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Imitating Modeling of Demographic Processes in the Region

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***Abstract*—In the article there is a brief analysis of the demographic processes on the territory of Russian Far East. The method of the multiplicative factor research is presented there for the purpose of monitoring the changing dynamic of the demographic indices with allowance for the indices of socio-economic factors. Simulation model is realized, are applied paradigms of system dynamics and the agent - the focused approach. Modeling of tendencies of demographic development of the Russian Far East is result. The main principals of Russian Far East demographic situation are produced.**

***Keywords*—simulation model, demography, multiplicative factor system.**

I. Introduction

The Far East is of great geostrategic importance for Russia due to its geographic and territorial location, variety of mineral resources, fuel, energy and bioresources. Economic opportunities growth in the Far Eastern territories is possible only with the social sphere development. However according to this factor, the Far Eastern Federal district ranks 7th among all Russian federal districts [1]. The local population life quality can be characterized by such demographic processes problems as the population decline (since 1990 by 23%), constant migration outflow, low life expectancy (FED ranks last). At the meeting of the State Council Presidium of the Russian Federation held in 2017 at the Eastern Economic Forum, dedicated to the issues of complex socio-economic development of the Far East regions, it was also noted that at present the task of improving the living standards of people comes to the fore, and it should not only achieve the average Russian ones, but exceed this level in the nearest future [2]. Regional development planning requires the implementation of mechanisms of accounting, monitoring and adjustment of economic agents' behavior strategies and parameters of society development. In this connection, the issues of studying the possibilities of forming demographic processes in the Far Eastern Federal district, considering the level of social benefits and economic resources, are becoming actual.

The models of socio-economic and demographic indicators interaction have been considered in many works of foreign and domestic scientists. The problems of improving the modeling and forecasting methods of socio-demographic processes are investigated in the works by D. Meadows and J. Forrester [3, 4]. The issues of studying the criteria for assessing demographic indicators and their correlation with the economic development factors were addressed by the following researchers: V.V. Boyko, A.G. Vishnevsky, B.T. Velichkovsky [5, 6, 7]. The authors note the negative changes in the dynamics of demographic processes associated with the reducing the population social protection level, the state of health care systems, and the environment quality.

The aim of this article is to model and quantify the impact of social and economic factors on the society demographic potential development and, therefore, on the population dynamics.

The initial data is the statistics of population dynamics, birth, mortality and migration rates, as well as data on the formation of the main socio-economic indicators in the Far Eastern Federal district taken from 1990 to 2017 [8].

The deterministic approach based on the theory of multifactor multiplicative models is used in the construction of a mathematical model of the region population dynamics [9, 10]. The equations that describe the functional relationship between the studied phenomena, namely demographic processes of birth, mortality, migration and socio-economic indicators of the region development, are the substantive basis. The set of effective indicators of population natural and migratory movement can be presented in the form of a multiplicative factor system, due to their decomposition into components-factors.

$$Y = a, b, c, \dots, k \qquad (1)$$

where Y is an effective indicator, a, b, c, …, k are factors.

The level of the effective indicator is calculated in stages taking into account only factor a, only two factors a and b, only three factors, etc. factors of the system. In general, the value of $Y_{a,b,\dots,k}$ being the level of the effective indicator considering the factors a, b, c, …, k dynamics, is calculated by the formula (2).

$$Y_{a,b,\ldots,k} = Y_0 \cdot I_a \cdot I_b \cdot \ldots \cdot I_k \quad (2)$$

where Y_0 is the value of the effective indicator for the base period, I_a, I_b, …, I_k are the indices modeling the influence of the corresponding factors. The calculation of any index involves a comparison of the comparable value with the base one.

The identification of the most significant socio-economic factors influencing the formation of the main demographic processes in the Far East was carried out by the correlation analysis methods. The sample is presented by following data: x1-life expectancy, x2-gross regional product per person, x3-industrial output, x4-number of unemployed persons, x5- average income per month., x6-living wage, x7- number of living space per person, x8-incidence, x9-number of doctors, x10 – number of abortions, x11- number of harmful emissions in the atmosphere.

The system dynamics method is chosen as the basic principle of simulation model construction. System dynamics is one of the methods of studying complex systems, proposed by J. Forrester and widely used for modeling socio-economic problems. It became possible due to the development of object-oriented languages [11]. In domestic practice, there are several developments in this area, among which the system-dynamic models of the Kirov and Chelyabinsk regions demography should be noted [12, 13].

The constructed model of system dynamics in the object-oriented modeling system Anylogic contains the following basic structural elements (Fig. 1).

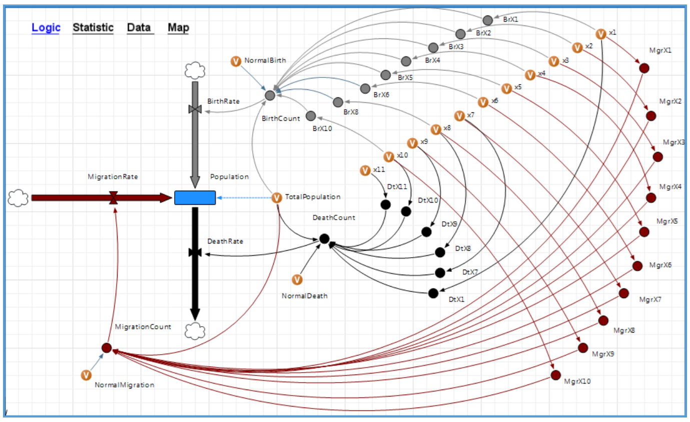

Fig. 1. The FED population change system dynamics model.

Population is a number of inhabitants the change of which is due to the incoming and outgoing flows by the formula:

$$\frac{d(Population)}{dt} = BirthRate + MigrationRate - DeathRate \quad (3)$$

where BirthRate, DeathRate and MigrationRate are the flows modelling the region corresponding rates of birth, death and migration. The decision functions determining the flow intensity are obtained in accordance with the formulas of the deterministic multiplicative model

$$BirthRate = BirthCount \quad (4)$$

where

$$BirthCount = TotalPopulation \cdot NormalBirth \cdot BrX1 \cdot BrX2 \cdot BrX3 \cdot BrX4 \cdot BrX5 \cdot BrX6 \cdot BrX8 \cdot BrX10$$

$$DeathRate = DeathCount \quad (5)$$

where

$$DeathCount = TotalPopulation \cdot NormalDeath \cdot DtX1 \cdot DtX7 \cdot DtX8 \cdot DtX9 \cdot DtX10 \cdot DtX11$$

$$MigrationRate = MigrationCount \quad (6)$$

where

$$MigrationCount = TotalPopulation \cdot NormalMigration \cdot MgrX1 \cdot MgrX2 \cdot MgrX3 \cdot MgrX4 \cdot MgrX5 \cdot MgrX6 \cdot MgrX7 \cdot MgrX8 \cdot MgrX9 \cdot MgrX10$$

Dynamic variables related to the calculation of incoming and outgoing flows act as indices determining the measure of the relevant socio-econoic factor demographic variability. For example, for the birth rate dependency on the indicator x1 (life expectancy) a "direct" correlation is defined by the formula:

$$BrX1 = 1 + BrX1\_1() \quad (7)$$

where $BrX1_1()$is a function containing a program code that determines the ratio of the birth rate regression dependence trend from x1 to the values of this characteristic obtained from statistical data in the corresponding year. At the verification stage, the model was traced on a real data stream, followed by a comparative analysis of the output results with known statistical data (Fig. 2).

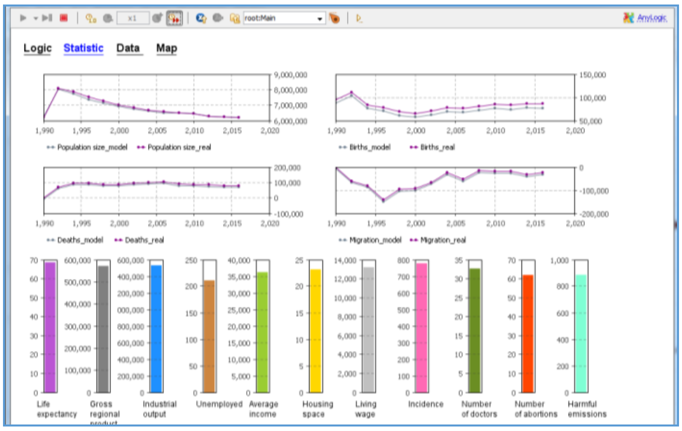

Fig. 2. Compilation of data at the model tracing stage.

When assessing the adequacy (or validation) of the system-dynamic model, Student’s t-test was used to test the hypothesis for the model average values proximity and the real system (the probability with which the hypothesis for inequality of average values is rejected p = 0.96). The simulation model is a model of run-type, the study of which consists in a series of experiments (Fig. 3).

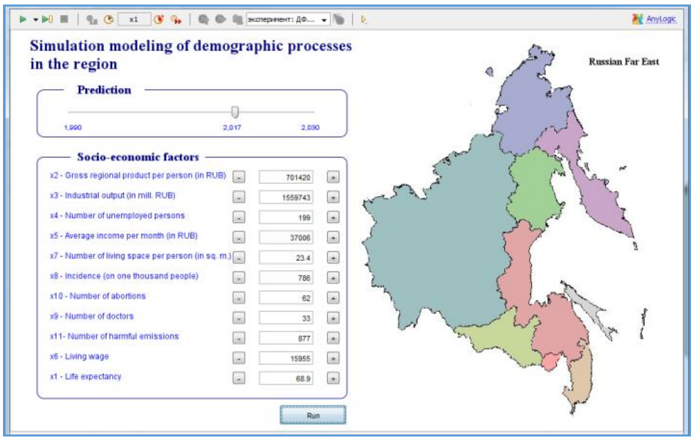

Fig. 3. Model launch pad.

Sensitivity analysis is one of the types of computational experiment, which allows to obtain information about the influence of controlled or input parameters of the model on its results-responses [14]. If we consider the vector X model as input data, then for each of its coordinates the interval of change is determined ($Xmin_q$, $Xmax_q$). The rest of its components are fixed and correspond to the center point. Because of running the model on the vector X data, the responses of the model are obtained for the q-coordinate ($Ymin_q$, $Ymax_q$). In the case of using relative values of variables, increments are calculated as follows:

$$\delta X_q^0 = \frac{(Xmax_q - Xmin_q)^2}{Xmax_q + Xmin_q} 100\% \tag{8}$$

$$\delta Y_q^0 = max\left\{\frac{(Ymax_q - Ymin_q)^2}{Ymax_q + Ymin_q} 100\%\right\} \tag{9}$$

Thus, the model sensitivity for the q-component of the vector X is determined by the pair $(\delta X_q^0, \ \delta Y_q^0)$[15].

The analysis of the model sensitivity on the baseline data from 1990 to 2017 revealed the influence of the following most significant variations on the population dynamics (Table 1).

TABLE I. THE MODEL SENSITIVITY ANALYSIS RESULTS

Factor	$(\delta X_q^0, \ \delta Y_q^0)$
x2 – gross regional product per person	(198,2%, 21%)
x7 – the number of living space per person	(48,1%, 25,3%)
x9 – the number of doctors	(18,6%, 10,4%)
x4 – the number of unemployed people	(98,2%, 6,7%)
x1 – life expectancy	(11,3%, 5,5%)

The experiment on the model data, with a relative increment of the controlled input parameters of the model by an average of 10%, allowed to rank the main input factors to which the model is most sensitive, namely living space per person, the volume of gross regional product, life expectancy in the region, the number of doctors and the number of unemployed, the living wage (Fig. 4).

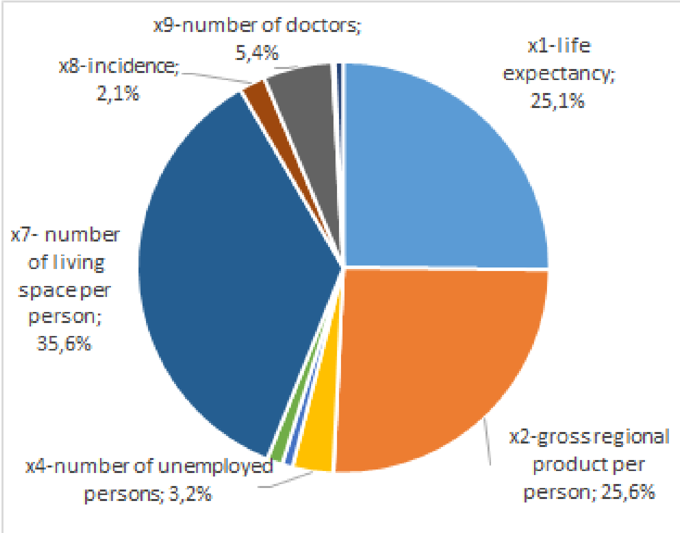

Fig. 4. Diagram of the results of the computational experiment with the model.

II. Conclusion

Thus, the use of the system-dynamic model allows to identify the most significant socio-economic factors and to assess their quantitative impact on the dynamics of population formation in the Far East, considering the processes of birth, mortality and migration.

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