Примечание [11]:

SCIENCE, EDUCATION AND KNOWLEDGE IN SUSTAINABLE DEVELOPMENT PROBLEM AND THE WAY FOR THEIR MODELLING

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Abstract

The development of science and education are the key factors for sustainable development.
Modeling and simulation of social phenomena are very important for understanding such phenomena.

Operational research supplis the tools for such goals.

OR of large social systems and processes in them and taking into account their interactions with the environment usually require the use of either appropriate models or at least more or less formalized concepts.

Currently, accounting for physical, natural and technical factors in OR studies is relatively well developed. An example is research on sustained development.

Far less developed (although also numerous) are OR studies that adequately take into account the inner nature of individuals as intelligent beings and their interaction in society.

This paper proposes the consideration of such human qualities as mentality, anticipation, the acquisition and generation of knowledge, especially when considering interacting individuals.

Considerations are based on models of society in the form of networks with associative memory with elements that also take into account the internal mental representations of individuals.

As the main examples, the tasks of supported development and transformation of society are considered.

Global and local educational problems are considered as the examples.

Also shown are examples of ethics accounting in such schemes of consideration of society.

MODELS FOR SUSTAINABLE DEVELOPMENT

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Taking into account all the discussions given above, now it is possible to return more specifically to the mathematical modeling of SD. Clearly, the global SD problem is very complex and multidimensional, with many 'pillars', variable processes, systems, hierarchies of levels, scales, etc. Recently the development of mathematical modeling took place in such a way that, first, models for specific clearly identified problem

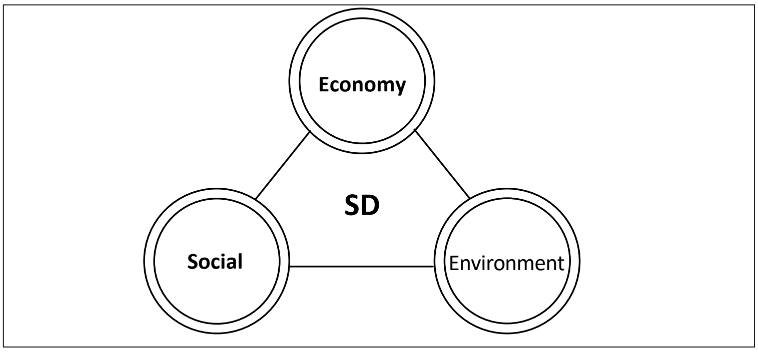

Fig. 1. Three 'pillars' SD

areas (for example, heat conductivity, elasticity, contamination propagation, molecular structure, biology of populations, etc.) were most developed. Therefore, when building global SD models for individual pillars, subsystems, processes, it is possible (and, thus, desirable) to use ready-made or well-adapted models. However, of course, there are problems of adequate coupling of such models in the integral model complex. By the way, we note that the general definition (or rather the description of the global SD) can help in the selection and coupling of models. True, the resulting integrated model, composed of different types of models, can therefore be very difficult to model (even with super-powerful computers), and the results are very complex in their interpretations.

Therefore, any attempts to construct integral models (especially with new principles of construction) can be extremely useful. Below, we present the basis for constructing global models of SD, built on new principles - allowing to consider qualitatively and quantitatively non-trivial questions such as mentality, scenarios, punctuated equilibrium, system transformation,

MODELS SD IN THE CLASS OF MODELS WITH ASSOCIATED MEMORY

The basic basic principles were developed by the author, starting from the 1990s (for references (Makarenko 1994, 1998, 2002, 2013). Here we give only a squeeze out of the main ideas of the approach, as well as some details of the development of models and approaches, as well as some ways of developing SD models and modeling SD.

Imagine a society consisting of N >> 1 personalities and let each individual be characterized by a state vector $S_i = \{s_1{}^i, ..., s^i_{k_i}, s^i{}_{k_i+1}, ..., s^i_{M_i}\}$, $s^i_l \in M^i_l,\ l = 1, ..., M_i$ where M^l_i is a set of possible values s_i. There are many opportunities to compose elements, blocks and levels in such models. In sufficiently developed societies, individuals have many complex connections. We formalize this. We assume that there are connections between i and j personalities. Let, J^{pq}_{ij} is the connection between the p components of the element i and the q components of the element j. Thus, the set $Q = (\{s_i\}, \{J_{ij}{}^{pq}\},\ i, j = 1, 2, ..., N)$ characterizes the state of society. (Figure 8). Analysis of recent models for environments from sets of elements and relationships shows the similarity of such models of society and neural network models.

Similarly, hierarchical systems can be described. We can initially assume that there are M hierarchical levels in the socio-economic system with $N(j)$ elements at the j-th level. Each i-th element at the j-th level has a description with the parameter vector. $Q_i{}^j$, $i = 1, 2, ...; N(j),\ j = 1, 2, ..., M$. Some elements at the selected

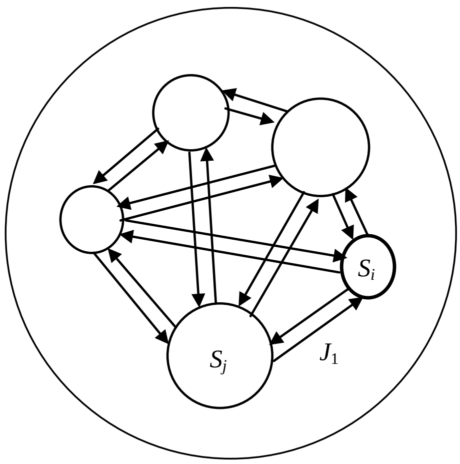

Fig. 2 Sample pattern of Q description in the simplest model

levels can be in the dependencies marked with a set of possible indexes in the dependencies $L_i^j \subset \{1,2,...,N_j\}$. Many elements in a developed society have a vast number of compounds on the upper and lower levels. Note that other processes of interest (political, social, educational, etc.) have a similar network representation and society, on the whole there is an association of such networks.

Now briefly describe the model. The first step in developing a model is to select model elements and describe them. Since it is required to take into account the mentality of the population, individuals were selected for the elements with a description of their qualities (mental and other: economic, demographic and other parameters). These parameters can be evaluated in some psychological scales, in sociology and other humanities (see for example the mental spaces of G. Fauconnier, the lattice of the repertoire sets of J. Kelly, and so on).

A critical step in creating new models is to take into account the notions of the global culture of society as a collection of all material achievements plus spiritual types of morality, ethics, religion, justice, education. Global culture is also sometimes called the collective memory of society. Global culture is a very stable construction and forms the basis of civilization (A. Toynbee, I. Wallerstein) - see (Wallerstine 1998). The proposed models have such dynamic principles that allow modeling the behavior of a global culture in time. This is due to the fact that models have the property of associative memory. The behavior of historical processes resembles the desire for very stable structures and so-called points of attraction (attractors) in pattern recognition in informatics and neurobiology. It is important that many social subsystems in society also have similar properties, and this allows us to consider individual sub-models.

In earlier works, the author considered a new class of models of society as a modification of models of the type of neural network Hopfield models or spin glasses (Haykin 1994; Sutton et al. 1988). It is known that the dynamics of the Hopfield model is derived from a consideration of a functional called "energy":

$$E = \sum_{i \neq j}^{N} J_{ij} s_i s_j, \qquad (1)$$

Where $\{+1, -1\}$ - possible states of elements in the network, N - number of elements, J_{ij} - connections between the i-th and j-th elements. In Hopfield models, the system tends to one of the few stable states with a minimum of functional (4). Many of the possible initial conditions lead to a small number of such minimal "energy" states, called points of attraction. The potential landscape of "energy" in this case looks approximately as in Fig. below (represented conditionally as the surface of the function from the states of the elements). In Fig. 10 shows a view "from above" on the landscape of "energy". A conditional "one-dimensional" illustration is shown in Fig.

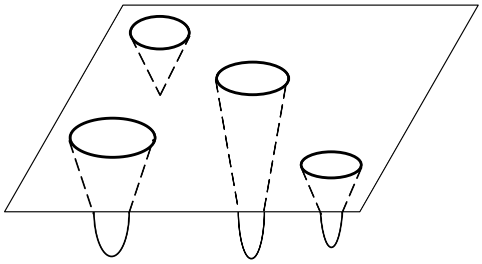

Fig. 3. Illustration of the potential "landscape" of the system

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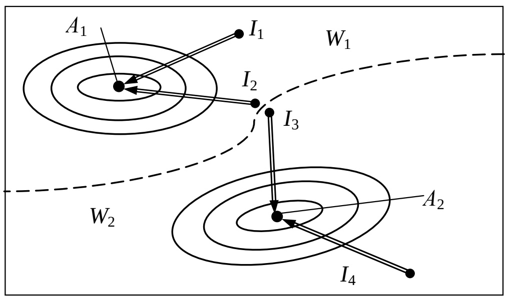

Fig. 4 The type of potential landscape "from above". The dynamic elements shown are: A_1 and A_2 - attractors of the system (in this case, point) W_1 and W_2 - attraction regions of attractors; $I_1 - I_4$ possible trajectories of ystem

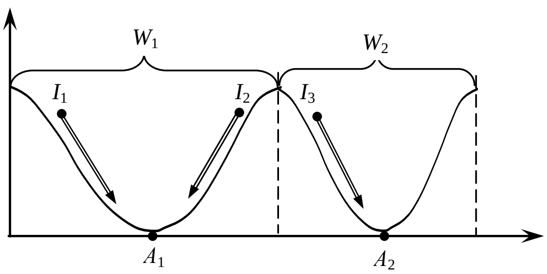

Fig.5. "One-dimensional projection" of the system dynamics

recall that such a law is correct only in the symmetric case, when $J_{ij} = J_{ji}$. In the general case, the models have the form

$$s_i(t+1) = f_i(\{s_i(t)\}, \{s_i(t-1)\}, \ldots, \{J_{ij}(t-1)\}, \ldots, b). \qquad (2)$$

In the simplest case, the model takes the form of the well-known Hopfield model, presented in many publications and whose dynamics equations have the form:

$$\begin{aligned} &s_i(t+1) = \mathrm{sign}(h_i); \\ &h_i = \sum_{j \neq i}^{N} J_{ij} s_j; \qquad (3) \\ &\mathrm{sign}(W) = \{+1 \ldots \text{if} \ldots W > 0;\ -1 \ldots \text{if} \ldots W \leq 0\}., \end{aligned}$$

where W is the argument of sign function. In the case of hierarchical systems and symmetric connections between different elements and different levels, there also exist a functional - an analog of "energy" in (1).

MODELS WITH INNER STRUCTURE OF NODES AND ACCOUNT OF THE MENTALITY

Internal representation of the external world

Accounting for the mentality requires consideration of internal structures and their inclusion in global hierarchical models. There are many approaches to accounting for the mentality (see an overview of some aspects in (Makarenko 2013). The most natural way to accomplish this task is to consider the model for the internal structure also in the class of neural network models. Recall that initially neural network models were introduced in the study of the brain. First, we can change the basic laws (4) or (6). At the phenomenological level, this can be realized by introducing a subdivision of the parameters of the elements into external Q_{ije} and internal variables Q_{ije} Q_{iji} and establishing separate laws for two parameter blocks

$$Y_e = f_e(X_e, X_i, P, E)\,, \qquad (5)$$

$$Y_i = f_i(X_e, X_i, P, E)\,. \qquad (6)$$

X_e, Y_e, X_i, Y_i - external and internal output and input parameters. Functions f_e and f_i can have absolutely different forms. For example, equations for external variables can take the form of neural networks, connected with differential equations for internal variables. But one of the most promising ways to account for the mentality is to search for equation (8) also in the neural class class. It is proposed to introduce the built-in mental models of the World in elements that represent individuals or centers of decision-making with human participation. The simplest way is to represent the image of the World in the brain of the individual or in the model as a collection of elements and connections between the elements. In such an image of the world, there is a place for representing the individual directly with personal faith, skills, knowledge, preferences. The individual is shown in Fig. .

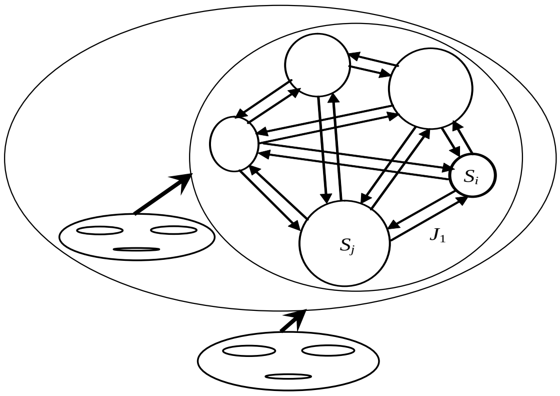

Fig. ***6*** Internal representation of the World of an individual

At the bottom of Fig. we have introduced some individual, Such individual has some idea about the structure of the World. This representation is similar to the "sample" in Fig. But an essentially new effect is that an individual can present himself as one of the elements of a "pattern". The mental structures of other persons are also represented in the same way. Thus, society as a complex system has essentially a new concept. At the first level of description we have a collection of elements that are connected by links. On the second level of the description, we connected the structure (some image of the world) to all elements. At this level, the construction resembles a bundle of differential topology. But our structure is even more complicated, because of the self-reflexivity property there exists an infinite chain of levels, where each representation in this continuation copies the whole chain.

One possible way of accounting for the mentality

The laws for elemental behavior must depend on such a representation. Formally, we can introduce projection operators P to represent the image of the external world in the individual brain: it is very important that each individual has his own personal image of the World. We note that the action of the operator P can be subdivided into many local projection operators. Then equation (5) from the previous section can be replaced by a more complicated one, substituting the self-representation of the individual in the right-hand side of the dynamic law for the elemental dynamic variation of the parameters. Some of the simplest versions will be presented in the next section, in parallel with the description of the proactive property. Of course, there can also be a recursion with many levels of recursion, as in the theory of reflexive systems of N. Luhmann (Luhmann 1995), G. Soros (Soros 2000), V. Lefebvre (Lefebvre 1982), and so on. In our scheme this can be represented as a mutual representation of all persons in the internal representation of each individual.

One approach to modeling mentality anticipation in the proposed models

We call the set $Q^{(1)}(t)$ "the image of the real world" at a discrete time instant t. We also introduce - $Q^{(1)}{}_{wish}(t)$ "the desired image of the world at moment t for the first individual" as a set of elemental states and desired connections for the first individual at a time.

$$Q^{(1)}{}_{\text{wish}}(t) = (\{s_i{}^{\text{wish}}(t)\}, J_{ij}{}^{\text{wish}}(t)\}). \qquad (7)$$

Then we assume that in the case of an isolated dynamic law, changes in the state of the first individual depend on the difference between the real and desirable image of the world:

$$D^{(1)}(t) = [[Q^{(1)}{}_{\text{wish}}(t) - Q^{(1)}(t)]]. \qquad (8)$$

Here [[*]] is some norm. We present the prerequisites for introducing the difference (10) in model.

Fig. presents "deformed" vision of the World by the individual. Exactly the same type of representation has the desired ("ideal") image of the World. Let us note that only the state of the real World is one for all personalities (in such models), but perceptions and "ideals" are different for different personalities. If we want to represent the "inner" part of the dynamic law in the same way as the "outer" part in Section 3, then we can adopt a dynamic law for the first element of the form

$$s_1(t+1) = F_1(h_1(t), D^{(1)}(t)). \qquad (9)$$

In formula (9) $h_1(t)$ represents the influence of the medium, since $D^{(1)}(t)$ in formulas (9), represents a part of the "internal representation". Function F takes into account both components of dynamic properties.

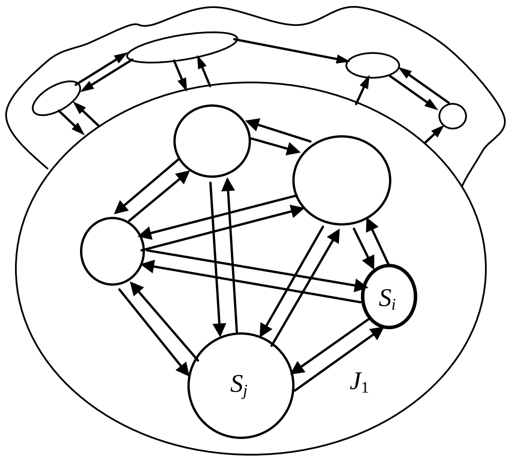

Fig. 7 The real state of the world and its internal representation (deformed) in the opinion of the individual

The next step is to compare the desired image of the world with the actual images of the world at the moments of time , $t,(t+1),(t+2),\ldots,(t+g(i))$. that are expected at these moments. Note that in the simplest case) of the first individual) here $g(i)=g(1)$. Parameters $\{g(i)\}$ determine the horizons of lead.

The generalization of models in the case taking into account the internal structures corresponding to Fig. , has the form

$$S_i(t+1)=F_i(h_i(t),D^{(i)}(t),D^{(i)}(t+1),\ldots,D^{(i)}(t+g(i)));\ i=1,2,. \qquad (10)$$

The system (10) and its modifications can form a basis for investigating many problems with internal and external images of the world. Substitution of all components into the system leads to an equivalent system:

$$S_i\ (t+1)=G_i(\{s_i(t)\},\ldots,\{s_i(t+g(i))\},R), \qquad (11)$$

where R is the set of external (control, structural, environment) parameters. We must emphasize that the right-hand side of (13) depends on the future values of the state of the element. This form is contrasted with the form of equations with delay. It is very promising that the structure of system (13) coincides in structure with the anticipatory systems investigated by D. Dubois (Dubois 2001, 2001a). This implies a possible similarity in properties of the solutions. The most important property is presumable multivaluedness of solutions. The examples of equations with such behavior see in (Makareko 2018).

SCHEME OF APPLICATION OF MODELS WITH ASSOCIATED MEMORY TO THE PROBLEM SD.

In the previous subsections, the principles of constructing models with associative memory for modeling large social systems were described. Below we discuss some possible ways on such models using in the SD problem.

General SD Circuits

Here is a description of commonly accepted illustration of SD schemes (Rogers 2007; Sheffran et al. 2012; Daly 2014;

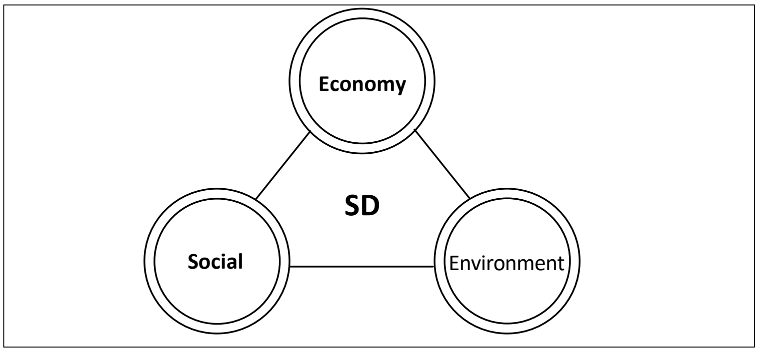

Fig. 14. Three 'pillars' SD

Dasgupta 2007; Theory 2013; DE Tombe 2015; Bruntland Commission 1987; Weizsaker, Wijkman 2018; Zgurovsky and Statyukha 2010). A full formal description requires a lot of space and will be placed in a separate work, but here we give only ideas on the construction of models and what can be obtained with the help of these models. At the same time, we will try to identify a special part of SD modeling that was least reflected in existing methods, concepts, models - namely, population properties, knowledge production, learning processes in a broad sense, a generation change. First, let us recall a more or less general idea of the three 'pillars' in the SD process. (Note that many SD indices are based exactly on such a partition).
The most developed class of models is the block "Environment" - there are differential equations in partial derivatives (atmosphere, pollution, climate change), system dynamics, econometrics, stochastic equations, CA, etc.). The economy also has many good established models: models of micro- and

macroeconomics, game theory, stochastic differential equations, econometrics, and, more recently, multi-agent systems.

The model concepts of the "social" block are comparatively less developed (although there already exists a special discipline called "social informatics." There are models in the psychology of the individual, game theory and multi-agent systems, partial

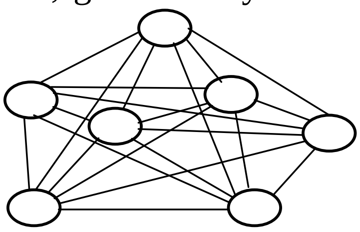

Fig. 15 Network structure

differential equations (Kapitsa et al. 1997; Vorobiev et al. 1998), cognitive maps, but to the fullest extent The models with associative memory (Makarenko 1994, 1998, 2002, 2013) allow us to satisfy the requirements for the modeling of social systems.

Note that this description is suitable both as a description of the external environment ('environment') of the element, and for describing the internal representation of the individual about the external world and the structure of existing knowledge (for example, semantic networks, cognitive maps, etc.). But in principle, phenomena from the blocks of ecology or economics also admit description and modeling using models with associative memory and network representation of the system. Sometimes it's quite simple and almost obvious, sometimes it's not obvious and very difficult. The network approach to various systems is being successfully developed in physics, sociology, psychology, biology, economics, etc. (Watts and Strogats 1998; Prigogine 2000; Wallerstine 1998). Therefore, in principle, even a complete general SD model can be written in the form of connected network structures and their dynamics in the class of dynamics with associative memory. That is, all the regularities described in (Makarenko 1994, 1998, 2002, 2013) and which can be present in such models can in principle be inherent in the global SD model.

Therefore, in the integrated SD model and especially its use, you should use all the available arsenal of models, linking them, but in principle everything can be translated into a single language of network descriptions and dynamics in the associative memory class. Note also that the local SD process (in the sense described above), when the time of the task is relatively short, on which conditions (both natural and social) do not have time to change significantly, it seems that in principle it is possible to model fairly well the already known models in first of all, differential. However, long-term changes, especially taking into account a significant change in society and in knowledge, can most simply be modeled by models with associative memory.

SD models and SD transitions taking into account internal variables of individuals

In this section we give elementary descriptions of the most complex issues in the study of problems related to the fact that SD is most dependent on the consideration of the properties of people and society as a collection of individuals. The most important tasks are the understanding of sustainable and non-sustainable ways of society's existence and then understanding of the transition between them and management, planning, foresight of such processes.

Again, the integral model of society would be necessary in all its completeness, and all existing models can be used to construct such a model (or a complex of models). But as it was repeatedly stated above, the most convenient models are the network structure and the associative memory property (from the classes given in (Makarenko 1994, 1998, 2002, 2013) and further from the development).

For better understanding of the concept, let us begin with the simplest geometric illustrations that allow us to lead to rigorous formal statements and possible interpretations. We give here the structure of the model (and even society) and in parallel the structure of the SD problem with its optimization nature.

So, we accept that society consists of a large number of individuals with connections between them. In this case, as indicated, there are various pillars. Each of the pillars corresponds to laws that describe their behavior, and each of the pillars can correspond to a network description. Therefore, at a certain stage, we will simplistically represent these states at a given instant of time as the states of the blocks in Fig. above.

Dynamics of blocks can be represented as a sequence of states of the elements of blocks at different instants of time (in the simplest case at discrete moments, but this is not a fundamental limitation). The laws of the dynamics of variables can be given in any known form. However, the most appropriate laws are those in the form of associative memory and its implementation by neural networks.

Now in the implementation of the construction of the proposed models, each individual has a certain idea about this environment (as far as his knowledge of the state of affairs, breadth of horizons, education, etc.). In addition, the individual has an idea of what state of the environment he represents best at certain intervals. Each of the individuals has all these parameters.

Society is a collection of such individuals and connections between them. Note that within the framework of the Fig. it is possible (and should) include the individual's views about his own place in society (self-referencing, reflection and also what is important for sustainable development of society, the idea of a supported development).

Ideally, then, its modeling is the study of the change in the parameters of all components (environment, pillars, individuals) over time with the help of dynamic laws adopted in models.

It is clear that in the fullness of the dimension of the parameter space and the number of equations for their evolution can be enormous. Therefore, as is customary in the study of complex systems, simplified models for various sub-processes are considered to obtain an understanding of the functioning of the entire complex system. Of course variants of simplified schemes can be different.

Research tasks and problems to be solved

Proposed approach allows developing the software and trying to understand some properties of society and particularly eGovernment. Here we describe some examples of computer experiments with the models which accounting the internal structure of participants and non-constant in time reputation of participants (Figure).

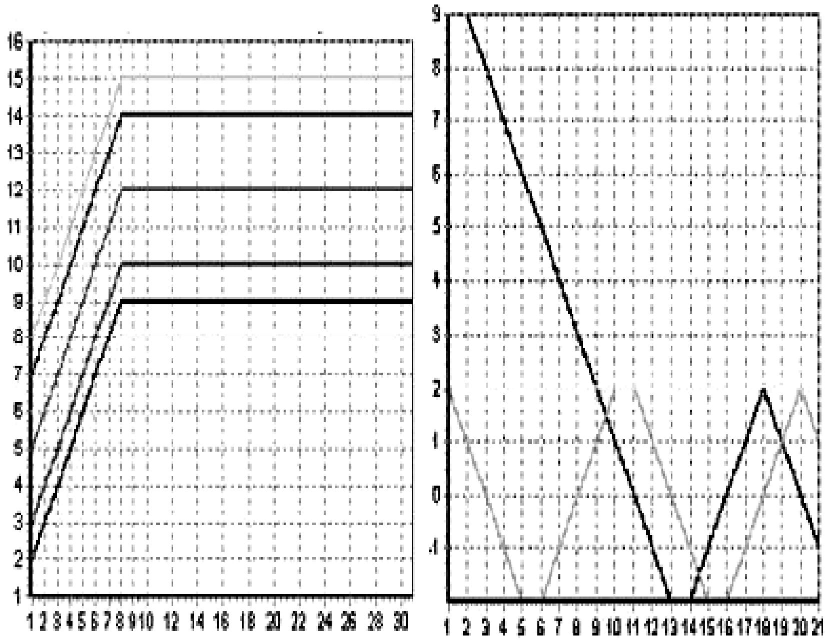

Figure 8. Example of opinion formation modeling.

EDUCATION AS A BASIC FACTOR IN TRANSITION TO SD.

Now, based on the proposed models, we described how SD can look and how one can understand the transformation processes in these systems, paying special attention to the aspects related to the mentality. Trajectory, in which the global SD is considered, are in a space of large dimension (including all "external" and "internal" parameters). A certain mode of operation of the SNET system corresponds to the motion in the attraction field of a certain attractor. There are resource constraints for trajectories. These restrictions must be taken into account at all considered time intervals. The transition from an unsupported to a supported development corresponds to transitions between attractors.

Here we shortly consider the role of individuals mentality in SD. Note that in the base pictures (Figure 14 in Section 8) there are 3 pillars for describing the systems. It is clear that innovation and knowledge are now playing a decisive role both for the adoption of SD, and generally for the evolution of society. Usually they are included in the social pillar. However, in the future they can be (together with other characteristics of individuals carried out in a separate pillar: faith, education, ontology, work skills, etc.). Actually, many modern research on artificial intelligence, semantic networks, distributed management, organizational science, etc. are directed to this direction (Watts and Strogats 1998; Prigogine 2000; Wallerstine 1998).

Taking into account the concepts proposed in (Makarenko 1994, 1998, 2002, 2013), the dynamics of social, economical, political etc. systems may be described by laws with associative memory. The structure of attractors in these systems and the evolution in them is determined by the connections, patterns and previous training.

Thus, the overall process of transition from non-sustainable development to sustainable development is as follows. Non-SD mode is defined as natural resources and restrictions on their use and knowledge and internal qualities of individuals. The latter can be represented by network structures of the form of an elementary concept (representations and connections between them). With other fixed conditions, changes in these systems and components (concepts and connections) lead to a transition from non-SD to SD development path. In the simplest case (when most variables are discarded), one can imagine that, in the limiting case, non-SD and SD modes correspond to fundamentally different target settings (and their different representations in the form of network structures of ideal representations of the individual). One network structure corresponds to the "economic" way of development, and the second - to "ecological". Note that here we can talk about the anthologies of different development regimes. What then does the transition mean? Absolute transition is a complete change for everyone from an "economic" to an "ecological" style of thinking. Such a transition is, of course, an idealization, but already this "absolute transition" shows what is the result when changing the modes. Even if the change of "internal" ideal images happens instantly (that is, the mode of using resources), then the real change will still occur gradually as a transition from the initial state to the force of the model's dynamics equation.

The second version of the model, although also simplistic, is a consideration of when the change in "ideal" (desirable) representations occurs gradually (for simplicity, it can be assumed that with the same speed for all individuals, although it is not difficult to take into account the heterogeneity of these changes).

We can say that simultaneously there is a co-evolutionary process, when both the situation and the people involved in the SNET system change. Then there is a change in the landscape caused by a change in views and a change in the landscape affects the change in views. It should be remembered that the full problem of multidimensional and "ecological" and "internal" (mental) coordinates enter the common space of the problem description. Therefore, the attractors in the projection only on the ecological coordinates can look as independent of the internal variables of the object. However, the transitions between them can be determined by "mental" (internal coordinates). (Figure 4 in Section 1 just corresponds to such situations - the areas between ($G_1 - G_2$) and ($G_3 - G_4$) correspond to different attractors, and the transitions P_1 and P_2 - are determined by changes in mentality).

Already these illustrative descriptions of problems allow us to consider (and, first of all, put them) on the basis of formal concepts and equations. It should be stressed that transition to global SD depends strongly on the acceptance of SD idea by society. So the first of the tasks of transformation is to change an "ideal" representations of the World in the individuals. It is important to study what proportion of the population should adopt new concepts for the transition to SD, what is the dynamics of the transition, what is the distribution according to individuals, how it depends on the new "ideal" structure, its difference from the old ideal structure. It is also possible to take into account the process of the generation change due to the loss of "old" individuals and the emergence of "young" people in the system for whom the process of obtaining new "ideal" representations comes from a "pure" structure (without replacing the "old" concepts - in "young" concepts at first simply no). Note that the above process is also suitable for modeling other problems about the behavior of social systems (previously the author had already discussed civilizations and formations, the birth of cities and states, the economy, the production of the future, the Government and much more).

Of course, the results given in this paper are, first of all, general and rather abstract in comparison with the needs of forecasting and managing real social systems. However, even such first steps made it possible to obtain interesting applied results (geopolitics, stock markets, etc.).

CONCLUSION

Thus in proposed paper some new investigations of sustainable development aspects had been proposed. The system analysis of SD problem stressed the role of restrictions on resources for general SD problem. The illustrative pictures in the paper allowed to better understand the need of accounting of restrictions. Proposed formal definition of sustainable development problem may hope to fill the gap between the qualitative descriptions of SD processes and application of strict methods of operation research. Application of proposed formal definition allows to reduce the problem of sustainable development to the problems of modeling and optimization of systems with constraints, which is the prerogative of operation research. Special class of models with associative memory for social systems had been described. Such class of models allows to consider also the internal (mental) properties of individuals which may be important for understanding of general sustainability property. Absolutely new is also attracting anticipatory properties for formalization of sustainable development (especially of strong anticipation).