SOCIAL SPHERE MODELING BASED ON SYSTEM DYNAMICS METHODS

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Abstract

This article describes a complex of social sphere simulation models aimed to support decision making in the social sphere, address such issues as a housing reform, public health services and social security. The complex is implemented on the basis of system dynamics methods and using modern simulation modeling techniques.

Key words: social service, decision support system, socio-economic development of a region, simulation modeling, system dynamics methods, description of the model complex, system flow charts.

Introduction

The social sphere comprises such industry systems as health care, physical culture and sport, education, culture, social services and social security, housing, social insurance and pensions.

The analysis of the current situation in the social sphere shows that its governance requires changes. The existing governance system is inadequate under current conditions: the current economic situation in Russia and rate of a new governance system development in Russia at various levels of the industrial and economic sector.

Only elaborate reforms of the social sphere governance will be able to improve the current situation in Russia. An essential component of the social sphere reform is the development of innovative social technologies based on decision support systems to provide information and analytical support to the government authorities in addressing social issues. This will also help optimize regional costs, forecast main socio-economic development indicators for a long-run period, and ensure living standards and regional economic growth.

The economic analysis of the social sphere is primarily aimed at analyzing the allocative efficiency of limited financial, material, labor and other resources of alternative ways of their use to find a solution that is commensurate with the costs of

these resources. The economic analysis should cover characteristics of processes and relationships associated with activities involving comparison and selection of efficient solutions in industry systems, integrated forecasting of living standards considering rates of social service provision. During the review of the economic system of the social sphere industries it is necessary to keep in mind that that these industries have specific economic features that distinguish them from other parts of the economy. They manifest in obvious imperfections in the exchange relations, extensive role of the government in the social service provision, forms of the public regulation and financing, their blending with market mechanisms, and prevailing non-profit organizations.

The analysis of socio-economic processes at the regional level, including its social sphere, should be conducted using a system approach that allows combining a set processes taking place in the economic, social, environmental and other sectors of a region. Making adequate and balance management decisions requires the consideration of regional features, dynamics of socio-economic processes, evolution of the system and its components, actual demographic trends, medical and demographic situation, etc. The socio-economic system under study is viewed as a complex semistructured system, which modeling involves the identification of a large number of complex interrelated causal relationships among factors reviewed within the complex system description and which effects are not always obvious in making decisions; the description of the modeling object structuring contains a significant portion of expert knowledge; the study requires taking into account a large number of stochastic factors under the condition of uncertain initial information. Management decision analysis tools should allow reviewing multiple alternatives and development strategies and be efficient in solving industry restructuring tasks.

The authors of this paper made an attempt to develop a set of models to adequately accommodate the current socio-economic situation in Russia, including such major social sphere subsystems as health care, housing, social welfare, education, culture; to describe demographic, economic and financial processes and solutions to meet contemporary challenges of the social sphere reforming.

Social Sphere Model Complex

The Social Sphere Model Complex is a system of models implemented based on the system dynamics methods that describe relationship of socio-economic development indicators of a region and its separate social sphere industries and are oriented on integrated regional social development forecasting based on national economic management scenarios considering the territorial aspect. Models within the complex are designed to perform scenario calculations based on expert formulated strategies with an explicit set of control actions, i.e. those socio-economic indicators of the social sphere which adjustment falls within the competence of the municipal, regional and federal authorities. The main objective of the regional management is to make such management decisions and select such economic management methods to arrive to such proportions of social reproduction that to the maximum extent help meet the public needs in a region and raise its living standards.

The Social Sphere model complex allows solving such tasks as developing an efficient social policy, planning and managing the social sphere (reforming of the housing and utilities, health care sector, financial planning of the social sphere), forecasting and comprehensive analysis of living standards across regions. Models

also analyze funding and commissioning of individual capacities within the educational system and cultural activities in a region at the expense of the budget. The complex includes an aggregate model of the social sphere, Housing and Utilities, Health Care and Pension System simulation models.

Social Sphere Aggregated Model

This model allows forecasting general development trends and situation in the social sphere in a region as a whole, main socio-economic development indicators of a region, conducting a comprehensive analysis of living standards and quality of life by territories in the short and long term.

As regional socio-economic development objectives are used such objectives as increase of income, improvement of education, nutrition and health care, poverty reduction, environmental enhancement, provision of equal opportunities, enlargement of personal liberty, and cultural life enrichment. In line with regional development objectives is defined a set of criteria and their corresponding regional socio-economic development indicators:

- Gross regional product (absolute value and per capita)
- Financial indicators of situation in a region, budget income and spending, ratio of consolidated regional budget income in its full expenditures, relative income of the federal center, regional budget deficit
- Average household income and its differentiation
- Social support for needy
- Regional unemployment
- Life expectancy, health in a region
- Consumption of goods and services
- Level of health care (provision of outpatient clinics, hospitals, quality of medical services)
- Provision of housing stock
- Level of education of the population of the region and provision of educational institutions across all levels of education (primary, secondary, tertiary)
- Cultural life enrichment and provision of culture institutions of the public
- Overall standard of living

In accordance with objectives and tasks specified a number of subsystems were singled out.

An economic subsystem details regional economic processes, forecasts GRP, requirement in labor forces, household income and payments to the budget. The subsystem is based on the Solow macroeconomic model.

A demographic subsystem describes the structure of population with its division into three age groups, population movement inside a region, birth and death rates, composition of social groups, unemployment in a region.

A financial subsystem describes the budgetary processes, tax collection, financial flows, itemized budget income and spending.

The Housing Stock subsystem divides the housing stock into several types depending on construction factors, housing stock depreciation and evolution, transition of the municipal housing stock to private ownership to citizens and businesses through its sale and privatization. Regional budget income from the municipal housing stock sale is also considered during modeling. A key socio-economic development indicator generated by this subsystem is public satisfaction with living conditions. Figure 1 illustrates a fragment of the Housing Stock subsystem flow chart.

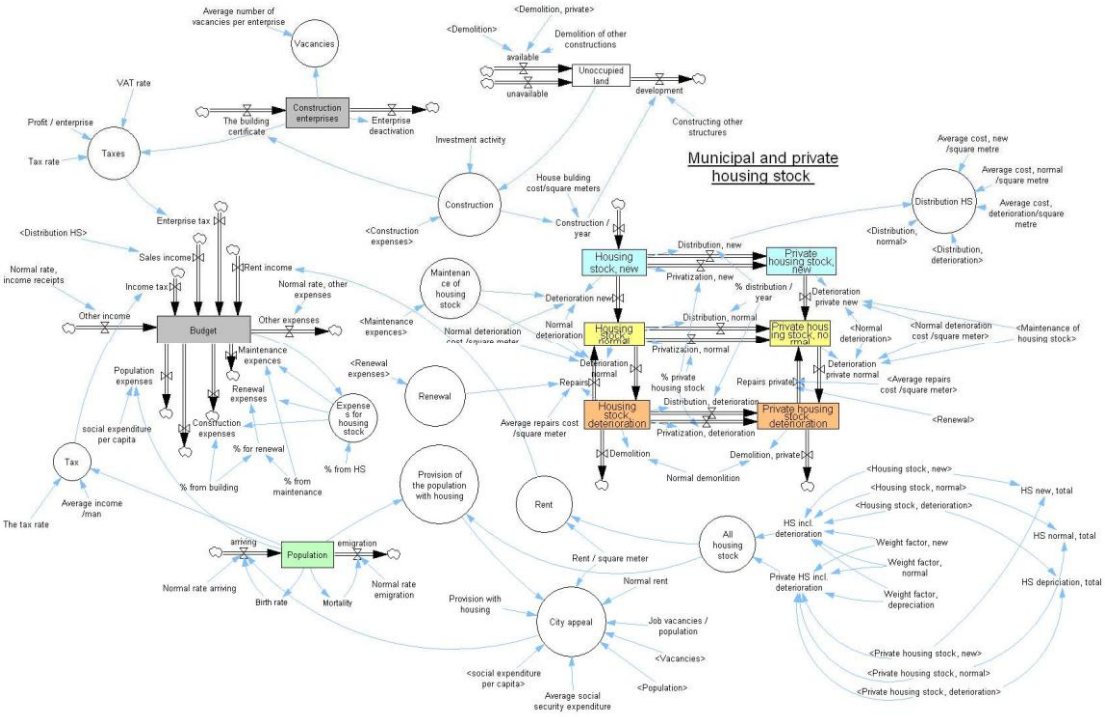

Fig. 1. Fragment of Housing Stock system flow chart

The Health Care subsystem describes the overall dynamics of morbidity rate (patient population), which depends on such factors as life pattern, environmental conditions, genetic risk, level of health care, professional risk, quality of medical services and others. The morbidity rate serves a basis for determining needs in medical care and demand for medical services. The subsystem describes general structure of outpatient and inpatient clinics and their staffing. A key indicator generated by the subsystem is public satisfaction with health care services in a region. Figure 2 illustrates a fragment of the Health Care system flow chart.

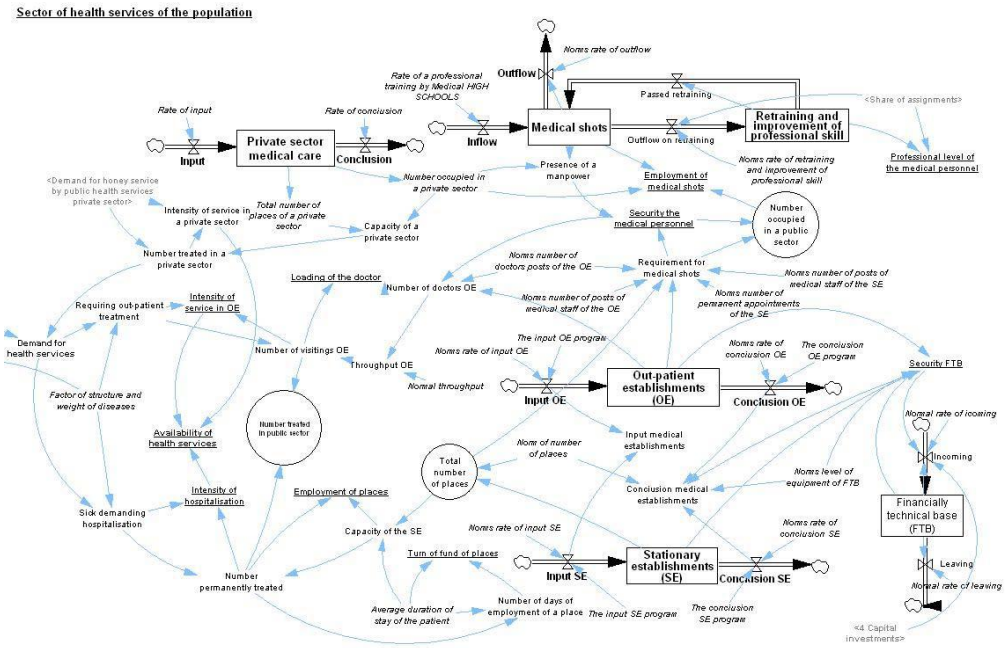

Fig. 2. Fragment of Health Care system flow chart

The Education and Culture subsystem gives an insight into the main educational institutions in a region by level of education, including primary, secondary, tertiary education. The subsystem measures the need in education services, provision of the educational sector with skilled personnel, dynamics of highly educated population and quality of education in a region. This subsystem generalizes public satisfaction with education and culture services.

An integrated living standards index in the model is implemented on the basis of rolled up indicators of public provision with basic social services.

Housing and Utilities Simulation Model

A computer model Housing and Utilities enables describing dynamics of urban development taking into account various factors such as evolution of the housing stock and planning of housing and utilities activities, budgetary process and business activity in a town or city, activities of construction companies, financial relations, actual demographic and migration processes.

The modeling is aimed at:

- Assessing and forecasting situation in the housing and utilities sector of a region provided that the current conditions stay unchanged (assessing the current management strategy defined by a set of controls)
- Analyzing performance of the housing and utilities sector – finding possible ways of influencing the situation (finding potential controls)
- Comparing and selecting different options of the regional housing and utilities sector development driven by alternative management decisions
- Planning budget spending for the housing stock to increase housing provision of population in accordance with social norms at stable regional development judging by main socio-economic indicators

During the problem area analysis the following factors and processes were identified and taken into account during modeling:

- Preparation of income and spending budget, local budget spending on the housing stock and infrastructure (maintenance, overhaul and construction, other expenditures)
- Evolution of the housing stock and infrastructure (new construction projects, depreciation, demolition of dilapidated buildings and structures)
- Segregation of elite housing class within the total housing stock of a town or city
- Housing stock sale to citizens and businesses
- Economic activity of developers and maintenance companies
- Investment processes in the housing stock and infrastructure construction
- Dynamics of household cash income
- Tariff policy in terms of housing and public utility services costs for the population
- Housing affordability for a family
- Living conditions, including a number of factors the main of which is depreciation of the housing stock and infrastructure, as well as provision of resources
- Specific subsidies to socially disadvantaged segments of the population for the purchase of housing
- Limited free lands for the development
- Differentiation of the housing stock by the form of ownership: municipal and non-municipal property

In accordance with objectives and tasks specified in the simulated territorial system were identified the below subsystems.

The Budget subsystem models local budget income and spending with an emphasis on the housing stock.

The Enterprises subsystem describes commercial legal entities, private entrepreneurs, municipal and public enterprises and organizations. The model identifies construction companies that are directly related to the new housing construction, as well as investment processes in construction. Investments can come from the government (from budget and off-budget funds), from enterprises and banks, as well as from the public.

The Housing Stock and Infrastructure subsystem covers all buildings suitable for permanent residence of citizens. The model distinguishes several housing types depending on factors of aging and the transition of the municipal housing to private ownership of citizens and businesses through its sale and privatization.

The Population subsystem. The population is the main consumer of the housing stock for whom such stock is created. The population can act as housing construction investors. The population also covers a certain part of public utility service and rental costs. The model takes into account various benefits, compensation,

rents, subsidies for housing construction and purchasing to socially disadvantaged segments of the population.

The Housing and Utilities simulation models are designed to address current issues discussed in the course of the housing and utilities reform implemented at the federal and regional levels.

Health Care Simulation Model

The Health Care model is aimed at solving a set of tasks associated with the development and assessment of strategic options for the development of social infrastructure in a region and health care system management to increase efficiency of industry resource potential use, improve medical service quality and living standards, and to improve population health in a region.

The health care process modeling is primarily aimed at conducting comprehensive analysis and forecasting living standards and health of population in a region taking into account impact of internal and external factors reflecting actual medical, demographic and economic situation in a region, assessing and comparing different health care system management strategies.

The Health Care simulation model is divided into four subsystems.

The Medical and Demographic subsystem describes population in a region, which dynamics is defined by fertility and mortality rates. Labor resources are separated from the total population. The model features population morbidity (patient population), which depends on such factors as life pattern, living standards, environmental conditions, genetic risk, level of health care, professional risk, quality of medical services and other. The population morbidity rate serves as a basis for defining needs in and demand for medical services.

The Medical Service subsystem describes outpatient clinics of a given capacity, inpatient facilities, hospital beds, material and technical basis, population medical service costs (labor costs, material and technical base maintenance costs, operating costs of outpatient and inpatient facilities), private medical and preventive treatment institutions (characterized by number of facilities, hospital beds and medical staff), absolute number of patients treated and service rate, medical personnel (itemized by medical and nursing staff), medical personnel employment.

The Financial subsystem models health care funding taking into account receipts from the federal budget, receipts from the regional budget, receipts from the compulsory medical insurance fund, receipts from commercial activities of medical and preventive treatment institutions and from other sources. Financial flows cover such expense items as financing of free medical care guaranteed to the population, operating expenses, medical personnel salaries, capital investments to new medical and preventive treatment facilities, R&D and new technology introduction expenses, pharmaceutical provision, cost of preventive actions, retraining and professional development and other expenses.

The Socio-economic subsystem describes regional economic situation (gross regional product) taking into account budgetary processes and employment.

In terms of health care industry management a health care simulation model developed should enable solving the following tasks:

- Analyzing and forecasting living standards in a region
- Analyzing and forecasting population health in a region
- Analyzing, assessing and forecasting provision of population with health care services
- Analyzing, assessing and forecasting health care sector needs in material, financial and labor resources
- Strategic planning and restructuring the network of medical care and preventive treatment facilities
- Financial planning for target areas within the health care sector
- Analyzing decisions made from standpoint of their impact on living standards in a region and quality and efficiency of the health care system

The model focuses on the overall assessment of the medical and demographic situation in a region and enables financial planning of the industry.

Pension System Simulation Model

The pension provision is one of the most acute social issues requiring government solution. A reasoned management decision should be preceded by statistical analysis of monitored data and "what-if ..." scenario calculations that allow assessing implications of management decisions made using simulation and mathematical models.

A pension provision system simulation model developed allows solving the following tasks:

- Analyzing financial sustainability of the Pension Fund
- Analyzing and forecasting average labor pension size
- Scenario modeling of allocation of pension savings between financial market segments and forecasting changes in profitability of the total investment portfolio as the result of changes in its structure
- Analyzing changes in amount of pension savings
- Analyzing financial market impact on investment portfolio profitability and amount of pension savings

The simulation model is implemented based on system dynamics methods and includes the following subsystems: insured persons, insurants, pension funds, management companies, pension legislation, and financial market.

Insured persons: The subsystem models the natural movement of population, employment, process of choosing a pension scheme by an insured, process of acquiring pension rights, social characteristics that entitle benefits. Basic social behavior processes are simulated by the subsystem using the agent-based computer simulation method with cognitive modeling elements. Expert methods and methods of multidimensional statistical analysis of pension system data coming from a data warehouse are used to parameterize a system dynamic model.

Insurants: The subsystem describes dynamics of performance indicators of employers by industry.

Pension funds: The subsystem generates revenues and plans expenditures of the pension system.

Pension legislation: The subsystem describes a pension scheme mechanism depending on wage rates, different pension formulas, pensioner social characteristics. The subsystem has production model features where a specific pension scheme is assigned for each insured person depending on his/her characteristics (age, wage, period of service, health, marital status).

Managing company: The subsystem models activities of management companies on investing pension savings, describes the formation of the aggregate investment portfolio consisting of assets in which pension savings are invested, including deposits, the funds in the accounts of credit institutions, the Russian government securities, securities of the Russian Federation constituents, municipal bonds, bonds of Russian business companies, unit investment funds, mortgage securities, shares of Russian emitters.

Financial market: The subsystem based on multi-agent financial market model describes dynamics of financial assets in which pension savings are invested.

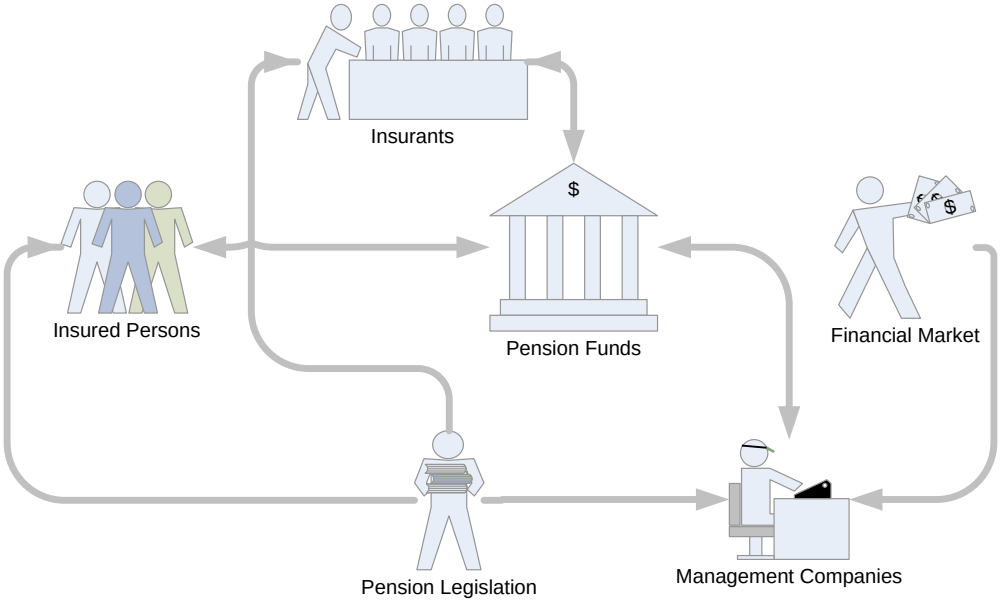

Fig. 3 - Subsystems of the Pension System simulation model

The model takes into account the differentiated rate of return on each asset and its fluctuations over time.

The simulation model output statistics is represented by socio-economic indicators and indicators of the pension system financial sustainability.

Socio-economic indicators:

- Average pension
- Pension adjusted for inflation
- Real wage
- Pension to real wage ratio

Indicators of the pension system financial sustainability:

- Current state of the Pension Fund

- Current position of a management company
- Average yield of an investment portfolio

PROGNOZ experience in modeling solutions

The PROGNOZ company (www.prognoz.com) was founded on base of the Perm State University during Perestroika by professors of economics and mathematics. The main clients of young company were government and local authorities of the Soviet Union and then the Russian Federation. And the basic tasks the company had to solve were analysis, forecasting, planning of the national and regional economy and sectors.

There were different applications on the software market but all of them were created for solving very partial tasks, not so complicated and sophisticated ones.

Large government analytical centers accumulate statistical data on economies of different countries, regions and industries. These data arrays include information from many different data-providers and are calculated using different methodologies and algorithms.

In decision making process specialists implement a wide range of econometrical methods including smoothing, extrapolation, regression and factor analysis, multidimensional statistical analysis and so on. And the main requirement of modelers is simple interface (without coding).

Beside econometrical tools handling a single equations it is required to make systems of equations, dynamic system of equations (Vector autoregression and Error-correction model), to sort equations and to analyze cycles in them. Designing of large-scale models also requires users to specialize in determined sectors of economy and corresponding blocks of model.

Besides simple scenarios of forecasting and simulations, practical tasks need to have instruments for optimization and dynamic programming.

Summarizing all the above mentioned, we can conclude that application oriented to such tasks solving should:

1. be integrated with industrial databases and include tools for data validation;
2. include many statistical and mathematical methods with user-friendly interface;
3. include tools for handling large-scale mathematical models;
4. have tools for forecasting and optimization;
5. include multiuser working with modeling and administration tools;
6. advanced decision making tools;
7. include results of visualization tools.

Large-scale model can include some hundreds and even thousands of equations and modeling variable. This feature allows users to take into account not only direct linkages between variables but also indirect ones and feedbacks. Sensitivity analysis allows users to estimate influence of different shocks on key macroeconomic variables and elasticities in dynamics.

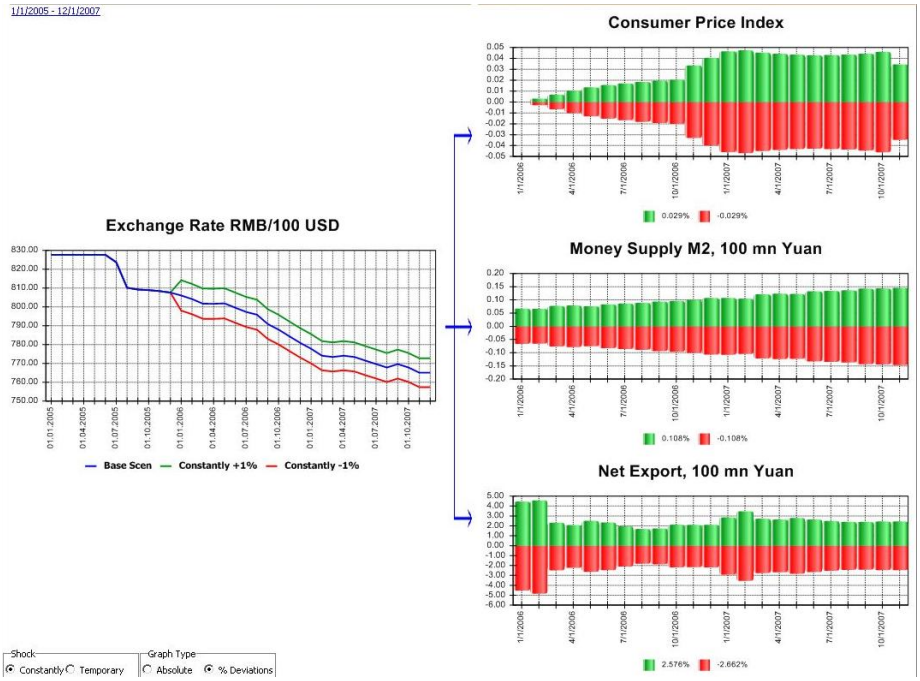

Fig. 4. Sensitivity analysis examples

Scenarios approach in these models allows experts to determine threshold values of exogenous variables. Such kind of analysis is used to determine limit of oil price that can be offered by oil exporter countries.

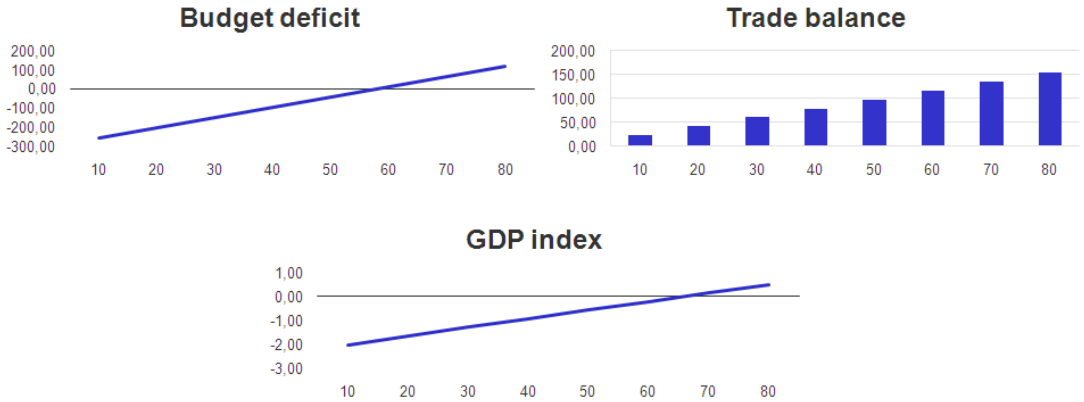

Fig. 5. Determination of oil price threshold value

Conclusion

The elaborated Social Sphere model complex allows forecasting regional socio-economic development and living standards, performing comprehensive analysis of alternative management decision on future regional socio-economic development by selecting financial, economic and other controls to ensure growth of living standards and sustainable development of a region as a whole. The model complex enables solving resource management and financial planning tasks in the overall social sphere and its industries, including housing, health care and others, as well as developing a social policy taking into account actual demographic trends, environmental, medical and demographic situation; financial, labor and other resources in a region. The use of the model complex in practice by regional and local governments will enable solving specified tasks using a computer model taking into account short-term and long-term outlook.

The simulation models are implemented in high-tech simulation environment powered by AnyLogic software based on regulatory schemes of system dynamics models with advanced ideographic capabilities for building and visualizing system flow charts, tools for scenario calculations based on simulation models.

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