SYSTEMS ANALYSIS AND GLOBAL SUSTAINABLE DEVELOPMENT

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Summary

The basic elements of the world system and main global problems are described. The outcomes of modeling of global development with the help of models of system dynamics and multimodel descriptions are considered. The outcomes of modeling of such fragments of world development as stabilization of a population, Kondratiev cycle, substitution of technologies and resources, warming of climate, and nuclear winter are examined. The concepts and paradigms of world development are discussed.

1. Introduction

The world includes the following basic subsystems: the human population, socium, economy, manufacture of foodstuffs, scientific and technical progress, natural resources, environment, and countries and regions of the world. Development of the interactions of the subsystems and their elements determine world dynamics.

1.2. Elements of a Global System

The population of the world grows, migrates between countries and regions, concentrates in cities, participates in economic activity and technological changes, uses natural resources, provides itself with the foodstuffs and other vital boons, raises the

living standards, changes the characteristics of environment, changes the forms of social and political organization of society, and participates in international and interregional interactions. The rates of growth of population vary with over time owing to of the changing face of life and environment and these rates vary with ethnic, social and religious groups.

The people accept the decisions and function within the framework of an established social environment - socium. The basic characteristics of socium are: political and economic mechanisms of regulation of human activity, dominant social and political ideas, standard system of values, attitude to work, distribution of income among the population, susceptibility to social and technological innovations, attitude to environment, demographic behavior, interethnic attitudes, and coordinated purposes of public development. Opportunities for a society to expect future changes and to adapt to them depend on these characteristics. The social and political ideas play the role of engines of public development, help predict, reveal and overcome difficulties, contradictions and conflicts.

The economy constantly increases manufacture, provides the population with the vital goods and services, creates new workplaces, updates production assets and technologies, uses natural resources, and pollutes the environment. The important parts of world economic system are the subsystems of world division of labor, world trade and finance where intercountry flows of the industrial goods are organized, foodstuffs, natural resources, and capitals. The rates of long-term economic growth form from the rates of demographic growth and growth of productivity of work. These rates determine the growth of load on environment due to economic activity and the rate of consumption of natural resources. The depletion of natural resources which are not compensated by scientific and technical progress raises the cost of final production and the economic growth is slowed down.

Production of foodstuffs is usually allocated from economy as the special subsystem, which includes four biological systems: agricultural land, pasture land, forest and water systems, including the oceans. Though these biological systems are under the test of constantly growing anthropogenic pressure, the total output of the foodstuffs grows except in the moments of climatic failure. The decrease of the area of farmland per capita is compensated by growth of energy cost on manufacture of the foodstuffs. However growth of the population and growth of manufacture of the foodstuffs are not always balanced. When the demographic growth begins to overtake growth of manufacture of foodstuffs, the consumption per capita of the foodstuffs begins to be reduced first of all in the poorer layers of the population and in the poor countries.

Scientific and technical progress gives rise to new technologies, which gradually supersede out-of-date and inefficient technologies in the economy. As a result of replacement of old technologies now the productivity of work and efficiency of use of natural resources grows, the power consumption of production and pollution of the environment is reduced, depleted natural resources are replaced by other resources. The technological level of economy constantly grows with rates equal to the product of speed of updating of production assets and relative efficiency of new technologies on new workplaces. However rates of scientific and technical progress are non-uniform; this results in long-periodic fluctuation in economic and technological development of

world system known as Kondratiev cycles.

The natural resources (water, ground, woods, minerals etc.) are classified as renewable and nonrenewable. The first group of resources requires constant maintenance of their quality and life cycle, and the second group - in new technologies for replacement of vanishing resources with new substitutes. The limitation of natural resources is shown through the long-term tendency of growth of their prices. The cost price of production of mineral resources usually grows with growth already of taken stocks, as the richest and accessible deposits are developed first of all. Volume of natural resources involved in anthropogenic activity, is increased together with economic growth, however scientific and technical progress reduces resource-capacity of final production.

Environment (biosphere) includes the atmosphere, the oceans and land. It is a huge receiver of flow of solar energy, which partially is reflected back into space, partially heats up the atmosphere and is acquired by biota. In the biosphere there is circulation of carbon, oxygen, nitrogen, and water through global cycles and also through cycles of biosystems. The most important characteristic of the atmosphere is the climate and average temperature, which depend on the concentration of carbon dioxide and aerosols. Anthropogeneous activity changes all characteristics of the environment. The growth in energy supply raises the concentration of carbon dioxide in the atmosphere, that leads to climate change and change in the conditions of manufacture of foodstuffs. Expansion of agricultural land, acid rain and chemical emissions result in reduction of forests and in general biota, that influences on global circulation. Toxic substances act in an environment as not decaying chemicals and radioactive elements, and then is direct or together with products of food act on the human organism and influence its physiology. Freon from refrigerating machines and sprays will be transformed in the top layers of the atmosphere to chlorine and destroy the protective ozone layer.

The world is divided into the states and blocks, into rich and poor countries, into regions with high and low densities of the population, into regions rich and poor in natural resources, into nations with and without nuclear weapons. The world has a diversity of ethnic, ideological and religious attributes. This diversity gives rise to various interests and various approaches to decision making for the same problems. Therefore trends in integration at the decision level in global problems clash with those towards dissociation. The division of the world by itself poses a threat to global security due to the possibility of application of nuclear weapons that are capable of causing global ecological catastrophe.

1.2. Global Problems

Human activity takes place in a thin layer of thickness of 10-15 kilometers over the surface of the globe with a radius of 6370 kilometers. The uncontrolled growth in the demographic, economic and technical characteristics of the world system, and also growth of pollution are in direct contradiction with the physical limitation of natural resources and environment. This growth generates global problems as the first symptoms of restrictions or bottlenecks on ways of unlimited growth in the limited environment.

The following global problems are usually regarded to be of paramount importance.

- overpopulation of the certain countries and regions of the world, threat of demographic explosion overtaking resource and economic opportunities of world system, uncontrollable migration of the population from regions of disasters to safe regions and explosion of interethnic intensity, growing demographic imbalance between North and South (1:3 in 1975 and 1:4 in 2000), and growing concentration of the population in cities;
- shortage of the foodstuffs for the poor countries and groups of the population, high number starving and suffering from malnutrition (up to 20 % of the population), fast reduction of the area of farmland befalling the inhabitants of the Earth, limited opportunities to increase of manufacture of foodstuffs with modern technologies because of degrading soil in an agriculture and high energy expenses;
- depletion of traditionally used natural resources, steady growth of the world prices of energy resources, future transition of part of the modern exporters of power resources into importers, and necessity of reorganization of structure of energy production and consumption system;
- degradation of environment as a result of growth of economic activity and pollution, increase of local ecological crises and accidents, global warming and possible rise of the level of the world's oceans, threat of nuclear winter as a result of nuclear war, destruction of the ozone layer, loss of capacity of the environment to absorb waste from anthropogeneous activity;
- persisting and even growing disparities of the countries and regions of the world in levels of consumption of natural resources and level of economic development, growth of number of the people living in conditions of malnutrition and poverty, and opposition of the rich North and the poor South;
- safety of development in conditions of transition from the bipolar world to the monopolar world with one superpower, safety in conditions of extending the nuclear club by holding and growth of interethnic intensity, safety in conditions of growing global competition for natural resources, local military conflicts, and growing military expenditures.

The scientific, technical, and social progress tries to answer these calls of time, softens global restrictions, helps world system to adapt to them, but can not remove them completely. World development too sluggish; the mechanism of feedback between global problems, acceptance and realization of the decisions on adaptation of world system to new conditions of development is also insufficiently effective.

An evident representation of possible dynamics of world macroindicators at different stages of the approach to global restrictions gives following illustrative macromodel for growth of population of the world:

$$x'/x = \alpha(1 - \beta x)\,(1 - \int_0^t \gamma x\, dt), \qquad (1)$$

where x (t) - population of the Earth, x' – the derivative of x, α,β,γ - non-negative parameters. The first multiplier is equal the right part (1) to rate of exponential growth of the population far from global restrictions; the second multiplier reflects influence

limited, but renewed resources - terrestrial surface, solar radiation, biota, fresh water; the third multiplier reflects influence of the limited not renewed resources - minerals and absorbing opportunities of environment.

If there is no scientific and technical and social progress, according to (1) initial trajectories exponential growth as approaching restrictions on renewed resources passes in logista, and then logista in process of exhaustion of not renewed resources passes in a trajectory of exponential recession. It means that the population at first is stabilized, and then begins to decrease.

The real modes of development and interactions of elements of world system are much more various and more difficultly. First, the managing influences, scientific and technical and social progress change dynamics of global processes. Secondly, due to difficult structure of world system collapse of its one part another can be accompanied by prosperity. In third, such factors as technological and social innovations, biological mutations, ecological accidents, climatic variations, and the social and political conflicts bring in to behaviour of world system stochastic elements. In fourth, on quasi-exponential trend of world development the periodic fluctuations are imposed which raise probability of accidents in critical phases of a cycle.

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Bibliography

Bremer S.A., Huges B.B. (1990). Disarmament and Development. Prentic Holl, New Jersey. [In this book the problems of the mutual guaranteed erasure of two opponents and possibilities of disarmament are considered.]

Dubovsky S. V. (1994). Kondratiev cycle as economic-technological pendulum with social consequences. Moscow, Economy and mathematical methods, volume 30, release 1, (in Russian). [The mathematical model of a Kondratiev cycle including model of non-stationary scientific and technical progress is offered. The existence of a periodic solution is shown, the accounts are conducted.]

Gelovani V.A., Dubovsky S. V. (1979-1991). Global modeling. Works of VNIISI, Moscow, (in Russian). [The materials of the Soviet global project - research, accounts, conclusions are represented].

Gelovani V.A., Piontkovsky A.A. (1997). Evolution of the concepts of strategic stability. Moscow, (in Russian). [The evolution of the concept of the strategic stability based on possibilities of a mutual guaranteed erasure of the opponents is described.]

Forrester Jey W. (1971). World dynamics. Cambridge , Massachusetts, Wright – Allen Press, Inc. [The full description of a model " the World 2 " and conducted accounts. The description of possible world crisis.]

Kapitza S. P. (1996). Phenomenlogical Theory of World Population Growth. Moscow, Successes of

physical sciences, volume 166, № 1, (in Russian). [The model of demographic growth which is taking into account demographic revolution and consequent stabilization of a population of the world is offered. The outcomes of accounts the prognosises are resulted.]

King A., Schneder B. (1990). The First Global Revolution. A Report by the Council of the Club of Rome. [Full exposition of the concepts and paradigms of world development.]

Krelle W. et al. (1989). The Future of the World Economy. Springer-Verlag, Berlin. [Fundamental outcomes of the international project on modeling of global development.]

Malthus T.R. (1798). An essay on the principle of population, as it effects the future improvement of society.

Marchetty C. (1986). Stable Rules in Social and Economic Behayior. International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria. [The exposition of a mathematical model of substitution of technologies and resources is accompanied by a plenty of statistical examples from economy and social life.]

Meadows D. et al.(1972). The Limits to Growth, Universe Books, New York.

Mesarovic M., Pestel E. (1974). Mankind at the Turning Point, Duttion. New York. [The full description of outcomes of the global project - model, accounts, interpretation.]

Moiseev N.N. etc. (1985). The man and biosphere. Moscow, Science. (in Russian). [The description of models of biosphere processes, analysis of their connection with socio economic development.]

Leontieff W. et al. (1977). The Future of the World Economy. A United Nations Study. Oxford University Press. [Outcomes of the global project - model, accounts, interpretation of outcomes.]

Turco R.P, Sagan C. (1983). Nuclear winter: global consequences of multiple nuclear explosions. Science, 222, №4630, p. 1283 - 1300. [The joint article of the American and Soviet authors deals with the description of the various aspects of consequences of nuclear explosion.]

Biographical Sketch

Sergey V. Dubovsky is Assistant Professor, candidate of physicist-mathematical sciences, head of laboratory of Institute of the Systems Analysis, RAS, Moscow, Russia. Graduated Moscow Physicist-technical Institute and graduate school CAGI. With 1968 year concerns with mathematical modeling social-economic systems. Reads economic and mathematical lectures in the Moscow Physicist-technical Institute and Russia University of the Friendship of Folk. Co-author of three known monographs: "Mechanics of the space flight" (in Russian, M. Science, 1975), "The Future of the World Economy" (N.Y., Berlin, 1989), "New paradigm of the development of Russia" (in Russian, M. Academia, 1999). Leader and performer 2 domestic and 3 international global projects. Author mathematical models of the scientific-technical progress, of cycle Kondratiev, of non-equilibrium economic growth, of non-stationary inflation, of exchange rate and foreign trade, of Russia social cataclysms, of variational principle economy. Author more than 80 scientific publications. Laureate bonus of Russia Fund of Fundamental Studies for 1998.