on his/her type of illness. Implementation of this scheme is visualized in animated presentation by moving the patient from one room to another, including movements accompanied by personnel; waiting till the necessary specialist or room is free etc.



Graph 2b. The example of the work of the model "Emergency Department" (Summary statistics)

Summary statistics (graph 2b) demonstrates among other the current indicators of the usage of departmental resources, average waiting time, total time, spent by patient in the department, including the time in the rooms.

Such computer simulation model visually demonstrates functioning of large/complex organizational systems, which is almost impossible to visualize by traditional means. Complex organizational mechanism is shown here as realistic picture of the changes for elements condition and links between them. The leader of such organization may use the model to analyze actual and possible reasons for emergence of lines and imitate accessible ways of improving the situation. The analysis of various scenarios of events development and the search for best solutions (including solving optimization tasks) is also possible.

Such model may become a useful tool of information for patients as well, if it is connected with informational system of organization and is regularly activated on the basis of the resulting real data (the intensity of specialist' work, the length of patient line etc.). The model may help patients obtain the forecast for the waiting time, estimate the total time and the required scheme of their treatment. The relatives of the patients may monitor this information through Internet.

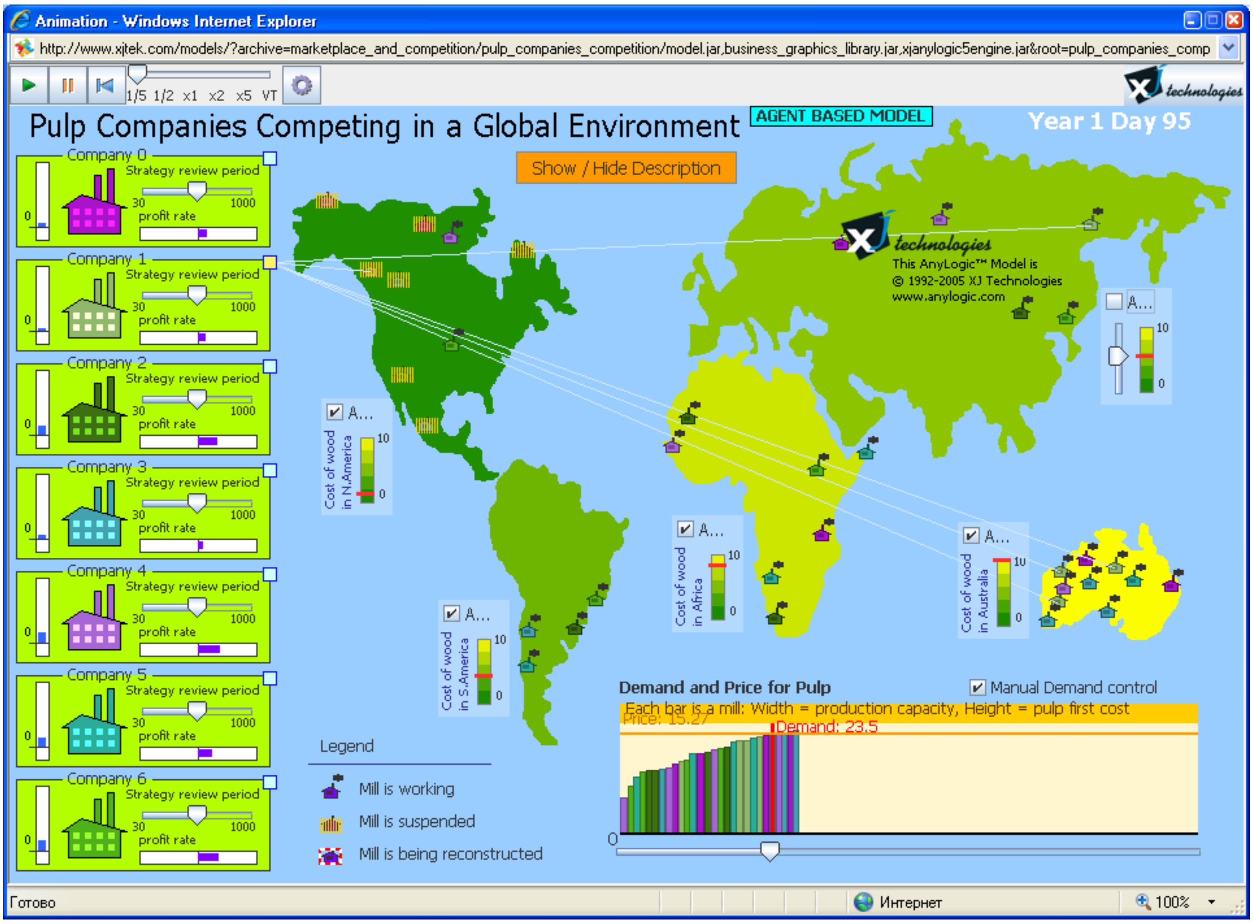
Model "Global Competition of Pulp Producing Companies"

Graph 3 demonstrates an example of the work of the model, imitating functioning of six transnational pulp producing companies (companies have several enterprises situated in different continents). Model simulates competition at the global pulp market, where companies with lower product cost (depending on the wood cost in the corresponding continents) receive comparative advantage. The link to the working version of the model may be found at http://www.xjtek.com/anylogic/demo_models/marketplace_competition under the name **Pulp Companies Competition**. The full original code of the model is included in distributive of AnyLogic 5 (in "Examples" section, "Marketplace and competition" subsection).

The adjusted parameters of the model include:

- world demand for pulp, which is changed by the moving indicator in the lower right part of the graph under the histogram **Demand and Price for Pulp**;
- cost of pulp at each continent, the current level of which is demonstrated by color/digital indicator, situated next to each continent (see **Cost of wood in …**); the color of the continent corresponds to the current cost of pulp, preset at the indicator. The color indicator allows changing the cost of the wood at the corresponding continent (if check box of the corresponding indicator is taken off, see example of Eurasia continent indicator);

- period of time, after which the company assesses the results of its activity and according to these results makes a decision about the change of its plants' status (suspension, reconstruction or closing). The value is changed by the arrow in the window of corresponding company (see **Strategy review period**), situated in the left part of animated model presentation.



Graph 3. The example of the work of the model "Pulp companies competition"

Each separate plant is represented by the capacity parameters and technological level. The cost of pulp production at a plant depends on the wood cost at the continent, where the plant is situated, and on the technological level of the plant. With regard to the current pulp price, a plant may turn out to be profitable or not.

The world pulp price is set in the model at its cost level at the final plant (the plants are ordered by the growth of cost), whose production is still necessary for satiating the world demand for pulp. The final plant has zero profitability. On the histogram **Demand and Price for Pulp** (at the lower right on Graph 3) profitable plants are situated to the left of the red line, marking the set level of world demand for pulp, and non-profitable ones – to the right of the line.

Parameters "world demand for pulp" and "the cost of wood" at the continents are assumed to be changed according to sinusoid inside the model, provided these parameters are not adjusted manually through arrows.

All the six companies implement similar strategy in the model:

- if working plant becomes unprofitable, it is suspended;
- if suspended plant may become profitable, it resembles work, otherwise it is reconstructed;
- plants, which have been reconstructed for several times and have not become profitable, are closed;
- if world demand for pulp is not satiated and the company is not big enough (the number of its plants is lower then the limit set in the model) it creates new plants in the regions with the cheapest wood.

Such simulation model is an example of describing behavior of independent agents with conflicts of interests (the gain of the ones means the loss of the others). In the case of equal opportunities of the participants, the optimal strategy is the necessity of negotiations and coordination of actions. The model creates conditions for coordinating the actions of the participants and may be an instrument, simplifying sustainability of independent coordinated agents by the system.

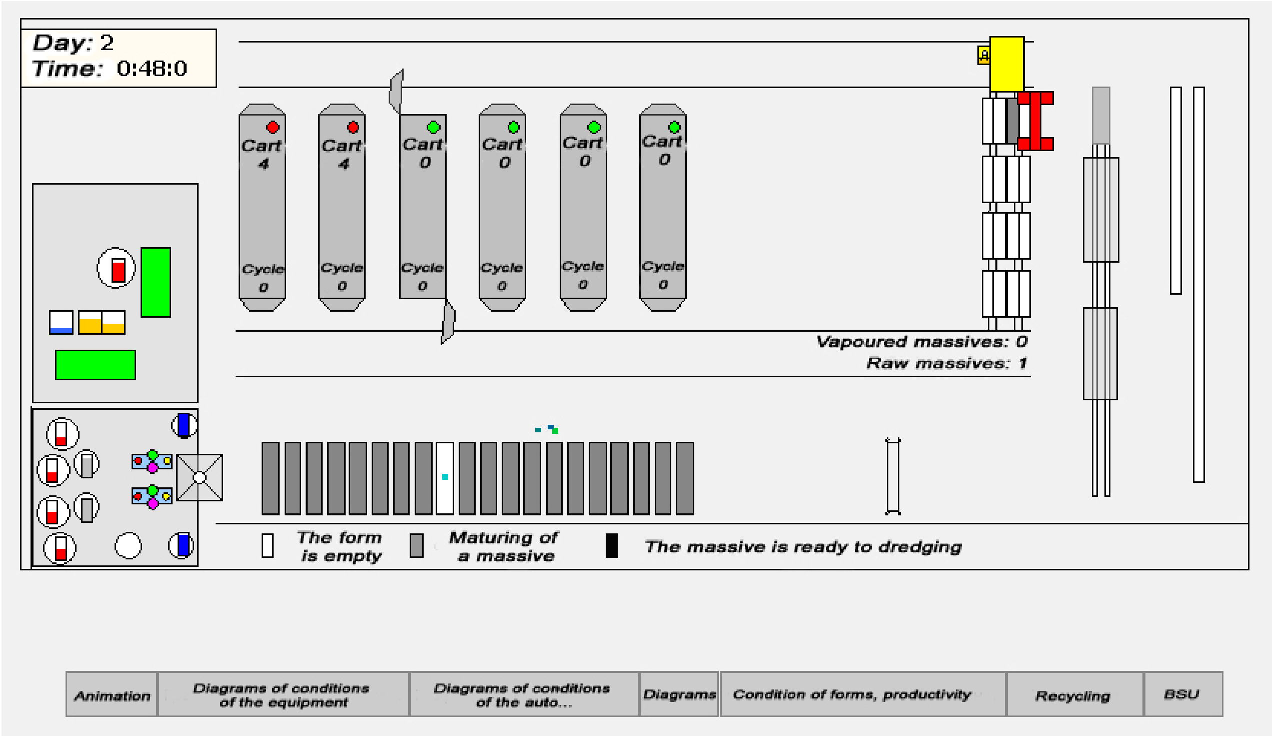
Model "Foam concrete production"

Graphs 4-5 demonstrate the example of work of the model, simulating technologic line for foam concrete production. As opposed to other models, the model does not have an open executive version and is not included in the distributive for **AnyLogic**. The model is developed by the company **XJ Technologies** with the help of **AnyLogic** by the order of **SET holding**. The examples of the model work are presented in this section at permission of **SET holding,** the owner of this simulation version.

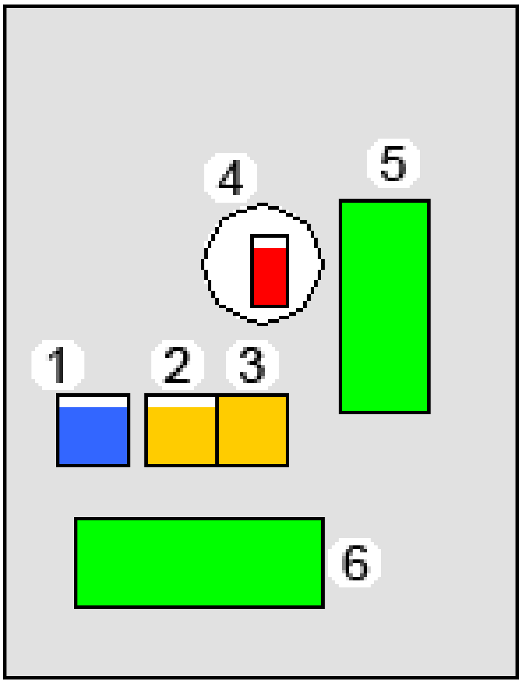
Simulation computer model of foam concrete production was created for solving a practical task: the department of foam concrete production, constructed by SET holding in Orlov region, could not reach the pre-calculated capacity. The managers of the department explained this by innovative character, complexity and novelty of production technology. The aim of creating computer simulation of production process was to analyze this situation, to understand the role of "human factor" in the problem of foam concrete production, as well as to reach better mutual understanding between the leaders of the plant and the managers of SET holding.

The model simulates the whole production process with high degree of precision. The process starts with preparation of concrete mix (grinding department on the left of Graph 4) from the existing stock of raw materials. Then the mix is poured by concrete moving cart into forms (Graph 4 shows 20 forms as grey rectangles in the lower part of the drawing, one form is currently empty). The spatial structure of the autoclave department (in the center of Graph 4) is close to the real one. The structure of grinding department is not so important, therefore, it is not shown as the block with raw materials stock level indicators. The scheme of department reflects all current production processes, e.g. pouring of the forms, movement of carts and cranes, movements of workers and foam concrete blocks, opening and closing of autoclaves, cutting, division etc.

The adjusted parameters of the model allow changing the number of the forms for pouring the mix, the number of autoclaves for maturing of products, as well as provide for imitating of different types of breaking of equipments and extreme situations, arising in the set production. The structure of extreme situations possible for simulations and the output data of the model are presented below.



Graph 4. The example of work of the model "Foam concrete production"



Graph 5. Indicators of milling divisions

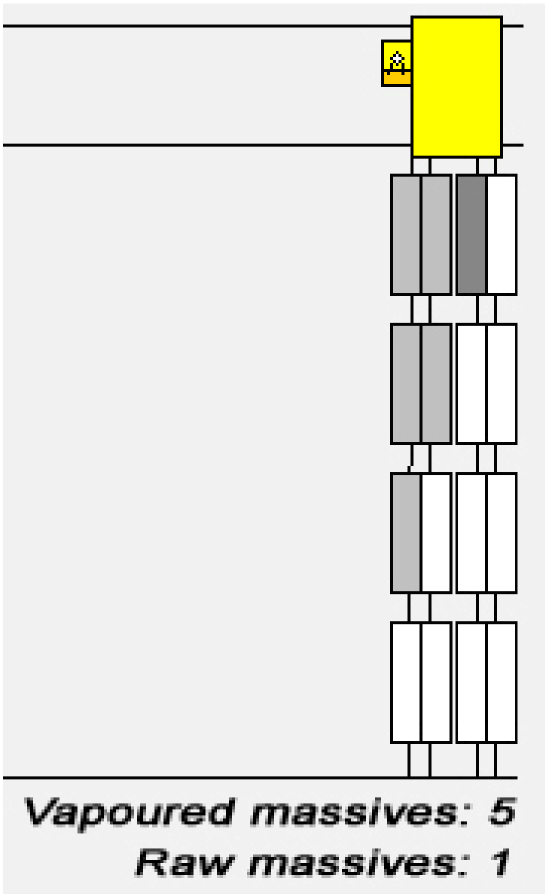
Division is presented in model animation as the block of changing indicator (see this fragment on Graph 5):

1. indicator of occupancy level of the input lime bunker;

2. indicator of occupancy level of input sand level (for mill of wet milling);
3. indicator of occupancy level of the second sand bunker (for mill of dry milling);
4. indicator of slime storage occupancy level;
5. indicator of wet milling mill work (green – works, red – does not work;
6. indicator of dry milling mill work (green – works, red – does not work.

The department has resource bunkers of slime, cement and gluing mix. The levels of their occupancy are reflected by indicators, placed under the milling division indicators on Graph 4.

The matured products, which have undergone cutting and have been waiting for shipping into autoclave, as well as forms, vapored in autoclaves and waiting the line for division, are stored in a certain place. In model animation it looks in the following way:

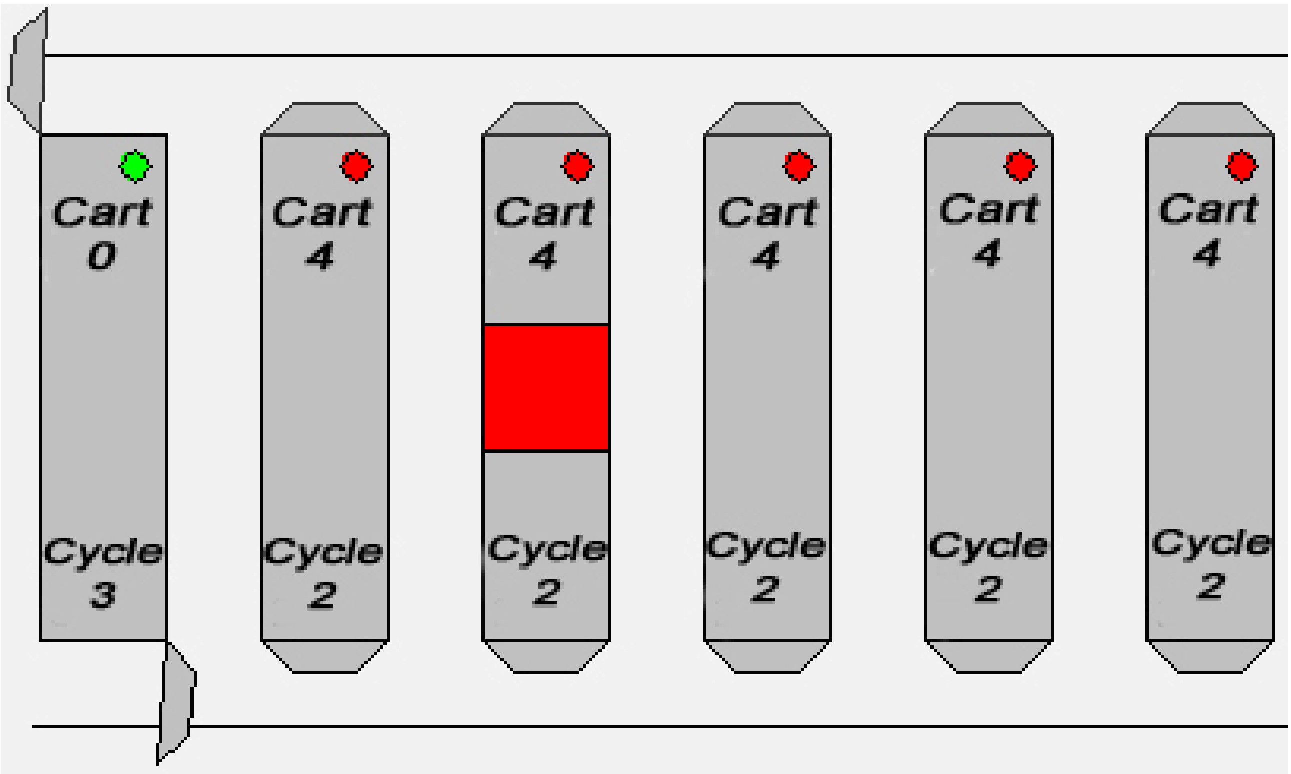


Graph 6. Storage of the forms.

The light-grey blocks represent the vapored forms and dark-grey ones – not yet vapored forms, which have undergone cutting.

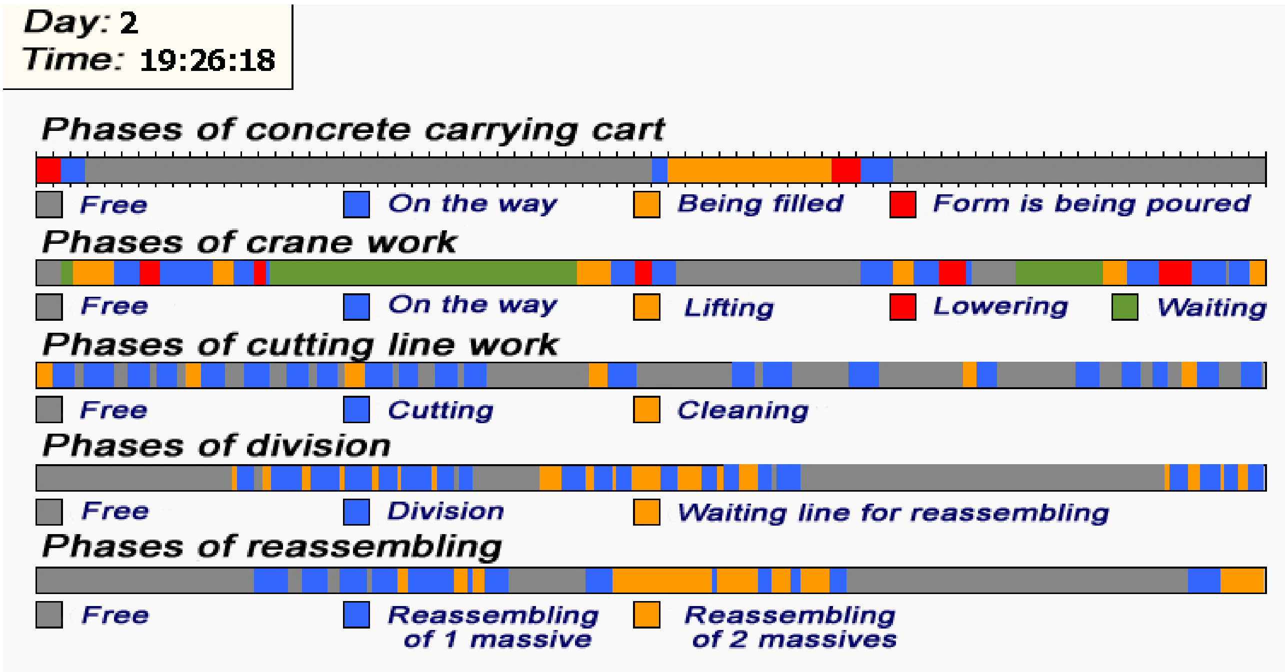
Autoclaves have a number of indicators, reflecting their condition (see Graph 7):

- the amount of carts – this figure reflects the number of pairs of foam concrete blocks in autoclave;
- the cycle – reflects the number of vaporing cycles, made by given autoclave;
- circle indicator, having the two colors, reflects the condition of autoclave. Red color means that autoclave is in vaporing process, and green indicator – that autoclave is not used in vaporing;
- red rectangle means that autoclave is broken.



Graph 7. Indicators of autoclaves

The model has a special section «Diagrams of equipment condition» (see the button, opening this section below on graph 4). This section allows tracking dynamics of the changes in the phases of equipment work (graph 8).

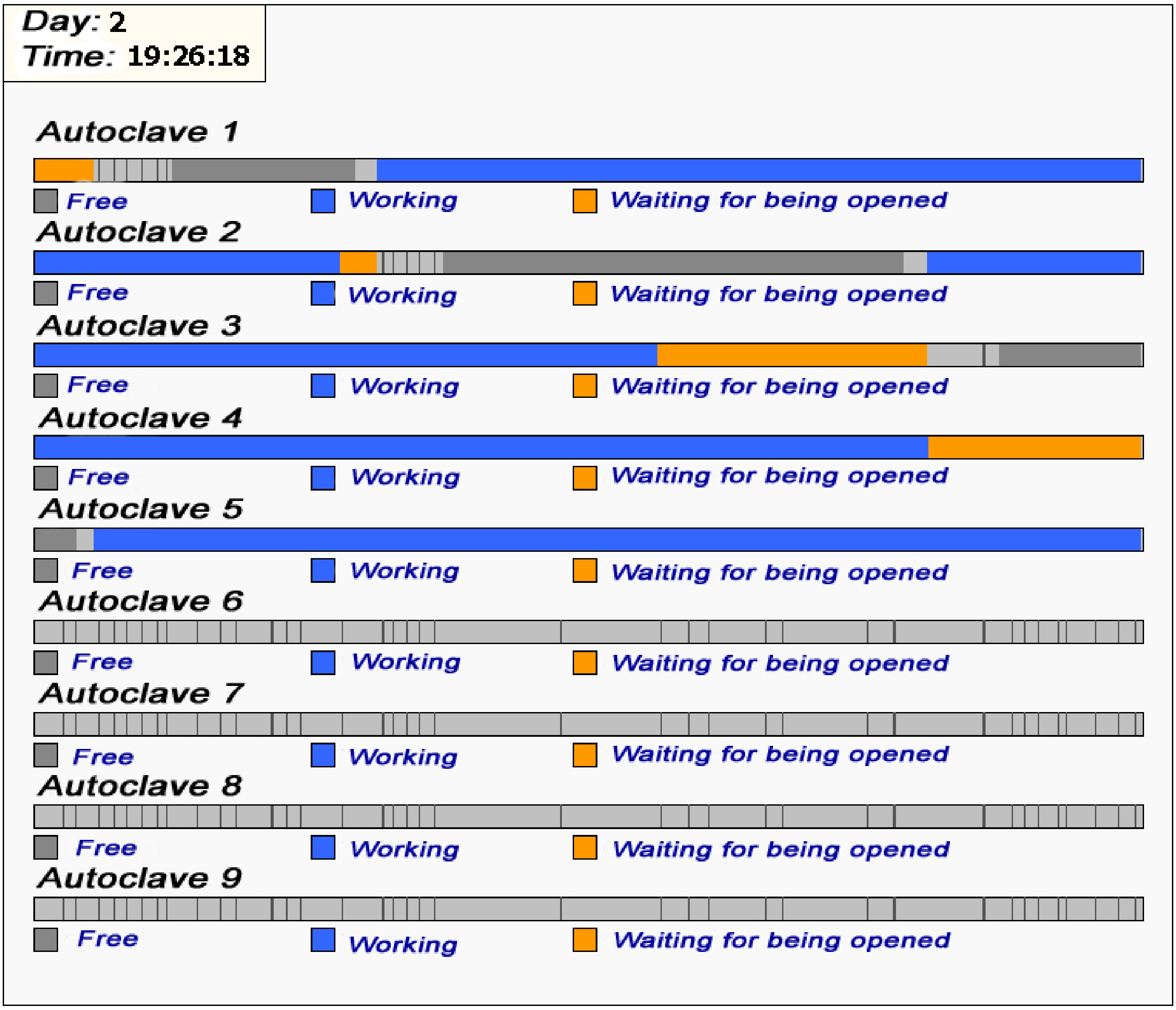


Graph 8. Diagram of equipment condition

Phase diagrams demonstrate the sequence of actions, completed by equipment. For example, on this phase diagram of crane work the typical sequence is the following «Free» → «On the way» → «Lifting» → «On the way» → «Lowering» → «On the way» → «Empty». These diagrams also allow visual assessment of the proportion of time of equipment work and rest.

The data from another section of the model "Diagrams of autoclaves condition" are analogous to diagrams of equipment condition. Graph 9 shows that the three last autoclaves are not active, since simulation is run with six autoclaves.

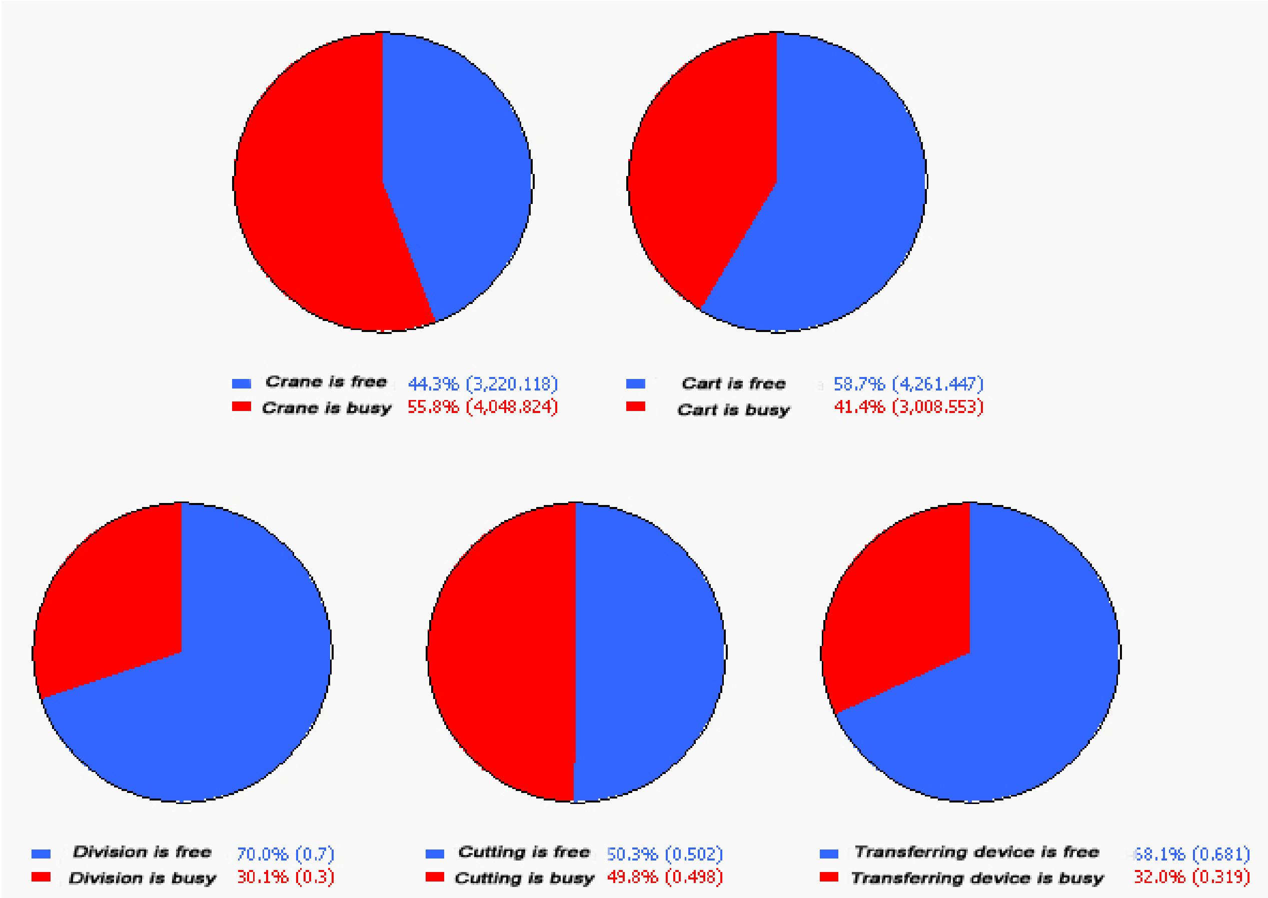
The model allows viewing the diagrams of various parameters for enterprise work, which reflect the intensity of resource usage (the degree of cutting and forming devices being busy, the size of line for division and the number of поддонов used). The model also demonstrates daily statistics about the amount of final products (divided and dismantled), as well as condition of each of the forms for pouring and total amount of free forms. These diagrams help monitoring dynamics of productivity and completeness of forms usage.



Graph 9. Diagrams of autoclaves condition

The "utilizing" subsection of the model shows circle diagram, demonstrating the degree of machine and production apparatus utilization (cutting, division device, transmission mechanism, crane, cart, Graph 10).

All the data about time characteristics for production processes (the length of various operations) are kept in the database and may be changed, if necessary. The database keeps, for example, the data of production process timing (the results of measurements of the length of operations in minutes). For each of the operation types there are usually several measurements results. The necessary value for model calculations is estimated via normal distribution. If for a certain type of operation there is only one value, it is used in calculations by itself.



Graph 10. The level of machine and apparatus usage

The above described model for foam concrete production demonstrates a real example of applying computer simulation for analyzing the problems and making decisions in complex technologic and organizational systems. The workers of the plant regarded it as a precise instrument for simulating the production process and for forecasting changes. This model provides manager with information which can be interpreted easier than traditional tables and graphs. It also gives operative picture of the plant functioning, enables manager to analyze the consequences of different breakdown and extreme situations. Due to its precision the model may serve an example of plant work, setting the normative for production processes, which would become a benchmark for determining the causes of variations.

See other publications about modern applied simulation modeling at http://www.xjtek.com/support/download/papers.

Scientific simulation modeling

Computer simulation modeling has been actively used for scientific research of the properties and special features of socio-economic systems for a long time. The reflection of the effectiveness of this approach is formation of independent research fields (computational economics[1], computational sociology[2] within various social sciences.

Modern direction of simulation modeling development in social sciences is formation of agent-based approaches in presenting behavior of socio-economic systems and creation of corresponding modeling complexes. The new scientific approach "Agent-based Computational Economics" (ACE)[3], developing methodology of computer modeled research of economic processes as dynamics systems of interacting agents, has already become quite popular. Axelrod and Tesfatsion distinguish four major goals of applying ACE in scientific research:

1) empirical research of socio-economic regulation systems and processes behavior (macro level), arising As a result of specific activity of a large amount of agents with own behavior at the micro level;

2) normative research of artificial socio-economic system functioning by computer simulations, which is one of the elements of modern organizational and institutional design for constructing socio-economic systems with pre-set properties;

3) qualitative analysis and theoretic generalization of the processes for socio-economic systems self-organization;

[1] http://en.wikipedia.org/wiki/Computational_economics
[2] http://en.wikipedia.org/wiki/Computational_sociology
[3] http://www.econ.iastate.edu/tesfatsi/ace.htm

4) development of methodology and scientific instrument for studying socio-economic systems and processes of their advance in modern world.

To obtain a systematic picture of scientific applications for simulation modeling we recommend the article Axelrod and Tesfatsion, which offers in-depth list of references and sources, illustrating the variety of forms and applications of agent-based modeling in social sciences as a whole and in economics in particular. The list of references is divided into the following blocks:

- Complexity and ABM;
- Emergence of Collective Behavior;
- Evolution;
- Learning;
- Norms;
- Markets;
- Institutional Design;
- Networks;
- Modeling Techniques.

Additional information about special features of using simulation modeling in modern research[4] in Russian language may be found in Makarov and Bakhtizin (2007), Tukhveber and Redko (2005), Parinov (2002).

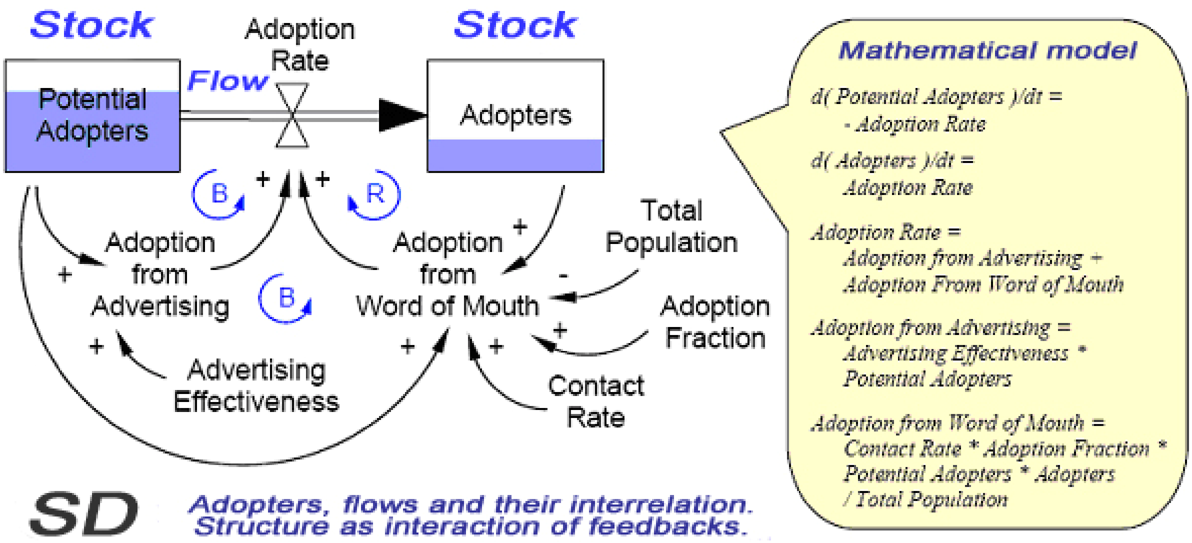
Below there is the list of innovations, which happened in recent years in methodological and programming instruments for simulation modeling. They offered new perspectives for applied modeling, as well as for its usage for research.

New approaches and instruments of simulation modeling

Modern computer simulation modeling of socio-economic systems and processes is a combination of three[5] main approaches: 1) system dynamics, 2)discrete

[4] Publications in the Journal of Artificial Societies and Social Simulation (JASSS) (http://jasss.soc.surrey.ac.uk) deals exclusively with this issue

events and 3)agent modeling. Borschev offers diagrams, illustrating special features of these approaches (Graphs 11-13).

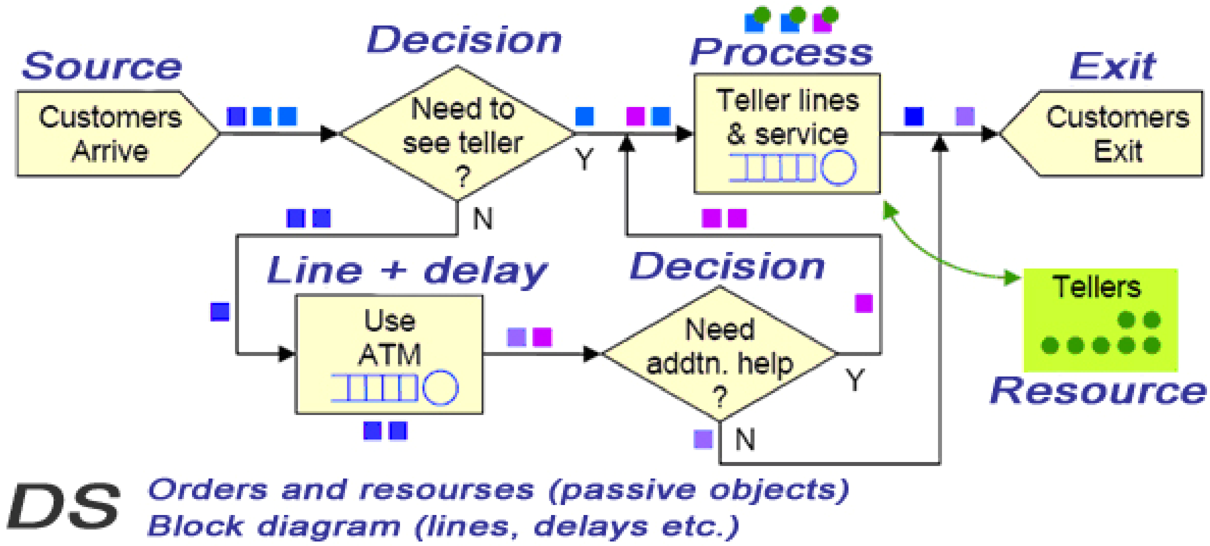


Graph 11. The example of system dynamics model structure (Borschev, p. 5)

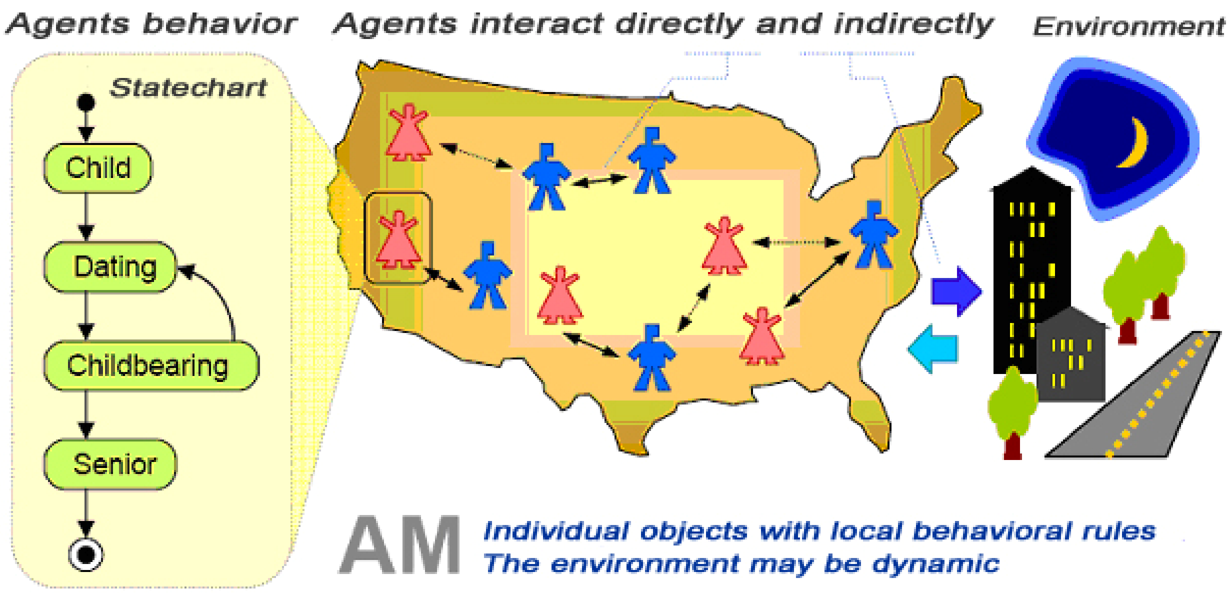
The special feature of the first approach (system dynamics) is presentation of the described socio-economic processes in the terms of “stocks” and “flows” and their increases. Models of this type are well-known in economic science, for example, the model “World dynamics” of Jay Forrester. Borschev (P.5) notes, that “modeling in system dynamics style, one regards the structure and behavior of the system as a set of interacting positive and negative feedbacks and delays”. This is demonstrated on Graph 11.

Discrete events modeling is described in Borschev (p.7) in the following way: the entities passive objects, representing people, details, documents, tasks, messages etc. travel through flowchart, stay in lines, are being processed, acquire and release resources, divide, unite etc. Typical flowchart is shown of Graph 12.

[5] Literature (e.g., Borschev) mentions the fourth approach: dynamics systems. However, we treat it as not widely applicable one in socio-economic problems.



Graph 12. The example of discrete events model structure (Borschev, p. 7)



Graph 13. The example of agent based model structure (Borschev, p. 8)

Agent modeling requires determining a set (it may be very large) of relatively independent modeled agents, whose behavior has an influence on each other and on their environment. Agents receive influence from the environment as well. The rules for agent behavior are set on individual level (see Graph 13, the left state chart in agent sub-model). Global model behavior emerges as a result of multiple agent activity (tens, hundreds, thousands, millions agents), each of them follows its own rules, "exists" in the common environment and interacts with the environment and other agents (Borschev, p. 8). Graph 13 provides an illustration to this statement.

Agent-based approach is I a certain sense the most general with regard to the first two, since it allows implementing all other approaches inside itself (see above diagrams 1-2). Agent-based model may include objects of varying qualities, in modeling which one could employ methods of system dynamics, discrete events, optimization etc.

In practice possibility of using combined processed for creating simulation models is fully determined by functionality by the chosen package for modeling.

Certain simulation modeling packages are narrow specialized, e.g. exclusively for agent-based modeling (RePast). At the same time they may have rather developed constructive base, but may not allow combining various approaches of simulation modeling. The package **AnyLogic 6** is not narrow specialized for agent based modeling. Therefore, in the contents of its constructive elements it does not lose to other packages, and on the contrary wins considerably due to possibilities for combining approaches.

A typical structure of agent-based model, which may be constructed in **AnyLogic 6**, is presented in Diagram 3. The details are provided in the followings section.

The above mentioned approaches in their different combinations are the essence of large number of programming packages. A list of packages for simulation modeling may be found at http://www.econ.iastate.edu/tesfatsi/acecode.htm. The package **AnyLogic** is mentioned among the first entities on the list.

Possibilities of AnyLogic

Since particular aspects of **AnyLogic** are described in detail in the following section, here we provide only its general description, borrowed from English language instruction to **AnyLogic 6**. Further general knowledge about the history of **AnyLogic** creation etc. may be found in Borschev, p. 18.

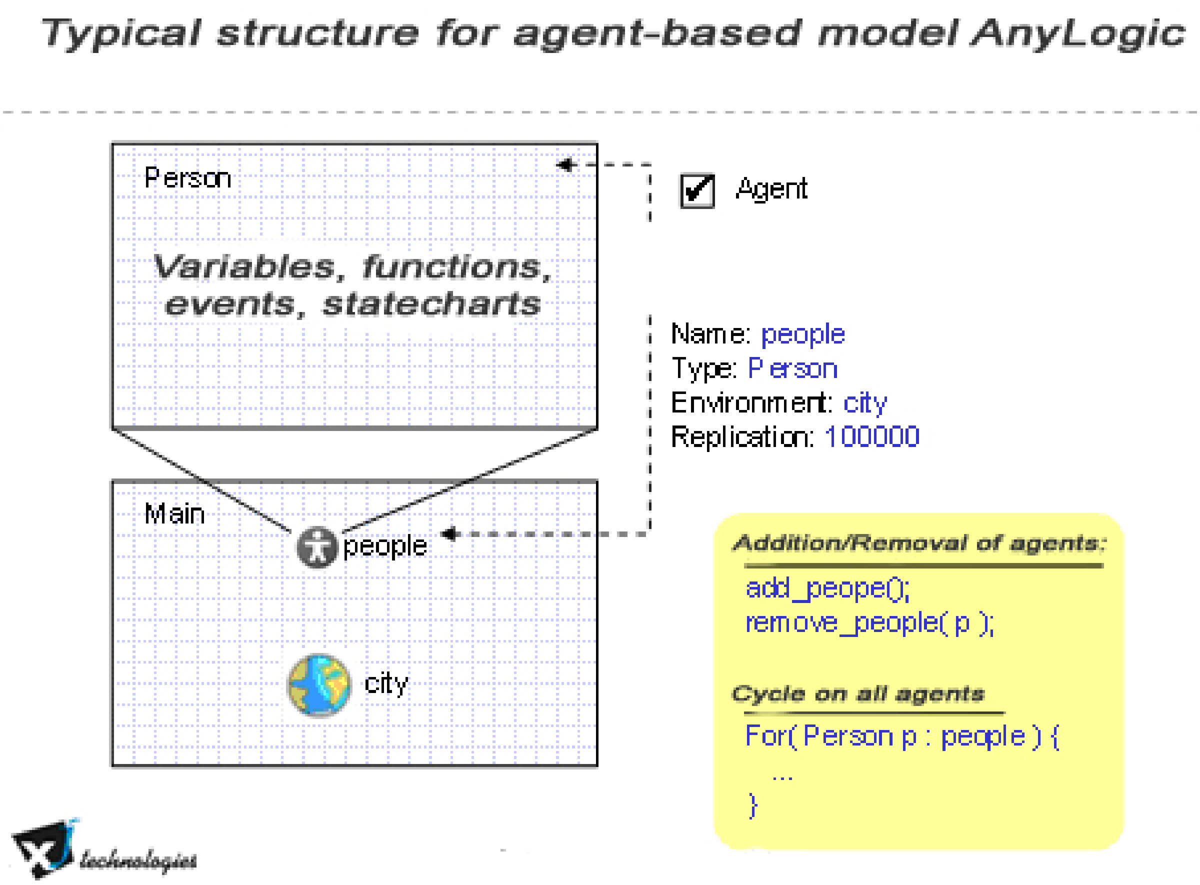


Diagram 3. The scheme of model realization of agent in AnyLogic 6

Certain advantages of **AnyLogic** have already been demonstrated in our discussion: models on Graphs 1-10 care created with the help of this very package. We also mentioned the possibilities of combining the three major approaches of modern simulation modeling.

The package allows creating complex two-dimensional visual presentations of the model work, with the help of the object structure of the very model (see examples of model presentations on Graphs 1-4). Presentations are constructed with the given set of figures (circle, rectangle, line etc.) and functions for managing them. Each figure has adjusted parameters for determining its visual representation (placement, height, width, color) in presentation.

All the figures have dynamic options (among adjusted parameters) allowing to determine the link between visual representation of the figure and current values of certain time variables of the model. Therefore, presentation will show how certain objects and their states change in the course of simulation. The examples of animated model presentations may be seen, if one runs the executive codes of the models, offered in description of the first three models in the section "Applied simulation modeling".

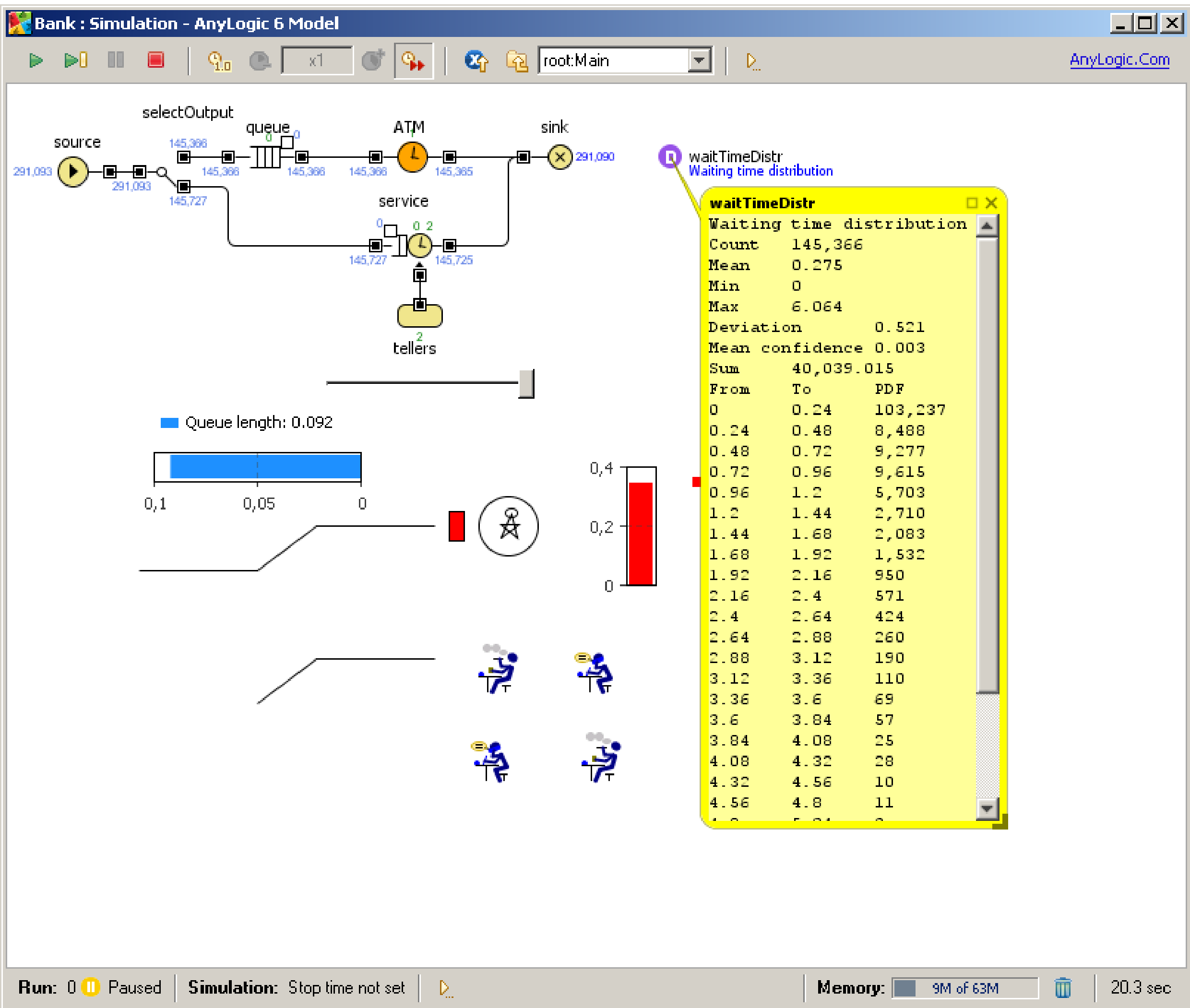


Diagram 5. The example of creating output for current states of the variables and parameters of the model

Model presentations may be made interactive (see built-in menus for changing parameters of the models during their work on Graphs 1-4), since **AnyLogic** offers a large variety of ruling elements (buttons, text input, check boxes, crawlers etc.). With the help of these tools the variables and parameters of the model may change in the course of simulation.

Model presentations may be multi-level (have hierarchy), transferring hierarchy of objects of the model. Presentations offer a set of modules, created separately for each object (Graph 1 presents objects "technological line", "warehouse of final product", "containers with bottles", "lifting and unloading machine" etc.). These modules for low level objects may be included in presentations of objects with higher level of hierarchy. **AnyLogic** controls the due assembly of modules within the visual picture, including placement and transformation of all the elements of presentations.

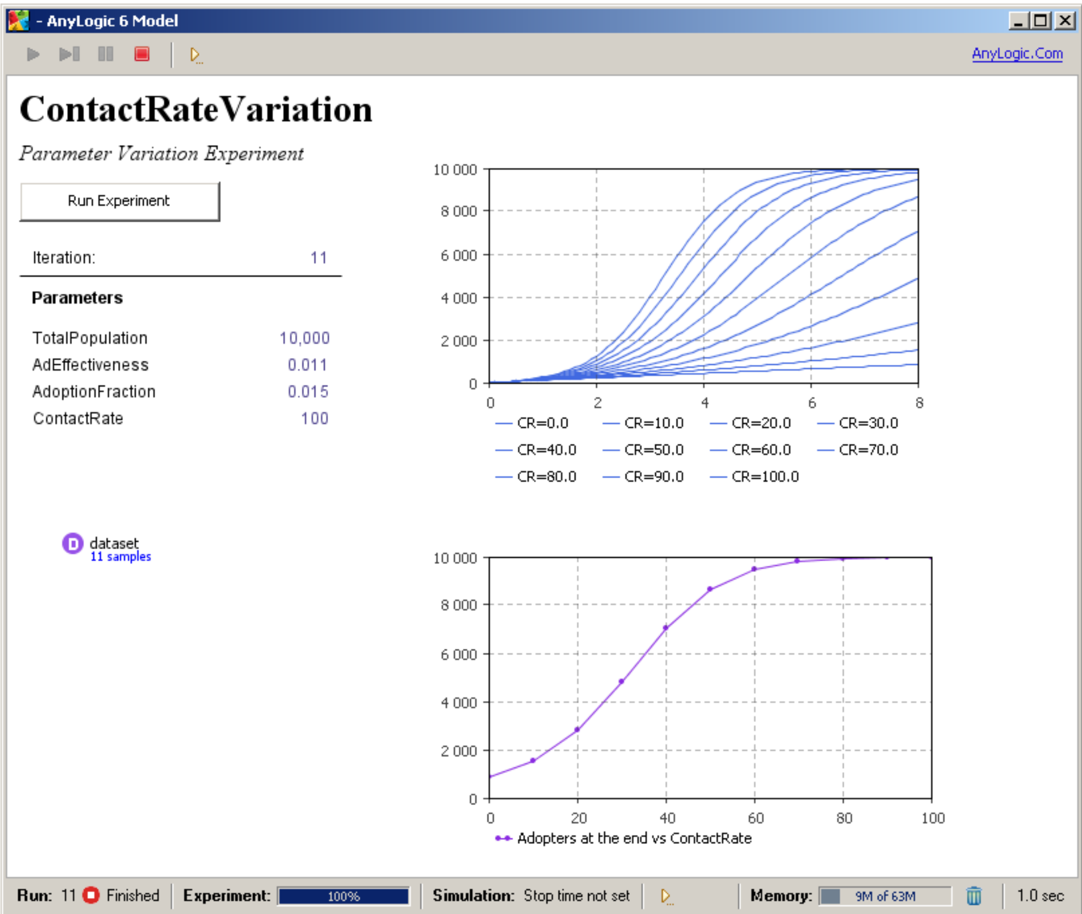


Diagram 6. The example of static experiment with model parameters

AnyLogic has developed tools for visualizing the results of model work, apart from built-in graphics. Diagram 5 demonstrates graphic diagram of the model, which shows how current parameters and variables values are represented in output form. The diagram also gives an example of "inspect" window, which may be opened for viewing conditions of the current state of the model.

This package has built-in tools for static analysis of the model. Diagram 6 offers an example of creating output of static experiment in one of the models.

Conclusion

Recent methodological and instrumental achievements in computer simulation modeling create opportunities for describing and studying complex socio-economic systems without the need of their considerable simplification.

The article illustrated the advantages of these innovations in applications to practical tasks of analyzing and managing complex business systems.

In applying these models innovations to scientific research the issue of studying socio-economic potential of organizational structures may be regarded as the most perspective one. Possibilities of modern agent-based modeling allow presenting large and complexly organized social systems as networks of a large number of independent interacting agents, having joint socio-economic activity. There emerges an opportunity for specification of network parameters and for determining mechanisms of their influence and on characteristics of socio-economic functioning. This, in turn, allows formalizing the scheme of analyzing socio-economic potential of organizational structures with regard to network parameters influence. There is also a possibility for analyzing scenarios and factors of socio-economic development, and of enhancing social efficiency by the means of varying network parameters.

References

1. Axelrod, Robert; Tesfatsion, Leigh. On-Line Guide for Newcomers to Agent-Based Modeling in the Social Sciences. http://www.econ.iastate.edu/tesfatsi/abmread.htm.

2. Tesfatsion, Leigh. Agent-Based Computational Economics. http://www.econ.iastate.edu/tesfatsi/ace.htm.

3. Borschev, Andrei. From System Dynamics and Traditional IM – to Applied Agent-based Models: the Objectives, Technology and Instruments. http://www.gpss.ru/paper/borshevarc.pdf.

4. Karpov, Yu.G. Simulational System Modeling. Introduction into Modeling with AnyLogic 5. Petersburg, BHV-Petersburg, 2006.

5. Makarov, V.L., Bakhtizin, A.R. Computer Modeling of Artificial Societies http://scmai.miem.edu.ru/S/s2.htm.

6. Parinov, S.I. On the Theory of Network Economics. Novosibirsk, IEOPP Siberian division RAS, 2002, Chapter 4, http://socionet.ru/RuPEc/xml/rus/book-ieieli/rusieieli97421.xml.

7. Tukhweber, S.M., Redko, V.G. Models of Multi-agent Economic Systems Evolution in Informational Society http://www.keldysh.ru/papers/2005/prep22/prep2005_22.html.

On Economic Issues of the Simple Model of Human Behavior

© V.A. Istratov (Moscow)

This article continues the series of introductory articles on the simple model of human behavior (Istratov, 2006, Istratov, 2007).

The simple model of human behavior stresses specific human characteristics, which has always been the issue for psychologists or sociologists. The model, however, is constructed for economic applications; therefore, this article will highlight certain features of the model which are of particular interest for economists.

There exist two types of agents in the model: individuals and organizations. The major and most obvious difference between the two types is the absence of personal characteristics (those include character features, emotional state, personal preferences and motivation) in organizations that interfere with making mathematically rational decisions by individuals. From this point of view organization is a more relevant reflection of the term *homo economicus* than an individual. Organizations are represented by firms, producing a certain good that is food. As an obvious consequence of the division in the above two types the model deals with employment which, however, is not described in the conventional way.

As was noted in the previous papers, the major incentive for individual is his inner necessity to perform a certain action. Employment is not an exception in this case, for individual has a genetically determined need to work – diligence, which is modeled as a function of a number of factors (mainly, income and cash). The feedback here is negative – the less he has or earns, the greater his desire to work in order to improve his well-being. Given the fixed payment (supposing a short-term period) an individual may only decide how many hours he would be working. After every individual has decided, whether he'll be working or not in the next period of time, we obtain the quantity of employees for the following period. At the end of this consequent period, individuals again face the choice of whether they should work or spend their time some other way. Agents get paid hourly in the model – the payment is conducted at the end of each working hour. This offers individuals possibility to work extra flexibly (to regulate the volume of professional activity in a much more flexible way than in fact is possible in most of the professions in real life).

Since the model is aimed at describing each particular individual, it does not seem reasonable at this stage to go into details of firm behavior. Therefore, firms are presented in a traditional way: each firm has its production function that determines its volume of production of food (in this case, food is the only product studied in the model). Function parameters are exogenous variables. Given that the costs of resources are fixed (assuming the short-term period), a firm can easily calculate its expenses and with a certain rate of profit (again, this is an exogenous parameter) is able to set the price of a unit of good. At this price food is offered to individual consumers. As opposed to individuals, a firm can not buy and resell goods for receiving profit.

The model also contains outside world, which is technically represented by the price of good, i.e. food. Outside world implies socio-economic structures and individuals that are directly related to production and distribution of good, but are only indirectly related (or even unrelated altogether) to the agents that are represented in the model. For instance, outside world may include producers, distributors or consumers of other countries or remote regions of Russia. And since they are located too far away, it is only the possibility to acquire goods they offer that matters. The way of ensuring this possibility is not relevant for the analysis.

As in other traditional mathematic exchange models, individuals have opportunity of accumulating the stock of food and money. At the same time individuals are not restrained by intra-model obligations to consume all the acquired goods. If the agent's value of good drops and the stock becomes too big, individual can sell the excessive amount.

In the model an individual has two potential sources of money: working and selling goods. Spare money is not invested and rather kept «under the blanket». Since the model deals with short-term period, we assume that individuals do not bring every received ruble to a bank or to an investment fund. This implies that there is no interest added on spare money in the model.

The model has some links to another field that is traditionally occupied by economists – the theory of expectations.

An individual is assumed to have expectations of certain results with regard to each action. These expectations are based on the experience of performing the corresponding actions before (Kahneman D., Thaler R.H., 2006). The model treats expectation so that it may enforce individual in his desire to accomplish this or that action, or may, on the contrary, prevent from performing an action. An individual remembers the results of the previous actions, but does not keep in the memory all of them.

Here we employ the theory (Kahneman D., Wakker P.P., Sarin R., 1997), proposing that the best remembered are initial and final moments of experience, as well as certain moments that were associated with particularly strong emotions (either positive or negative). All other moments of experience blend in the perception of individual, regardless of their total duration.

And the model mechanism of emotions (Istratov, 2007) suits here to determine emotional peaks – the moments of the most intense emotional experience (in mathematical terms, here we talk about local extremum). After calculating these peaks, it is determined which actions have led to such striking emotions. These are the very results that are kept in the memory of an individual. They serve the basis for him to decide what to expect from performing each of the actions.

If an action has been never performed before, the affect of experience for the first period is determined exogenously.

Obviously, it is not always easy to make distinction between the issues of different social sciences (economics, sociology, psychology). And this is natural since all these sciences have the same object of analysis, studied at different angles. This article was an attempt to underline the purely economic approach.

References

1. Istratov, V.A. (2006) Simple model of human behavior. *Artificial Societies*. Vol.1. No.1.

2. Istratov, V.A. (2007) Simple model of human behavior: new developments. *Artificial Societies*. Vol.2. No.1.

3. Kahneman D., Thaler R.H. (2006). Anomalies: utility maximization and experienced utility. *Journal of Economic Perspectives*, Vol. 20, No. 1

4. Kahneman D., Wakker P.P., Sarin R. Back to Bentham? Explorations of experienced utility. (1997). *The Quarterly Journal of Economics*, Vol.112, No.2.

Happiness as an economic issue

© *T.A. Konkova (Moscow)*

Recently the level of country's well-being is starting to be measured not only by per capita GDP, but also by the level of happiness. More scientists concentrate on the new field – economics of happiness. According to Clark, GDP doesn't describe all what is necessary. Clark thinks that the formula of happiness could become a new break through in economics. David Cameron introduced the concept of general well-being as an alternative to GDP. The science about happiness combines psychology and economics. The major issues is the question «Are you happy?», which is addressed to every citizen.

The economics of happiness is currently based on statistical data. Ruut Veenhoven from Rotterdam university has collected the database of thousands sociological surveys dealing with life satisfaction. Systemizing the data for the years 1995-2005, Veenhoven (2006) constructed the world happiness rating. The average happiness level according to this rating is 6 on the 10 point scale. Denmark, Sweden and iceland have the values of 8 points and above. The countries with the lowest happiness values (slightly above 3) are Zimbabwe and Tanzania.

Interpreting this data is not an easy task Currently, 3 tendencies have been discovered: the level of unemployment, disability and long comuting time to work have negative influence on happiness. Accroding to Veenhoven (1999) happy people live in economically developped societies with high level of civil rights and low level of corruption.

The low happiness values for post-soviet countries become an interesting result of the study. As for Veenhoven (2006) rating, Russia is one of the most unhappy countries. This paradox was hard to interpret and finally Veenhoven argued that this can be explained by the envy to well-to-do European countries and to rich Russians. This envy becomes the reason to dissatisfaction with one`s own life.

The 2001 happiness value for Russia equals to 4,4. Veenhoven estimates that Russia will reach the value of 6 points not earlier than in 10 years. This improvement in the feelings of Russians will be due to the rise in average per capita income. Fewer power people – fewer unhappy people.

Another unexpected result is the fact that while the richer are logically happier than the powerer, the developped countries do not become happier with economic growth.

The science about happiness offers two explanations to this paradox:

- capitalism transforms the luxury goods into necessities and brings elite consumption goods to mass consumption;
- people may not have the firm understanding of their needs. For example, widely advertised and hence rather expensive pyramid-shaped tea bags do not add much happiness to a person. When people do not remember their feelings, they can not forecast them well. People may have wrong expectations about the feelings due to moving to a new town or winning the lottery. The accused imagine solitary confinement much worse than it really is. Mother expecting babies think that the birth would be much more painful than it could be. This deals not only with unusual events in human life. People have difficulties in predicting their tastes in music or in choosing the type of ice-cream.

It may be argued that the following considerations might be added to explanation of the above developing countries paradox:

- with pace of life acceleration we lose the feeling of difference between casual (work) and holiday clothes people easily go to theatre or restaurant after work;
- the same can be applied to food, people can afford good food any time.

It should be also taken into consideration, that a considerable part of happiness is its expectation. And what might be expected if everything is already present?

What could economists advise in this case? One of the opinions – people should work less, even if it leads to deterioration of their life style.

In England this new fields of science is taken so seriously, that recently the Government working group on well-being was formed in order to develop the happiness parameters as well as recommendations for their growth. According to LSE economist Layard (2007) unemployment was the main issue for British economy in the beginning of 1990-s. Now the number of unemployed equals only to 960 000. But At the same time more than 1 million workers feel stress and depression, which makes them unsuitable for work. Therefore, just the growth of employment may not be treated as satisfactory sign. The rise in "enjoyment" is argued to be necessary, too. However, increasing it is not such an easy task. The national surveys demonstrate that the happiness level has been stable in the past 50 years.

Despite the Russian saying "with beloved person paradise may be even in tent», happiness does depend on income level. Therefore, economists began studying the issue of happiness. How does economics influence happiness? Which criteria should be taken into consideration in determining happiness? What should be done in order to raise the level of happiness? These questions can not be yet given an exact answer by the happiness science.

References

1. http://worlddatabaseofhappiness.eur.nl.
2. Ruut Veenhoven (1999) «Quality of life in individualistic society».
3. Ruut Veenhoven, Michael Hagerty (2006) «Rising happiness in nations,1946-2004. A reply to Easterlin».
4. Andrew E.Clark, Yannis Georgellis, Richard E. Lucas (2007) Lags and Leads in Life Satisfaction: A Test of the Baseline Hypothesis.
5. Richard Layard, Guy Mayraz, Stephen Nickell (2007) «The Marginal Utility of Income».

About the authors

Makarov Valery Leonidovich	–	Academician-secretary of the Social Sciences Division of the Russian Academy of Sciences, Director of the Central Economics and Mathematics Institute of the Russian Academy of Sciences
Parinov Sergei Ivanovich	–	Doctor of technical sciences, Leading researcher of the Central Economics and Mathematics Institute of the Russian Academy of Sciences
Istratov Victor Aleksandrovich	–	Researcher of the Central Economics and Mathematics Institute of the Russian Academy of Sciences
Konkova Tatiana Aleksandrovna	–	Engineer of the Central Economics and Mathematics Institute of the Russian Academy of Sciences