ABOUT PROBLEMS OF DECISION MAKING IN SOCIAL AND ECONOMIC SYSTEMS

Oleksiy Voloshyn

Abstract: The reasons of a restricted applicability of the models of decision making in social and economic systems. 3 basic principles of growth of their adequacy are proposed: "localization" of solutions, direct account of influencing of the individual on process of decision making ("subjectivity of objectivity") and reduction of influencing of the individual psychosomatic characteristics of the subject (" objectivity of subjectivity ") are offered. The principles are illustrated on mathematical models of decision making in ecologically- economic and social systems.

Keywords: decision making, ecological, economic and social systems, sequential analysis of variants, indistinct analysis, methods of expert estimation, collective decision making, and decision-making support system.

ACM Classification Keywords: K.3.2 Computer and Information Science Education.

Introduction

The second half of XX century gave birth to the many mathematical models of ecological, economical and social process [1]. However the success in application of them is incomparable with practical achievements in application of the models of the «lifeless nature». Economical, political man-caused and the ecological crises are typical to separate countries, regions, political and economical systems, and mankind. Penetrating into the depths of the Universe, uncovering secrets of a micro-world, modern civilization is not able to prevent military conflicts, famine, and terrorist acts. It is enough to tell, that for 5500 years of a modern history the mankind lived without wars only 292 years, and from 6.4 billion of dwelling people are starve more then 800 million one, though food is made on 20% more indispensable. There are unsolved ecological problems, which one threatens to the survival of mankind.

There is a natural question — why the use of the modern achievements in the decision-making theory in practice of modeling of economical and social processes is very limited? The answer is obvious, because they have very low "adequacy" to a substantial world and very high scale of result uncertainty. Moreover, frequently this result is "meaningless" (i.e. basically is not testable). It is referred to normative mathematical models of economic and social processes, and positive one. The normative models are answer of a problem "what it is necessary to do to achieve desirable?" and positive models are answer of a problem " why we have that we have?" and, at the best case, "what will be?"

Within the framework of existing paradigm of the development and analysis of ecological, economical and social processes for overcoming the indicated defects are necessary for taking into account following aspects. At first, to take into account as a lot of the factors as possible, which one influences on a process of decision-making. This fact lead to "damnation of dimension". Secondly, it is necessary to take into account an inaccuracy and illegibility of parameters means of model (quite often and it full absence). These inaccuracies are connected as with "by objective uncertainty" [2] (which one is proper of the organization of our world), and with "by subjective uncertainty " (which one is characteristic to the human nature as a whole). The standard approaches of development of algorithms, which one guarantee convergence (in classic comprehension) to precise solution, create more illusion of their solution, than decide the delivered problems.

The problem consists not in finding to any desired degree of solutions precision of a problem (especially if the initial data is not exact!), but its "localization" [3]. It is necessary to determine intervals of solution component changes. These intervals depend on accuracy of data calculation. In an ideal it is desirable to achieve maximum localization of solution - minimum (in some metrics) intervals of solution uncertainty. Such approach in natural sciences, for a long time already became natural (we shall recollect "a principle of uncertainty " of the Heisenberg [4]). At simulation of social and economic processes this approach has not found broad application. And it provided that the subject is their active component! All features of subjective perception of a choice of decision-making in the "classic" approach include in to an axiomatic. In this case problem of the contributor is lead to testing of their "reality" [5].

In such aspect is a priori accepted, that "reality" of a hypothesis means its "reality" for each subject at any moment of time (or in a continuous enough time interval). From a beginning 70 years of past century are successfully used in acceptance of political-military solutions principles of the theory of group thinking [6]. In modern mathematical economy these principles have not found application. In 90 years of XX century the necessity of subjective features usage for decision making in economy has lead to appearance "situational economy ". Originating in 60 years of past century of the "indistinct analysis" [7] also is confirmation of necessity of direct usage of the subject at construction of social and economic models. In this case "functions of an accessory" meaning of indistinct set can be interpreted as "subjective probability".

Thus, during the mathematical informational model construction of social and economic processes there are two problems. At first "subjectivity of objectivity that is"direct consider of influencing of the subject on decision-making process. In second "objectivity of subjectivity" that is a reduction of influence of the individual characteristics of the subject and accounting of subject’s "objective" psychosomatic features of reality knowledge.

"Subjectivity of objectivity", lead to necessity of usage at construction and research of models of the indistinct analysis theory, group thinking theory, development of algorithms solution locating. "Objectivity of subjectivity " in models can be carried out on the basis of social and psychological disciplines. For example, to take into account subject attitude to the one of the socionic types, tendency to risk, independence degrees etc. [8]. In turn to increase the objectivity it is reasonable to use the description of the subject in an unclear form. Ideally "objectivity" of the subject should be imposed on "subjective" description of an object for the increase of the objectivity degree.

The offered principles are illustrated below on idealized and applied models of decision-making problems in social and economic systems.

Models of the Analysis of Static Balance of Large Dimensional Ecological and Economic Models

The static balance Leontieff — Ford model [9] is considered in these settings:

$$\begin{cases} x_i^1 = \sum\limits_{p\in I} a_{ip}^{11} x_p^1 + \sum\limits_{q\in J} a_{iq}^{12} x_q^2 + y_i^1, \\ x_j^2 = \sum\limits_{p\in I} a_{jp}^{21} x_p^1 + \sum\limits_{q\in J} a_{jq}^{22} x_q^2 - y_j^2, \\ i\in I,\ j\in J;\quad x^1 > 0, x^2 \geq 0; \end{cases} \tag{1}$$

where $x^{1T} = \left(x_i^1\right)_{i\in I}$ — a vector of production volumes, $x^{2T} = \left(x_j^2\right)_{j\in J}$ — a vector of contaminants volumes destroying, I = {1,2, …, n}, J = {1,2, …, m} — are sets of indexes of variables representing «economical» and «ecological» model component, T — a sign of transposition; $A_{11} = \left\| a_{ji}^{11} \right\|_{i\in I}^{j\in I}$ — a square matrix of normative factors of the product cost j by production of a product unit i , $A_{12} = \left\| a_{ij}^{12} \right\|_{j\in J}^{i\in I}$ — a rectangular matrix of normative factors of the production cost i at killing unit of contaminant j, $A_{21} = \left\| a_{ji}^{21} \right\|_{i \in I}^{j \in J}$ — a rectangular matrix of normative factors of ejection of contaminant j by production of product unit i $A_{22} = \left\| a_{ji}^{22} \right\|_{i \in J}^{j \in J}$, — a square matrix of normative factors of contaminant ejection j at killing unit of contaminant i , $a_{ij} \in [0;1]$, $y^{1T} = \left(y_i^1\right)_{i \in I}$ — a vector of volumes of final product, $y^{2T} = \left(y_j^2\right)_{j \in J}$ — a vector of volumes of contaminants, which one are not deleted, $y_i^1 > 0, i \in I$, $y_j^2 \geq 0$. $j \in J$

$X = \prod_{i \in I} X_i^1 \times \prod_{j \in J} X_j^2$ — a hyper parallelepiped of problem solutions, which takes into account the contents of limitations of economic and ecological components:

$$X_i^1 = \begin{cases} \left[d_{i(H)}^1, d_{i(B)}^1\right], & i \in I^{(H)}, \\ \left\{d_{i(H)}^1, d_{i(H)}^1 + 1, \ldots, d_{i(B)}^1\right\}, & i \in I^{(Ц)} = I \setminus I^{(H)}, \end{cases} \tag{2}$$

$$X_j^2 = \begin{cases} \left[d_{j(H)}^2, d_{j(B)}^2\right], & j \in J^{(H)}, \\ \left\{d_{j(H)}^2, d_{j(H)}^2 + 1, \ldots, d_{j(B)}^2\right\}, & j \in J^{(Ц)} = J \setminus J^{(H)}, \end{cases} \tag{3}$$

where $d_{i(H)}^1$, $d_{i(B)}^1$ and $d_{j(H)}^2$, $d_{j(B)}^2$ — are variables border (upper and lower accordingly) x_i^1 and x_j^2 accordingly, $d_{i(B)}^1 \geq d_{i(H)}^1 \geq 0$, $d_{j(B)}^2 \geq d_{j(H)}^2 \geq 0$ (in case of an integer formulation (1) $d_{i(H)}^1$, $d_{i(B)}^1$ and $d_{j(H)}^2$, $d_{j(B)}^2$ are considered integer), the indexes (H) and (Ц) divide set of indexes on sets of indexes accordingly of continuous and integer variables. If the initial borders do not given, $d_{i(B)}^1$ and $d_{j(B)}^2$ are considered as zero points, and $d_{i(H)}^1$, $d_{j(H)}^2$ are selected large enough (proceeding from economic reasons).

In a basis of methods, which one are offered for overcoming the difficulties, indicated in the introduction, which one arise at the analysis of models (1-3) large dimensions, the scheme of a sequential analysis of variants lay [10-15]. The basis of algorithm of problem solving (1-3) is compounded by a WB procedure [16] approximating of set D of solutions by a hyper parallelepiped X^* by such, that $X \supseteq X^* \supseteq D$.

The analytical estimation of performance of a WB procedure looks like the following. Let ε_1 : $\varepsilon_1 > 0$, ε_2 : $\varepsilon_2 > 0$, - percentage errors of magnitudes nearing $Q^{1(k)}$ and $Q^{2(k)}$, $k = 0, 1, \ldots,$ to boundaries

$$Q^{1*} = \lim_{k \to \infty} \left(y_{\min}^1 \sum_{s=0}^{k} \lambda_1^s \right) = y_{\min}^1 \lim_{k \to \infty} \sum_{s=0}^{k} \lambda_1^s = \frac{y_{\min}^1}{1 - \lambda_1} \quad , \quad Q^{2*} = \lim_{k \to \infty} \left(y_{\min}^2 \sum_{s=0}^{k-1} \lambda_2^s \right) = y_{\min}^2 \lim_{k \to \infty} \sum_{s=0}^{k-1} \lambda_2^s = \frac{y_{\min}^2}{1 - \lambda_2} \quad .$$

Then $k_1 \leq \frac{\log_2 \varepsilon_1}{\log_2 \lambda_1} + 1$, $k_2 \leq \frac{\log_2 \varepsilon_2}{\log_2 \lambda_2} + 1$, where $\lambda_1 = \min_{i \in I} \frac{\sum_{p \in I,\, p \neq i} a_{ip}^{11}}{1 - a_{ii}^{11}}$, $\lambda_2 = \min_{j \in J} \frac{\sum_{q \in J,\, q \neq j} a_{jq}^{22}}{1 - a_{jj}^{22}}$.

Let $L = \left((n+m)^2 + 3(n+m)\right) \log_2 a$ - length of an input of a problem (1), $a = \max \left| \log_2 a_{ij} \right| + 1$, then a percentage error of a solution $\max \{\varepsilon_1, \varepsilon_2\} = \varepsilon \geq 2^{-L}$.

The amount of elementary operations M WB procedures has the order $M = O(L)$, and the computational complexity is given in to [17]: $N = O(Mk) = O\left(-\frac{L^2}{\log_2 \lambda}\right)$, where $k \le \frac{\log_2 \varepsilon}{\log_2 \lambda} + 1$, $\lambda = \min\{\lambda_1, \lambda_2\}$. At non-existence of original limitations: $d^{1(0)}_{i(H)}$, $d^{1(0)}_{i(B)}$, $i \in I$, $d^{2(0)}_{j(H)}$, $d^{2(0)}_{j(B)}$, $j \in J$, for a WB procedure it is possible to put: $d^{1(0)}_{i(H)} = \frac{y^1_{\min}}{1-\lambda_1}$, $i \in I$, $d^{2(0)}_{j(H)} = \frac{y^2_{\min}}{1-\lambda_2}$, $j \in J$, $d^{1(0)}_{i(B)} = \frac{y^1_{\max}}{1-\bar{\lambda}_1}$, $i \in I$, $d^{2(0)}_{j(B)} = \frac{y^2_{\max}}{1-\bar{\lambda}_2}$, $j \in J$, where $y^1_{\max} = \max_{i \in I} y^1_i$, $\bar{\lambda}_1 = \max_{i \in I} \frac{\sum_{p \in I, p \ne i} a^{11}_{ip}}{1 - a^{11}_{ii}}$, $y^2_{\max} = \max_{j \in J} \{A_{21} y^1 - y^2\}$, $\bar{\lambda}_2 = \max_{j \in J} \frac{\sum_{q \in J, q \ne j} a^{22}_{jq}}{1 - a^{22}_{jj}}$.

More detailed results of computational experiment on a WB procedure are given into [18].

The productivity of a computational procedure is instituted by time spent for calculus, and fidelity of result. At a percentage error to within the sixth sign and dimension of a problem m+n=1000 the time for a solution of a continuous and integer problem compounds about 30 min. As at magnification of dimension of a problem the specific weight of nonzero members is moderated, introduces practical concern update of a WB procedure on a case of sparse matrixes [18]. At a reduced percentage error and dimension about 10000 at matrixes entry on 1 % the time for a continuous integer problem compounds about 10 min.

Fuzzy and Multicriteria Models

"Subjectivity of objectivity" guesses fissile involvement of the subject in decision making, account in the patterns of social and economic processes subjective reluctance. Let's esteem two basic methods of realisation of this principle - illegibility (for example - the static Leontieff pattern [1]) and multicriterion (for example - a collective decision making problem [21]).

Let's esteem the Leontieff pattern x = Ax + y, x≥0. . The bulk of final consumption, as a rule, is set by the way of hyper parallelepiped Y = $\Pi[y_j^-, y_j^+]$, where y_j^- - - lower “norm” of consumption j-th of a product, y_j^+ - upper. Moreover, is logical (as a rule, it is done) on an interval $I_j = [y_j^-, y_j^+]$ the function of an accessory μ_{Ij} by the way of expert recommendations for bulk of consumption j-th of a product is set. Similarly for the pattern Leontieff-Ford is logical to set lower and upper “norms” of bulks of the not erased contaminants, that is to set a hyper parallelepiped $Y^2 = \Pi[y_j^-, y_j^+]$. Then also solution of the patterns x $\in$ X is logical to discover, allowing wishes of the experts, by the way functions of an accessory μ_X,

For the Leontieff pattern (for the pattern Leontieff-Ford the constructing similar) are necessary for finding {x $\in$ {x: x = Ax + y, x $\in$ X, y $\in$ Y} at given functions of an accessory μ_X, μ_Y. Let's record indistinct set by the way: X~ = $\bigcup_{\alpha \in [0,1]} \alpha X_\alpha$, were $X_\alpha = \{x \mid \mu_X(x) \ge \alpha\}$.

On definition the function of an accessory of indistinct set α A is set as following: $\mu_{\alpha A}(a) = \begin{cases} \alpha, a \in A \\ 0, a \notin A \end{cases}$.

Similarly Y~ = $\bigcup_{\alpha \in [0,1]} \alpha Y_\alpha$. The basic conjecture, which one is superimposed on a solution of the indistinct pattern Leontieff, consists in following: $x \in X_\alpha$ in only case when, when $x - Ax \in Y_\alpha$

Let's esteem piecewise linear functions of an accessory, then:

$$X_\alpha = \prod_{k=1}^{n} \left[x_k^-(\alpha), x_k^+(\alpha)\right] = \prod_{k=1}^{n} I_\alpha(x_k),\ X_\alpha^\pm(\alpha) = x_\alpha^\pm(0)(1-\alpha) + x_\alpha^\pm(1) \cdot \alpha,\ \mu_X(x) = \prod_{k=1}^{n} \mu_i(x_k).$$

Let's designate: $AX = \{Ax \mid x \in X\}$, $X + Y = \{x + y \mid x \in X, y \in Y\}$.

Allowing, that $(AX)_\alpha = AX_\alpha$ and the additive property of a WB procedure, boundaries calculus of a hyper parallelepiped for each value a is carried on separately by the formula:

$$AX = \prod_j \left[\sum_{j,a_{ij}>0} a_{ij}x_j^- + \sum_{j,a_{ij}<0} a_{ij}x_j^+ ; \sum_{j,a_{ij}>0} a_{ij}x_j^+ + \sum_{j,a_{ij}<0} a_{ij}x_j^- \right].$$

At applying the depicted above approach to a problem with indistinct data we have:

1 Solutions of an indistinct problem is lead to a solution p (on an amount α - - levels) customary problems Leontieff, which one are decided separately;

2 As solution of an indistinct problem we shall consider indistinct set with an accessory function to making up by level lines for each of a these *p* components of problems solution;

3 The algorithm of a sequential analysis of alternatives does not degrade arguments of a solution: „equivocation» of a solution of an indistinct problem will be «not greater » uncertainty of original data.

The proposed approach is applicable and in case of an indistinct matrix of normative coefficients.

Most general formulation of a problem of acceptance of a collective solution having a numerous application in economics, policies and other fields of human activity, bound with analysis and resolution of conflicts, is lead to a following mathematical model:

$$U_i(x) \to \max ,\ i \in I,\ x \in \Pi X_i \tag{4}$$

Where: U_i - utility function i-th of the agent, X_i- set of its policies, the set of policies x is called as a situation.

In classic posing of a gamble problem of strategy are selected by the gambler (agents) simultaneously and separately. Generally players can agree about queue of courses, about a share choice of strategy the etc. Most popular principle of optimal behaviour ("principle of an optimality ") in a problem (4) is considers "the Nash equilibrium" [19]. In this principle the individual deflections of the gamblers from strategies, which are included in this situation, do not augment a scoring of the declined gambler, if the remaining gamblers hold on to the strategies, fixed in this situation. The considerable situations of equal balance as the challenger for optimal behaviour are natural enough. However situations of equal balance can have a series of properties handicapping their operational use. First of all is non-uniqueness, and the miscellaneous situations of equal balance are preferential to the miscellaneous gamblers. In [19] two yardsticks of a choice of single equal balance - prevalence on a scoring and prevalence on risk are selected. When prevalence on a scoring and prevalence on risk have the different directions, the writers of [19] return priority to prevalence on a scoring. However in practice is reasonable to allow for psychosomatic features of the agents. In this case this is "tendency to risk" [25]. Is generally logical to esteem a multicriteria choice with allowance for two given criteria. With the purpose of “subjectivity” of the model (4) are expedient for esteeming not scalar utility functions Ui, but vector functions [20,21], and to apply convolutions depending on psychosomatic features of a making decision person (MDP). In absolute majority of cases of value of utility functions there is a result of an expert estimation. For this reason practical concern consideration of fuzzy formulations (4) [22] is interesting.

Methods of an Expert Estimation

In the given partition we shall esteem a possibility of sharing of principles of localisation and subjectivity of the pattern for a problem of an expert estimation [23].

Was held studies about deriving the consistent information from the expert about numerical values of weighting coefficients of criteria. It demonstrates that the expert or (MDP) can adequately define weighting coefficients, if the amount of object arguments does not exceed "magic" number 5-9 [24]. If these objects are characterised by a great number of arguments, it is necessary to apply indirect methods. In these methods the ratios of preference sequentially are updated on the basis of accepted before solutions (intervals of relative relevance of plants "are localised").

Let A - set of objects a^j, $j \in J$. Each of objects a_j is characterised by a set of arguments

$a^j = (a^j_i)$, $i \in I$. It is necessary a_j to deliver object in conformity vector estimation in R^n, which defined by a set of criterions, on which one MDP values objects.

Let's esteem two objects a^1 and a^2 from set of effective objects And. The object $a^1$is considered as "best", than the object a^2, if the sum of fluidised deflections of arguments from their best values for object a^1 is less, than for a^2, i.e.

$$\sum_i \rho_i \omega\left(a_i^1\right) < \sum_i \rho_i \omega\left(a_i^2\right) \tag{5}$$

Where ρ- normalised vector of relative relevance of objects arguments for the assertion MDP about a ratio of preference between objects; $\omega\left(a_i^j\right)$ - some monotonic transforming, defining extent of deflection from a best value of argument and conversing all value of arguments to a dimensionless aspect in a spacing [0,1].

On the basis of a method of localisation of solutions [3] the procedures of calculus of intervals are proposed [$\rho_i^н$, $\rho_i^в$], conserving a ratio (5). The software is designed, which one in real-time mode allows to decide problems with 50 objects.

Decision–making Support Systems

Methods of social and economical processes progressing estimation which one are "a past prolongation", allows to receive the forecast, as a rule, with a very high scale of ambiguity. As the knowledge, operating of the subjects of these processes is "suspended" past expertise in these methods. Desire as much as possible to approximate subjective perceptions to an actuality is lead to following. First of all it led to necessity of the expert information usage in the given point of time. Secondly, the complication of modelled processes does not allow using immediate knowledge of the expert in broad fields. Therefore there is a problem of creation of "flexible" systems of decision making. Such systems should be customised on a particular data domain. They require narrow professional, "local" knowledge. This knowledge, naturally, will be ill structured and fuzzy. "Objection" of such shapes of knowledge is possible by the account of psychosomatic features of the expert and his previous expertise.

It is generally recognised that one of decision-making, most adequately modelling process, by the person is the method of a decision-tree [25]. However its applying is hampered by a "damnation of dimension", which one arises at its usage. Mining of a special processing techniques of a decision-tree therefore is indispensable [8].

On the basis of the above-stated concepts the development support system of creation applied decision-making support systems (DMSS) in different fields is designed. The constructing of applied DMSS is resulted to separation by the experts of problems and sub problem (tops of a tree) and links between them (arcs of a tree). Further experts are assigned the weight coefficients of transferring probability between tops. The indistinct estimations of the experts with the help of logical variables are enabled. These variables are described by values of a membership function (vectors of true numbers from 0 up to 1). Each expert sets three estimations: optimistic, realistic and pessimistic. Scalarization of these estimations is carried out with allowance for psychological type of the expert. The type is assigned on a foundation of the psychological tests, which one is input in a system. On the basis of the psychological tests the coefficients of "truthfulness", "independence", "caution" etc. [8] are assigned also.

The tree is under construction on the basis of collective estimations of the experts with applying of a pairwise comparison method. The algebraic processing techniques of the expert information are applied to constructing a resultant tree. As spacing interval between ranging the metric of the Hamming and measure of straddling of ranks of objects is applied. The resultant tree is assigned as a Kemeni- Snell median:

$$Arg \min_{A} \sum_{i=1}^{n} d(A, A^i) \text{ Or as the compromise: } Arg \min_{A} \max_{i} \ d(A, A^i) .$$

Where A^i - matrix of i-th expert, in which one a member a_{ij} =1 in only case when, when i-th the top is more preferential to the j-th expert, a_{ji} = -1, for equivalent objects a_{ij} =0, a_{ii} =0. .

In case of the definition of advantage in the indistinct shape the members of a matrix are set through functions of an accessory.

For determination of optimal paths in a tree the algorithms of a sequential analysis of alternatives are t suggested [10-15]. These algorithms allow to process trees with hundreds tops.

The tables set the solution-tree. Each table is a separate level of a tree. Each table line is separate top at this level. Each element of line is a probability, with which one the transferring from the given top in top of a lower layer is possible. These probabilities are set by functions of accessories representing of real numbers vector from 0 up to 1 of any lengths. The table is filled by interrogation of the experts. The existing functions allow to add columns, line, to set the dictionary. This dictionary allows verbal estimations of the expert to pose in conformity of probabilities, by the definition of definite levels, to save the tables in the file, to read out the tables from the file.

Matrixes assigned by the expert way. This is the result of tops variants comparison. They can be included in a tree. On the basis of analysis of matrixes the tops are assigned. They are included in a tree. As on the basis of matrixes analysis the probabilities are assigned, with which one the transferring in them from top-level tops is possible. If a tree of a solution decomposed on some sub trees, and these sub trees have identical leafs, probabilities of these leafs in each of them in the beginning are evaluated, and then evaluated the probabilities for all tree as a whole.

Up to the moment there are created a series of application systems: forecasting of exchange, account of a gross national product, diagnostics of cardiovascular diseases, forecasting of index inflation and so on.

Bibliography

1. Леонтьев В.В. Межотраслевая экономика. - М.: Экономика, 1997. - 479 с.
2. Нариньяни А.С. Неточность как Не - фактор. Попытка доформального анализа. – Москва – Новосибирск, 1994. Препринт РосНИИ ИИ, №2. - 34с.
3. Волошин А.Ф. Метод локализации области оптимума в задачах математического программирования //Доклады АН СССР. - 1987. - Т. 293, № 3. - С. 549–553.
4. Орир Дж. Физика. - М.:Мир,1981,том 2. - 288с.
5. Nikolson W. Microeconomic theory. -The DRYDEN PRESS, 1998. -821 p.
6. Janis I.L. Groupthink//Psychology Today, 1971. –P.43-46.
7. Орловский С.Г. Проблемы принятия решений при нечеткой исходной информации. - М.:Наука,1981.
8. Voloshin O.F., Panchenko M.V. The System of Quality Prediction on the Basis of a Fuzzy Data and Psychografphy of the Experts// “Information Theories & Applications”, 2003, Vol.10, №3.-P. 261-265.
9. Леонтьев В.В., Форд Д. Межотраслевой анализ воздействия структуры экономики на окружающую среду // Экономика и математические методы. - 1972. - т. VIII, вып. 3. - С. 370–400.
10. Михалевич В.С. Последовательные алгоритмы оптимизации и их применение // Кибернетика. - 1965. - № 1. - С. 45–55; -№2. - С.85-89.
11. Волкович В.Л., Волошин А.Ф. Об одной схеме последовательного анализа и отсеивания вариантов // Кибернетика. - 1978. - № 4. - С. 98–105.

12. Михалевич В.С., Волкович В.Л., Волошин А.Ф. Метод последовательного анализа в задачах линейного программирования большого размера // Кибернетика. - 1981. - № 4. - С. 114–120.
13. Волошин О.Ф., Мащенко С.О., Охрименко М.Г. Алгоритм послідовного аналізу варіантів для розв'язання балансових моделей // Доповіді АН УРСР. - 1988. - Сер. А, № 9. - С. 67–70.
14. Волкович В.Л., Волошин А.Ф. и др. Методы и алгоритмы автоматизированного проектирования сложных систем управления. - К.: Наукова думка, 1984. - 216 с.
15. Волкович В.Л., Волошин А.Ф. и др. Модели и методы оптимизации надежности сложных систем. - К.: Наукова думка, 1993. - 312с.
16. Волошин О.Ф., Чорней Н.Б. Алгоритм послідовного аналізу варіантів для розв'язання міжгалузевої моделі Леонтьєва-Форда // Вісник Київського університету. - 1999. - Сер. фіз. - мат. н., № 1.
17. Пападимитриу Х.,Стайглиц К. (Christos H. Papadimitriou, Kenneth Steiglitz) Комбинаторная оптимизация. - М.:Мир,1985. - 510 с.
18. Волошин А.Ф. Методы анализа статических балансовых эколого-экономических моделей большой размерности//Киевский национальный университет им.Т.Шевченко, «Научные записки», 2004, Том. VII.-С.43-55.
19. Харшаньи Дж., Зельтен Р. (John C. Harsanyi, Reinhard Selten) Общая теория выбора равновесия в играх.-Санкт-Петербург: «Экономическая школа», 2001.-406с.
20. Мащенко С.О. Равновесие Нэша в многокритериальной игре//Вестник Киевского университета,2001,№3.-С.214-222.
21. Волохова О.В. Задача коллективного принятия решений с векторными функциями полезности//Труды школы-семинара «Теория принятия решений», Ужгород, 2004.-С.14.
22. Мащенко С.О. Равновесие Нэша в нечетких играх//Вестник Киевского уни-та,2004,№2.-С.204-212.
23. Волошин А.Ф., Гнатиенко Г.Н. Метод косвенного определения интервалов весовых коэффициентов параметров объектов//Проблемы управления и информатики, 2003, №2.-С.34-41.
24. Тоценко В.Г. Методы и системы поддержки принятия решений.-Киев:Наукова думка, 2002.-382с.
25. Ларичев О.И. Теория и методы принятия решений.-М.:Логос,2000.-296с.

Author's Information

Oleksiy F. Voloshyn – T. Shevchenko Kiev National University, Faculty of Cybernetics, professor. Kiev, Ukraine. e-mail: ovoloshin@unicyb.kiev.ua

OPTIMUM TRAJECTORY OF DYNAMIC INPUT-OUTPUT BALANCE MODEL FOR OPEN ECONOMY

Igor Lyashenko, Olena Lyashenko

Abstract: When export and import is connected with output of basic production, and criterion functional represents a final state of economy, the generalization of classical qualitative results of the main-line theory on a case of dynamic input-output balance optimization model for open economy is given.

Keywords: dynamic input-output balance, optimization problem, main-line theory, open economy, trajectory of the balanced growth.

ACM Classification Keywords: J.1 Administrative Data Processing: Business, Financial, Government