MULTIPURPOSE SIMULATION SYSTEMS FOR REGIONAL DEVELOPMENT FORECASTING

The planning for public sector development of the national economy should take into account main socio-economic peculiarities of regions. Otherwise, the realization of each alternative of the development of national economy in a particular region can unpredictably affect its social-economic conditions. In the process of development of public goods production infrastructure, social and economic conditions can change as a result of close interaction and their constant mutual interdependence.

Nowadays, the responsibility of provision of public goods is shared between different levels of Ukrainian government. However, "the Center" is still responsible for fair distribution of resources to make sure that all the needs of population are satisfied. The method for regional development planning, we want to discuss in this paper, is referred to as a large system that enables one to use a system approach to scientific solution of arising problems. Here stands the point where a problem of rational planning becomes a problem of optimal system control. The efficiency of public service delivery can be measured in economic and social terms and may be estimated with the help of modern information technologies, widely known economic-mathematical methods, and computer engineering tools.

In the countries of former Soviet Union and other post-socialist countries the problem of control of social-economic development for the regional planning is of current interest of great importance, because of multidimensional way of development of their economies in transition period. The significant role of planning for socio-economic development makes it possible to manage a wide range of controlled parameters to achieve the optimal result. On the one hand, the latest circumstances favor improvement in planning efficiency, but, on the other hand, make this problem more complicated elevating it to the multidimensional level.

Increased significance of this issue for national economy requires explicit solution based on the present-day scientific methods. Regional automated control systems are developed, constructed and operated in our country to improve control at the territorial level. As a rule, subsystems of social sphere development control are included into regional Automatic Management Systems (AMS) to take into account social-economic factors of social sphere development, studying peculiarities of interaction between various model components. Along with account-informational problems these subsystems allow for finding a solution for forecasting and optimization problems. The solution of such problems in the AMS framework should provide a variety of the most efficient alternatives of regional development scenarios based on fundamental social and economic logic.

The solution of certain optimization and forecasting problems for regions has been a standard practice for domestic and foreign researches during several recent years. In particular, several approaches to the mentioned problems of such character have already been introduced into software of the operating AMS. Methods for formalization of problem statements, applied here, vary greatly from one to another in their targets, as well as in various structural and functional features. In spite of the benefits that derive from solutions of such problems one should remember that their diversity does not allow for using all advantages of modern mathematical methods and computer technologies. This, as well, does not give the possibility to take into account a sufficient degree of various factors in their interrelations, i.e. to realize and apply a system approach to the problem solving. It would be advisable to construct, on the basis of a unified mathematical methodology and general technical and information bases, a system of forecast-optimization problems which will help to find substantiated answers to a broad class of questions on regional development planning. The work, which is presently carried on in this direction under the supervision of the National Academy of Sciences of Ukraine is one of possible ways for resolving of these complex issues.

For resolving of forecast-optimization problems at the regional level it is necessary to take into consideration various arising aspects - demographic, purely social, economic, productive, financial, organizational, judicial, etc., which are closely interconnected. These characteristics hamper the use of such traditional, mathematical methods as mathematical programming, critical-path approach, and theory of random processes. In fact, the method of computer simulation processes is the only mathematical method suitable for reflecting various features of systems for social-economic development at the regional level which is capable of giving the required accuracy of results. This method may be successfully used due to its considering of random factors' behavior when obtaining not only local (individual) but also integral (generalized) estimates. This feature characterizes a spread of figures being forecasted and checks the accuracy of the obtained forecast.

Among various known simulation methods the most suitable one is the method of *automaton simulation* [1,2] developed at the Institute of Cybernetics of the National Academy of Sciences of Ukraine. This method possesses essential practical advantages and is presently rigorously substantiated from the mathematical point of view and proved successful in solving a great number of practical problems mainly in the fields of transportation economics, inventory control, and rational design.

A multidimensional vector having the property of Markoff processes is used as a basis for construction of a large system automaton model. If this process has a special property called the property of conditional independence of components, each component of the process may be identified with a relevant state of particular automaton from the standpoint of automata theory. If this takes place, the signals circulating between automata reflect interrelation of system characteristics of certain automata. The existence of this property permits executing the operation of simulation for different states of a system, component-by-component. In /1,2/ it is shown that under fairly broad range of assumptions with respect to the initial Markoff vector (a finite number of interrelated random actions) the property of conditional independence of its components may be satisfied. A general practical method of realizing such a procedure is described below.

The essence of the approach for forecast-optimization problems of regional development is not to reduce the problem task to a simple prediction of the future condition. On the contrary, such approach is a complex algorithm that envisages an active reproduction of a free process, multistage classification for possible control, selection of the relevant choices, and estimation of process characteristics. That is why each forecast-optimization problem, at its final stage, leads to the construction of a model of the complex system with many branches intended for solving a whole aggregate of individual interrelated problems.

For constructed and operated models to meet the requirements placed upon them, the leading algorithms should make provisions for periodic interference of a researcher in the model operation process. The researcher's interference in the model operation chiefly amounts for the problems of a considered class, for execution of the following two functions:

1) classification, selection, change, and correction of control alternatives;
2) choice and assignment of the modes for model operation, definition of a list of output figures. According to this function, the algorithm of the model for forecast-optimization problem possessed the general structure shown at the following block-diagram in Fig.1.

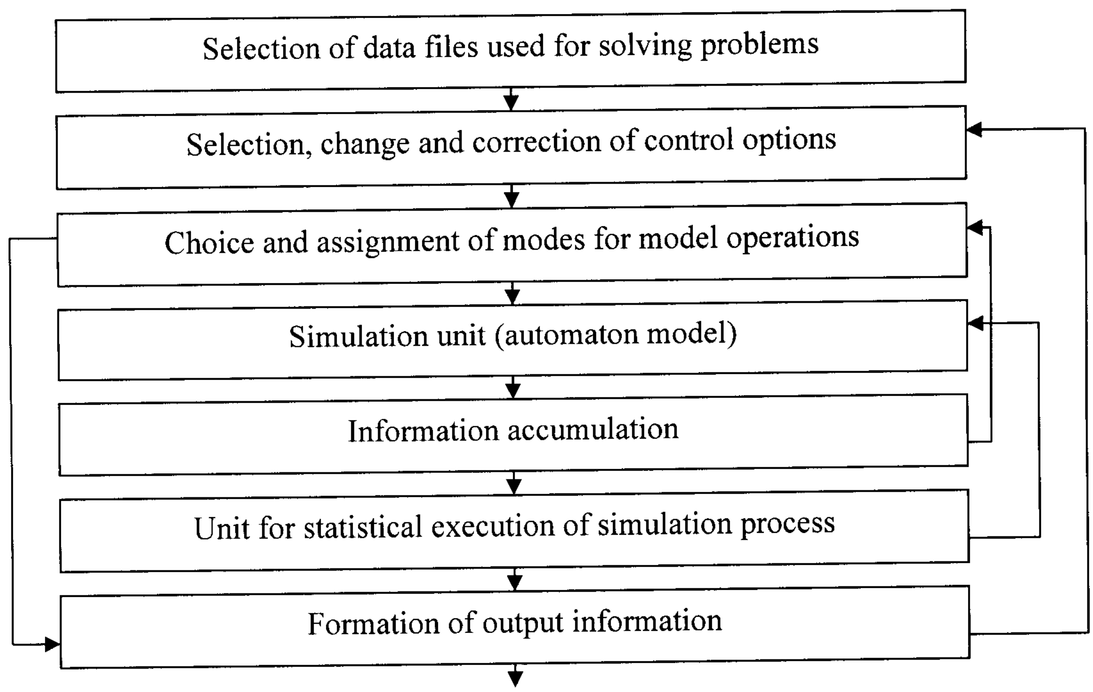

Fig. 1. Block-diagram of the general structure of the model of forecast-optimization problem

The stated considerations are used as a basis for elaboration of social-economic developments of forecast-optimization problems at the regional level. The first stage of this approach includes several models which have, in designers' opinion, the foremost significance as far as their applications are concerned. All models of the first stage correspond to a general structure of problems for a considered class, allow for the dialog-mode operation, and are constructed in the form of simulative automaton models.

The analysis of real situations of social-economic development of a region shows that the influence of demographic factors is in primary importance for modeling process. Thus, the first constructed model of the first stage system hierarchy is the model for forecasting the development of demographic situation in a region. The model uses extensively all advantages and possibilities of the chosen mathematical method. This model possesses a central place in the general structure of a system, and its outcomes are successfully used for solving other similar problems.

To obtain close forecast figures of population size with respect to gender and age groups, it is necessary for the model to take into account the elements of development of family relations of the considered population. The constructed model, along with classification of the population with respect to gender and age groups, also takes into consideration a number of marriages in terms of ages, and simulates the process of marriages and divorces. Incoming and outgoing migration flows are taken into consideration by estimating gender and age distributions, marriages and divorcees of those who migrate.

One of the solid applications of this method has been a model of Forecasting of the Regional Population (DEPROG), which is represented in the following formulae where:

$B_{xy}(t)$ is the number of married couples in the region for women of age x and men of age y at the end of year t $(t = 0,1,\ldots, T)$;

$a_x(t)$ $(x=0,100)$ is the number of unmarried women of age x in the region at the end of year t;

$c_y(t)$ $(y=0,100)$ is the number of unmarried men of age y in the region at the end of year t;

$g_x(t)$ $(x=16,100)$ is the actual ratio of the number of marriages with women of age x during the current year to the total number of unmarried women of age x;

$d_x(t)$ *and* $d'_x(t)$ (x=16,50) is the number of births in the region by married and single women of age x respectively during the year $t + 1$;

$e_x(t)$ $(x=0,100)$ is the number of deaths of women of age x in the region during the year $t + 1$;

$f_y(t)$ $(y=0,100)$ is the number of deaths of men of age y in the region during the year $t + 1$;

$h_x(t)$ $(x=16,100)$ is the number of divorces of women of age x in the region during the year $t + 1$;

$m_i(t)$ $(i=1,I)$ is the current annual in-migration flow of type i (total number of immigrants of type I entering the region during the year $t + 1$);

$n_j(t)$ $(j=1,J)$ is the current annual out-migration flow of type j (total number of emigrants of type I leaving the region during the year $t + 1$);

The table of conditional functional transitions (CFTT) is written as the following system of independent difference stochastic equations:

$$b_{xy}(t+1)=\{0,b_{x-1,y-1}(t)+$$

$$+\frac{a_{x-1}(t)g_{x-1}(t)u^{*}_{y-z}\min\left\{c_{y}-1(t),\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}a_{z-1}(t)g_{z-1}(t)u^{*}_{y-z}\right.}{\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}a_{z-1}(t)g_{z-1}(t)u^{*}_{y-z}}+$$

$$+\frac{1}{2}\sum_{i=1}^{I}m_{i}(t)\upsilon_{i}v_{ix}w_{i,y-x}-b_{x-1,y-1}(t)\frac{f_{y-1}(t)}{c_{y-1}(t)+\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}b_{z-1,y-1}(t)}-$$

$$-b_{x-1,y-1}\frac{e_{x-1}(t)}{a(t)+\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}}b_{x-1,z-1}(t)}-h_{x-1}(t)u_{y-z}-$$

$$-\frac{1}{2}\sum_{j=1}^{J}n_{j}(t)\upsilon^{*}_{j}v^{*}_{jx}w_{i,y-x}\left\{x=16,100\ ;\ y=\left\{\begin{array}{ll}16,x+30 & if\ x=16,46\\ x-30,x+30 & if\ x=47,70\\ x-30,100 & if\ x=71,100\end{array}\right\}\right.$$

$$a_{x}(t+1)=\max\{0,a_{x-1}(t)+\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}}\frac{b_{x-1,y-1}(t)f_{y-1}(t)}{c_{y-1}(t)\ \sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}b_{z-1,y-1}(t)}+h_{x-1}(t)+\sum_{i=1}m_{i}(t)(1-\upsilon_{i})a_{ix}-a_{x-1}(t)\frac{e_{x-1}(t)}{a_{x-1}(t)+\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}}b_{x-1,z-1}(t)}-$$

$$\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}}\frac{a_{x-1}(t)g_{x-1}(t)u_{y-x}\min\left\{c_{y-1}(t),\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}a_{z-1}(t)g_{z-1}(t)u_{y-z}\right\}}{\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}a_{z-1}(t)g_{z-1}(t)u_{y-z}}-\sum_{i=1}^{j}n_{j}(t)(1-\upsilon_{j})a_{jx}\ (x=1\ldots100);$$

$$c_{y}(t+1)=\max\left\{0,c_{y-1}(t)+\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}\frac{b_{x-1,y-1}(t)e_{x-1}(t)}{a_{x-1}(t)+\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}}b_{x-1,z-1}(t)}+\right.$$

$$+\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}}h_{x-1}(t)u_{y-x}+\sum_{i=1}^{I}m_{i}(t)(1-\upsilon_{i})\beta_{ij}-$$

$$-c_y(t)\frac{f_{y-1}(t)}{c_{y-1}(t)+\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}} b_{z-1,y-1}(t)}-$$

$$-\min\left\{c_{y-1}(t),\sum_{\max\{16,y-30\}}^{\min\{100,y+30\}} a_{x-1}(t)g_{x-1}(t)u^*_{y-x}\right\}\sum_{i=1}^{j} n_j(t)(1-\upsilon^*_j)\beta^*_{jy}\ (x=\overline{1\ldots100});$$

$$a_0(t+1)=\gamma(1-\delta)\sum_{x=16}^{50}\left[d_{x-1}(x)+d'_{x-1}(t)\right];$$

$$c_0(t+1)=\gamma(1-\delta^*)\sum_{x=16}^{50}\left[d_{x-1}(x)+d'_{x-1}(t)\right];$$

$$d'_x(t+1)=p_x(t)\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}} b_{x-1,y-1}(t)\ (x=16,50);$$

$$e_x(t+1)=q^*_x(t)(a_{x-1}(t)+\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}} b_{x-1,y-1}(t)\ (x=1\ldots100);$$

$$f_y(t+1)=q^*_y(t)(c_{y-1}(t)+\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}} b_{x-1,y-1}(t)\ (x=1\ldots100);$$

$$g_x(t+1)=\xi_x(t)\quad x=(16\ldots100);$$

$$h_x(t+1)=\eta_x(t)\sum_{\max\{16,x-30\}}^{\min\{100,x+30\}} b_{x-1,y-1}(t)\ x=16\ldots100);$$

$$m_j(t+1)=\xi_i(t)\quad(i=1\ldots I);$$

$$n_j(t+1)=\upsilon_i(t)\quad(i=1\ldots I);$$

Initially, the model is designed to be used for forecasting on the basis of appropriate data files related to the City of Kiev, Kiev Region, and some selected towns and rural regions of Ukraine.

One of the factors profoundly effecting social-economic development of a region is the development of production of private and public enterprises on its territory. This factor links regional development to the branch planning of national economy, its territorial realization. The production factor, as well, strongly depends on present demographic and social conditions in the region and, in particular, on availability and growth of a labor force. That is why the second model of the first stage problems relates to the study of interrelations between production development in a region and migration flows. The model uses statistical data accumulated during several previous years. The second model is based on applying the first model to a study of demographic development of an observed region, as well as of the adjacent regions.

The third model of the first stage refers to optimization and forecasting of development of service provided to population of the region. In the well-known publications by domestic and foreign authors this problem is solved in a variety of ways which are, in fact, are very general approaches to this problem.

During last few years in many towns of our country there has been an observed tendency towards transforming these towns into exemplary ones. The concept of an exemplary town up to the present time has only qualitative character and comprises a big number of improvements from the viewpoint of economic conditions, further gain in productivity of labor, progressing in the sphere of service provision, and ecological conditions. In the future, all means aimed at development of towns and big cities should be used with maximum efficiency for improvement of the welfare of population. That is why the tendency of transformation of towns into the exemplary ones should be taken into account while solving forecast-optimization problems of regional development and, in particular, the problem of optimization of the service delivery to population.

The problem arises at the level of development of mathematical formalization of an exemplary town. In spite of the difficulties of working out such formalization criterion, this problem seems to be solvable. In the model, the process of time consumption by the regional population is simulated on the basis of certain statistical data and the average time budget. The relation between the average required time and the average free time may be taken as an adequate indicator for measuring efficiency of functioning of service sphere.

Main model dialog mode operation with the user friendly interface allows for optimal distribution of allotted capital investments among various types of services throughout the territory of a region. Such an alternative for development is given a preference when one Ukrainian hrivna of expenditures yields the maximal increase of the average free time of the regional population. The same index may be used to obtain a qualitative estimate according to which the given town can be granted a status of the *exemplary town*. Apparently, for towns of various categories (national, regional and rayon, centers) a different grading should be used to determine whether the town is considered to be an exemplary one. The index should proportionally grow with the growth of the population well-being and socio-economic development of a region.

The developed model may also be used to obtain recommendations about rational distribution of resources among different towns and places for organization of public service provision.

The designers of the model hope that their work will contribute to improvement of a well-being of population and to the efficiency of capital investment in big cities and towns in various parts of our country and primarily in the City of Kyiv.

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