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N-COMPONENT PIECEWISE-LINEAR MODELS: ENHANCING ECONOMIC EVENT PREDICTION THROUGH SOFTWARE

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***Abstract**: For the last 15 years in periodic literature there has appeared a series of scientific publications that has laid the foundation of a new scientific direction on creation of piecewise-linear economic-mathematical models at uncertainty conditions in finite dimensional vector space. Representation of economic processes in finite dimensional vector space, in particular in Euclidean space, at uncertainty conditions in the form of mathematical models in connected with complexity of complete account of such important issues as: spatial in homogeneity of occurring economic processes, incomplete macro, micro and social-political information; time changeability of multifactor economic indices, their duration and their change rate. The above-listed one in mathematical plan reduces the solution of the given problem to creation of very complicated economic mathematical models of nonlinear type. In this connection, it was established in these works that all possible economic processes considered with regard to uncertainty factor in finite-dimensional vector space should be explicitly determined in spatial-time aspect. Owing only to the stated principle of spatial-time certainty of economic process at uncertainty conditions in finite dimensional vector space it is possible to reveal systematically the dynamics and structure of the occurring process. In addition, imposing a series of softened additional conditions on the occurring economic process, it is possible to classify it in finite-dimensional vector space and also to suggest a new science-based method of multivariant prediction of economic process and its control in finite-dimensional vector space at uncertainty conditions, in particular, with regard to unaccounted factors influence.*

***Keywords:** Finite-dimensional vector space; unaccounted factors; unaccounted parameters influence function*

I. Introduction. Formulation of the problem

Development of modern society is characterized by the increase of technical level, complication of organizational structure of production, intensification of social division of labour, making high demands on planning and economic management methods-different optimization models and optimization methods based on the use of mathematical simulation find effective application by solving practical operational problems. Today, newest achievements of mathematics and up-to-date calculating engineering find wider application in economic investigations and planning. According to the basic conditions, the simulation process stages acquire their specific character.

1.1 Statement of economic problem and its quality analysis

The given stage means explicit formulization of the problem's essence, accepted assumptions. This stage includes distinction of the most important features and properties of the modeled object and its abstraction from the secondary ones; study of the structure and basic dependences connecting its elements; formulation of conjectures (even if preliminary ones), explaining the behavior and development of the object.

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1.2. Construction of mathematical model

This stage is the stage of formalization of an economic problem, its expressions in the form of concrete mathematical dependences and relations (functions, equations, inequalities and etc.). Usually, at first the basic construction (type) of a mathematical model is determined, then the details of this construction (concrete list of variables and parameters, connection forms) are specified. It is incorrect to assume that the more facts takes into account a model, the best it "works" and gives best results. We can say the same on such characteristics of complexity of the model as the used forms of mathematical dependences (linear and nonlinear), accounting of accidental nature and uncertainty factors and so on. Superfluous complexity and awkwardness of the model makes difficult the investigation process. It is necessary to take into account not only real possibilities of information and software but also to compare simulation expenditure with the obtained efficiency (by increasing the complexity of the model, increase of expenditures may exceed the efficiency increase). Intercom parison of two systems of scientific knowledges i.e. economic and mathematical ones are realized in the process of construction of the model. It is natural to try to get a model belonging to the well studied class of mathematical problems. Often it is succeeded to do it by simplifying initial premises of the model that don't distort the essential features of the modeled object. However the situation when the formalization of the economic problem reduces to the mathematical structure unknown earlier, is also possible.

1.3. Mathematical analysis of the mode

The goal of this stage is elucidation of general properties of the model. Here truly mathematical investigation methods are used. The most important moment is to prove the existence of solutions in the formulated model (existence theorem). If it turns out well to prove that a mathematical problem has no solution, then the necessity in the subsequent work on the initial variant of the model falls away then either the statement of the economic problem or the ways of its mathematical formalization should be corrected. By analytic investigation of the model such questions as for example, if the solution is unique, which variables (unknown ones) may appear in the solution, what relations will be between them, in what limits and under which initial conditions they change, what tendencies of their change and etc. Analytic investigation of the model compared with empiric (numerical) one has the advantage that the obtained conclusions remain valid for different concrete values of external and internal parameters of the model. As the economic-mathematical simulation develops and gets complicated, its separate stages are isolated into specialized investigation fields, the difference between theoretical-analytical and applied models increases, differentiation of models by the levels of abstraction and idealization happens. Theory of mathematical analysis of economics models has been developed into a special branch of contemporary mathematics to mathematical economics. The models studied within mathematical economics loose direct connection with economic reality; they exceptionally deal with idealized economic objects and situations. By constructing such models, the chief principle is not so much approximation to reality as to obtain a possible great number of analytic results by means of mathematical proofs. The value of these models for economic theory and practice is that they serve as a theoretical basis for applied type models. Preparation and processing of economic information and development of software of economic problems (creation of data base and information banks, program of computer-aided construction of models and program service for economists-users) become independent fields of investigations.

1.4. Preparation of input information

Simulation presents rigid requirements to the information system. At the same time, real possibilities of information receipt restricts the choice of models intended for practical use. Not only principal possibility of information preparation (for certain periods) but also expenditures for preparation of appropriate information areas is taken into account. These expenditures should not exceed the efficiency from the use of additional information. The methods of probability theory, theoretical and mathematical statistics are widely used in the course of preparation of information. Under system

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economic-mathematical simulation the initial information used in one models, is the result of functioning of other models.

1.5. Numerical calculation

In this stage, the algorithms for numerical solution of the problem are worked out, the programs in ECM are composed and calculations are conducted. Difficulties of this stage are stipulated first of all by the great size of economic problems, by necessity of processing of considerable information areas. Usually, calculations on economic-mathematical model are of multivariant character. Owing to high speed of contemporary ECM we can conduct numerous "model" experiments studying "behavior" of the model under different changes of some conditions. The investigations conducted by numerical methods may essentially complement the results of analytic investigation, and for a lot of models it is a uniquely realizable one.

6. Analysis of numerical results and their application

On the final stage their arises a question on correctness and completeness of simulation, on degree of practical applicability of the latters. Mathematical verification methods may elucidate incorrect constructions of the model and by the same token contract the class of potentially tame models. Informal analysis of theoretical conclusion and numerical results obtained by means of the model, their comparison by the available knowledges and facts of reality also allow to reveal the short-comings of the economic problem statement, constructed mathematical model and its software.

Introduction of computer-aided systems of economic information processing allows to lower essentially the expenditures connected with data processing, to increase labour productivity of the labour of the workers in the field of economics, improve relations between different subdivisions of enterprises. At present, there is a great mass of software intended for application in the field of economics, but regretfully, often it is necessary to "adjust" the readymade software under individual features of the enterprise even if these programs stood the test by time. However, the arising difficulties of calculating character require the creation of special software for computer programming and creation of an action algorithm for economic processes at uncertainty conditions in finite-dimensional vector space.

In this connection, in [1,2,7,13-15], by means of 2-component piecewise linear economic-mathematical models with regard to unaccounted factors a special program is developed for computer modeling for numerical construction and definition of multivariant prediction quantities of economic event in many-dimensional vector space, in particular, in two, three and four-dimensional vector spaces. The scientific results obtained in these works compose necessary theoretical and calculation instrument for creating a principally new, perspective software for computer modeling by constructing and multivariant prediction of economic state by means of piecewise linear economicmathematical models with regard to unaccounted factors influence in m –dimensional vector space.

In this article, the developed software algorithms for constructing two-component piecewise-linear model and for multivariant prediction of economic event at uncertainty conditions in m-dimensional vector space will be stated on the base of the Matlab program, and a number of numerical examples will be given. A packet of programs will be suggested, a numerical analysis of multivariant prediction of economic event at uncertainty conditions will be suggested.

II. Materials and methods.

Development of software for computer modeling and multi-variant prediction of economic event at uncertainty conditions on the base of 2-component piecewise-linear economic-mathematical models in m– dimensional vector space

2.1. Actions algorithm for computer modeling by constructing 2-component piecewise-linear economicmathematical models

In this article, on the basis of the Matlab program we'll suggest an algorithm and numerical calculation method for numerical construction of 2-component piecewise-linear economic-mathematical models in mdimensional vector space. It should be noted that the Matlab program has its restrictive properties

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that compels us to introduce some additional denotation and adhere to certain proper sequence in calculation operations. According to the suggested theory [1-4,6-9,11,13-15], for the case of 2-component piecewise-linear vector function in mdimensional vector space we write the min equations and mathematical expressions that are subjected to numerical programming.

Let in m-dimensional vector space R_m a statistical table describing some economic process in the form of □
points (vectors) set $\{a_n\}$ be given. Let these points be represented in the form of adjacent 7-component piecewise linear vector equation of the form:

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□ □ □□□
z_1 □ a_1 □$\mu_1(a_2 - a_1)$ (1) z□$_2$ □z□ □$_1$^{k1} □μ_2(a□$_3$ -z□$_1$^{k1}) (2)
□ □ □ □

where z_1 □ $z_1(z_{11},z_{12},z_{13},\ldots z_{1m})$ and z_2 □ $z_2(z_{21},z_{22},z_{23},\ldots z_{2m})$ are the equations of the first and second □□piecewise-linear straight lines in m-dimensional vector space. The vectors $a_1(a_{11},a_{12},a_{13},\ldots,a_{1m})$,
□ □ □ □
a_2 □ $a_2(a_{21},a_{22},a_{23},\ldots,a_{2m})$ and a_3 □ $a_3(a_{31},a_{32},a_{33},\ldots,a_{3m})$ are the given points (vectors) in m-dimensional space, of the form:

□ □ □ □ □
a1 □ a11i1 □a12i2 □a13i3 □...□a1mi m ,
□ □ □ □ □
a_2 □ $a_{21}i_1$ □$a_{22}i_2$ □$a_{23}i_3$ □...$a_{2m}i_m$ (3)
□ □ □ □ □
a3 □ a31i1 □a32i2 □a33i3 □...□a3mi m
□□k1 □

Here $\mu_1 \geq 0$ and $\mu_2 \geq 0$ are arbitrary parameters, z_1 is the intersection point of the straight lines z_1 □□and z_2 .
□ □ □

The goal of the investigation is the following. Giving the approximative points a_1 , a_2 , a_3 and also the values of the parameters μ_1^{k1} □ μ_1^* and μk_2^2 □ μ^*_2 to develop a computer calculation algorithm of the following equations and mathematical expressions in m–dimensional vector space: *z*□□1*k*1 □ *a*□1 □□1*k*1 (*a*□2 -*a*□1)
(*a*
2 1 2 □□□□*k*1)2 *k k k* 3 □ *z*1
□1 □□1 □□2 (*a*□□□ *z k*1)(*a*□2 □*a*□1)

3 1
z□□1*k*2 □ *a*□1 □□1*k*2 (*a*□2 -*a*□1) *z*□*k*2 □ *z*□1*k*1 □(□1*k*2 □□1*k*1) (*a*□3 □(*a*□*z*□□$_3$1*k*□1)(*z*□$_1$ *a*□*k*13) □2 *a*1) (*a*□3 □ *z*□1*k*1) 2 □□ (*z*1*k*2 -*z*□1*k*1)(*z*□1*k*2 -*z*□1 *k*1)

cos□1,2 □ *z* □*k*2 -*z*□1*k*1 *z*□1*k*2 *z*□1 *k*1
1
*k*1 -□1*k*2) *a*□*z* □2 *k*-2*a*(□1*z*□1*kz*□□11*k*-1*a*□-1*a*□)1
A □ (□1
1

□2*k*2 *z*□□1*k*2 -*z*□1*k*1 *a*□3 -*z*□1k 1 *z*□1*k*2 (*z*□1*k*1 -*a*□1) □2 □ □ *k*1 -□2*k*2 □ *z*□1*k*2 (*z*□1*k*2 - *z*□1*k*1) □ *a*□2 -*a*□1z□1k 1 -*a*□1

1

□2 (□2,□1,2) □□2*cos*□1,2

□□ *z*□□2 □ *z*1*k*2{1□ *A*[1□□2 (□2,□1,2)]}

□ □ □□□

z_1 □ a_1 □□$_1$ (a_2 -a_1)

□ □

(□$_1$ □□$_1$^{k}1)□ (*a*3 □(*a*□z$_3$1k□1)(*z* □*a*□k12)□2 *a*□1)

□$_2$ □

1 □2 □1 □1^{k1} -*a* □□1 *a* -*a* *z*

A(□1) □ (□1*k*1 □□1) *z*□$_1$(*z* □*k*1 *a*□1)

1 □

□$_2$(□1) □ *k*□1 -2□1 □ *z*□1*z*□-1z□□(1*kz*□1 1 -*a*□*z*□31*k*-1z□)1k 1 □ *a*□2*z*□1- (*a*□*z*□11*k*1*z*□1-k 1*a*□1-) *a*□1

□1

□$_2$ (□$_1$) □□$_2$ (□$_1$) *Cos*□$_{1,2}$

□ □

z_2 (□$_1$) □ z_1{1□ *A* (□$_1$)[1□□$_2$ (□$_1$)]} (4)

Introduce the following denotation:

□□□□□□□□□*k*1 *m*1*k*1; □1*k*2 □ *m*1*k*2 , *z*□1*k*1 □*z*1*k*1, *z*□□1*k*2 □*z*1*k*2; *a*1 □*a*1; *a*2 □*a*2; *a*3 □*a*3; □1 □*m*1; □1 □

z□$_2$^{k2} □ *z*2*k*2; *z*□$_1$ □ *z*1; □$_2$ □ *m*2; □$_2$^{k2} □*m*2*k*2, *A*(□$_1$) □*Am*1,

□$_2$ □*La*2, □$_2$(□$_1$) □ *La*2*m*1;

□ □□□$_2$ (□$_2$,□$_{12}$) □□$_2$ (□$_1$) □*w*2*m*1, z_2 □*z*2, z_2 (□$_1$) □*z*2*m*1. (5)

Using the introduced denotation (5), for the system (4) compose a program for numerical construction of 2component piecewise-linear economic-mathematical models with regard to unaccounted factors influence in mdimensional vector space in the Matlab program in the following form [1,2,7,13-15]:

```
a1=[a11  a12  a13  ...a1m] a2=[a21  a22  a23  ...a2m] a3=[a31  a32  a33  ...a3m]
m1k1=(m1)* m2k2=(m2)*
for m1=J1: J2 :J3
z1k1=a1+m1k1*(a2-a1);
m1k2=m1k1+m2k2*((a3-z1k1)*(a3-z1k1)')/
((a3-z1k1)*(a2-a1)');  z1k2=a1+m1k2*(a2-a1);  z2k2=z1k1+(m1k2-m1k1)*((a3-z1k1)*(a2-a1)')/((a3-
z1k1)*(a3-z1k1)')*(a3-z1k1);  cosa12=((z1k2-z1k1)*(z2k2-z1k1)')/(sqrt((z1k2-  -z1k1)*(z1k2-
z1k1)')*sqrt((z2k2-z1k1)*(z2k2-z1k1)'))
A=(m1k1-m1k2)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1k2*(z1k1-a1)');
p1=m2k2/(m1k1-m1k2);
p2=(sqrt((z1k2-z1k1)*(z1k2-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1k2*(z1k2-z1k1)');  p3=(z1k2*(z1k1-
a1)')/(sqrt((a2-a1)*(a2-a1)')*sqrt
((z1k1-a1)*(z1k1-a1)')); La2=p1*p2*p3; w2=La2*cosa12; z2=z1k2*(1+A*(1+w2)); z1=a1+m1*(a2-a1)
m2=(m1-m1k1)*(((a3-z1k1)*(a2-a1)')/((a3-z1k1)*
(a3-z1k1)'))
Am1=(m1k1-m1)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k-a1)*(z1k1-a1)'))/(z1*(z1k1-a1)')  p1m1=m2/(m1k1-
m1);
```

```
p2m1=(sqrt((z1-z1k1)*(z1-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1*(z1-z1k1)');             p3m1=(z1*(z1k1-a1)')/(sqrt((a2-a1)*(a2-1)')*sqrt((z1k1-a1)*(z1k1-a1)'));
La2m1=p1m1*p2m1*p3m1; w2m1=La2m1*cosa12  z2m1=z1*(1+Am1*(1+w2m1))
end                                                    (6)
```

2.2. Algorithm of multivariant computer modeling of prediction variables of economic event on the base of
2-component piecewise-linear economic-mathematical models

In this section we suggest a software algorithm for multivariant prediction of economic event at uncertainty conditions on the base of 2-component piecewise-linear economic-mathematical model in m-dimensional vector space. For the case of 2-component piecewise-linear vector function at uncertainty conditions in m-dimensional space on the base of the Matlab program we represent an algorithm and numerical program for multivariant prediction of economic event.

According to the theory [1,2,7,13-15] for the case of 2-component piecewise-linear vector-function at uncertainty conditions in m-dimensional vector space we have the following equations and relations for multivariant prediction of the economic event:

z□□1k1 □a□1 □□1k1 (a□2 -a□1)   2   1   2   □   □□k1)2
(a
k   k   k   3 □ z1
□1   □□1 □□2 (a□3 □ z□1 k1)(a□2 □a□1)
z□□1k2 □a□1 □□1k2 (a□2 -a□1)
□k2=z□1k1 □(μ1k2 -μ1k1) (a□3 -□ z□□1k1)(□a□2 -a□□1) (a□3 - z□1k1)
z2

$$(a_3 - z_1^{k_1})^2$$

$$\cos\alpha_{1,2} = \frac{(\vec{z}_1^{k_2} - \vec{z}_1^{k_1})(\vec{z}_2^{k_2} - \vec{z}_1^{k_1})}{\left|\vec{z}_1^{k_2} - \vec{z}_1^{k_1}\right| \cdot \left|\vec{z}_2^{k_2} - \vec{z}_1^{k_1}\right|}$$

$$A(\mu_1^{k_2}) = A = (\mu_1^{k_1} - \mu_1^{k_2}) \frac{\left|\vec{a}_2 - \vec{a}_1\right| \left|\vec{z}_1^{k_1} - \vec{a}_1\right|}{\vec{z}_1^{k_2} (\vec{z}_1^{k_1} - \vec{a}_1)}$$

$$\lambda_2(\mu_1^{k_2}) = \lambda_2^{k_2} = \frac{\mu_2^{k_2}}{\mu_1^{k_1} - \mu_1^{k_2}} \cdot \frac{\left|\vec{z}_1^{k_2} - \vec{z}_1^{k_1}\right| \left|\vec{a}_3 - \vec{z}_1^{k_1}\right|}{\vec{z}_1^{k_2} (\vec{z}_1^{k_2} - \vec{z}_1^{k_1})} \cdot \frac{\vec{z}_1^{k_2} (\vec{z}_1^{k_1} - \vec{a}_1)}{\left|\vec{a}_2 - \vec{a}_1\right| \left|\vec{z}_1^{k_1} - \vec{a}_1\right|}$$

$$\omega_2(\lambda_2^{k_2}, \alpha_{1,2}) = \lambda_2^{k_2} \cos\alpha_{1,2}$$

z□□2 (□1k2)□ z□2=z□1k2{1+A [1+ω2 (λ2k2 ,α1,2)]}
□   □   □   □□□
z1(□1)□z1 □a1 □□1(a2 -a1)
□   □
(□1 □□1k1)□ (a3 □(a□z31k□1)(z□1 a□k12)□2 a□1)
□2 □

-□1) a□2z□1-(a□z□11 k1z□□-1k1a□1-)a□1 A(□1) □ (□1

□□□k a□□-z□k □□□
□2

(□1) □ □1k□1 -2□1 □ z1z□-1z(1 z□1 1 -z□31k1)11 □ a□2z1-(a□z11k1z□-1k1a□1-) a□1

$□_2 (□_2 (□_1),□_{12})$ □ $□_2 (□_1)$ □ $□_2 (□_1) \cos □_{1,2}$
□ □
$z_2 (□_1)=z_1\{1+A (□_1)[1+\omega_2 (□_1)]\}$

□ *m* □
*a*4 □ □*a*4 *jij*
j□1
*a*42(1) □ (*a*□4)2 □ *z*22*k*2 □ *a* 22 □*a* 12 (*a*41(1)□ *z*21*k*2) *a*21 □*a* 11

□ *k*2 *a*23 □*a* 13 (*a*41□1□□ *z*21*k*2)
*a*43□1□□ (*a*4)3 □ *z*23 □
*a*21 □*a* 11

*a*44□1□□ (*a*□4)4 □ *z*24*k*2 □ *a* 24 □*a* 14 (*a*41□1□□ *z*21*k*2) *a*21 □*a* 11

--- *a*4*m* □1□□ (*a*□4)*m* □ *z*2*km*2 □ *a* 2*m* □*a* 1*m*
(*a*41□1□□ *z*21*k*2) *a*21 □*a* 11
□ □
*q*1 □ (*a*□2 (□*a*□*a*□□$_3$1□)(□*ak*31□)2*z*1*k*1)

*z*1
□ □
q_2 □ (*a*3 □(*a*□*z*$_4$1*k*(11)()*a*□□4*z*□(1$_{2\,k}$)2)□2 *z*□2*k*2)

□3 □ (□1 □□1*k*2)*q*1*q* 2 *z*□2 (□1)□ *z*□□2*k*2 □ *a*□4 (1)□ *z*□2*k*2
q 3 □ *z*□$_1$(*z*□□($_1$)□ *z*□$_2$ k_2) $_2$ □
*q*4 □*a*□□*z*□□1(*a*□*z*□ □1*k*□1 *z*□□*k* *a*1□1□) *a* □1
2 1 1

□
□3(□1) □ *k*1 3 □*q*3 □*q* 4 □1 □□1
cos□2,3 □ (*z*□*z*2□(₂□(□1) $_1$)□□*z*□□2□*k*2*k*)2 □*a*(□*a*4□(41() 1)□□*z* □*z*2□*k*2 2*k*2)
*z*2

a
$A_3(□_1)$ □ (□$_1$*k*1 □□$_1$)□ □2 *z*□□$_1$(*a*□*z* □1 *k*□1 *z*□□1*ka*1□1□)*a*□□1
1 □

□3(□3(□1),□2,3) □□3(□1) □cos□2,3
□ □
$Z_3(□_1)$ □ $z_1\{1□ A_3(□_1)[1□□_2 (□_1)□□_3(□_3,□_{2,3})]\}$ (7) $a□_1$, $a□_2$, $a□_3$, $a□□_4$ (1) and also the values of parameters $□_1k1$ □$□_1$* and $□_2k2$ □$□_2$* .
Give the approximative points
$Z_3(□_1)$ □ *z*3*m*1*p*; $Z_3(□_1)$□ *z*3*m*1*pM* ;
□ □
$z_1(□_1)/Z_3(□_1)$ □(*z*1*M*)/(*z*3*m*1*pM*) □ B_1;

□ □
z_2(□$_1$)/Z_3(□$_1$) □(z2m1M)/(z3m1pM) □ B_2;
□ □
z_1(□$_1$)/ z_2(□$_1$) □(z1M)/(z2m1M) □ B_3;

For the general m-dimensional case we write the symbolic representation of relations of the vectors in the following compact form:

□ □
z_i(□)/ z_j(□) □(zi(□))/(zjm1□(□)) □ B_{ij}(□) (9)

□
Here the indices i and j (i, j □1,2,3) indicate the number of the vector z_i the index □ the coordinate of the vector
□□z_i. And in m-dimensional case □ takes integer values □□1,2,3,....m .
Using the introduced denotation (8)-(9), the algorithm and approximate numerical program for the system (7) in the Matlab language will be represented in the form:

```
a1=[a11 a12 a13 a14... a1□...a1m] a2=[a21 a22 a23 a24...a2□...a2m] a3=[a31 a32 a33 a34...a3□...a3m ]
m1k1=(m1)* m2k2=(m2)* a4(1)=a4(1)* for m1=J1:J2:J3 z1k1=a1+m1k1*(a2-a1);
m1k2=m1k1+m2k2*((a3-z1k1)*(a3-z1k1)')/((a3-z1k1)*(a2-a1)'); z1k2=a1+m1k2*(a2-a1);
z2k2=z1k1+(m1k2-m1k1)*((a3-z1k1)*(a2-a1)')/((a3-z1k1)*(a3-z1k1)')*(a3-z1k1);
cosa12=((z1k2-z1k1)*(z2k2-z1k1)')/(sqrt((z1k2-z1k1)*(z1k2-z1k1)')*sqrt((z2k2-z1k1)*(z2k2-z1k1)'));
A=(m1k1-m1k2)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1k2*(z1k1-a1)');
p1=m2k2/(m1k1-m1k2);
p2=(sqrt((z1k2-z1k1)*(z1k2-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1k2*(z1k2-z1k1)');
p3=(z1k2*(z1k1-a1)')/(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)')); La2=p1*p2*p3;
w2=La2*cosa12; z2=z1k2*(1+A*(1+w2)) z1=a1+m1*(a2-a1) z1M=sqrt((z1)*(z1)')
m2=(m1-m1k1)*(((a3-z1k1)*(a2-a1)')/((a3-z1k1)*
(a3-z1k1)'))
Am1=(m1k1-m1)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1*(z1k1-a1)'); p1m1=m2/(m1k1-m1);
p2m1=(sqrt((z1-z1k1)*(z1-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1*(z1-z1k1)'); p3m1=(z1*(z1k1-a1)')/(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'));
La2m1=p1m1*p2m1*p3m1; w2m1=La2m1*cosa12; z2m1=z1*(1+Am1*(1+w2m1))
z2m1M=sqrt((z2m1)*(z2m1)')
a4(2)=z2k2(2)+[(a2(2)-a1(2))/(a2(1)-a1(1))]*
(a4(1)-z2k2(1));
a4(3)=z2k2(3)+[(a2(3)-a1(3))/(a2(1)-a1(1))]*
(a4(1)-z2k2(1));
a4(4)=z2k2(4)+[(a2(4)-a1(4))/(a2(1)-a1(1))]*
(a4(1)-z2k2(1));
q1=[(a2-a1)*(a3-z1k1)']/[(a3-z1k1)*(a3-z1k1)'];
q2=((a3-z1k1)*(a4-z2k2)')/((a4-z2k2)*(a4-z2k2)');
m3=(m1-m1k2)*q1*q2 q3=(sqrt((z2m1-z2k2)*(z2m1-z2k2)')*sqrt((a4-z2k2)*(a4-
-z2k2)'))/(z1*(z2m1-z2k2)');
q4=[z1*(z1k1-a1)']/[sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)')]; La3m=[m3/(m1k1-m1)]*q3*q4;
cosa23=((z2m1-z2k2)*(a4-z2k2)')/[sqrt((z2m1-z2k2)*
(z2m1-z2k2)')*sqrt((a4-z2k2)*(a4-z2k2)')];
```

```
Am1p=(m1k1-m1)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1*(z1k1-a1)');
w3mp=La3m*cosa23;
z3m1p=z1*[1+Am1p*(1+w2m1+w3mp)] z3m1pM=sqrt((z3m1p)*(z3m1p)')
B1=(z1M)/(z3m1pM)
B2=(z2m1M/(z3m1pM))
B3=(z1M)/(z2m1M)
B4=(z1(1))/(z3m1p(1))
B5=(z2m1(1))/(z3m1p(1))
B6=(z1(1))/(z2m1(1))
B7=(z1(2))/(z3m1p(2))
B8=(z2m1(2))/(z3m1p(2))
B9=(z1(2))/(z2m1(2))
B10=(z1(3))/(z3m1p(3))
B11=(z2m1(3))/(z3m1p(3))
B12=(z1(3))/(z2m1(3))
B13=(z1(4))/(z3m1p(4))
B14=(z2m1(4))/(z3m1p(4))
B15=(z1(4))/(z2m1(4))
---------------------------------------------------------------- ------------------------------------------------
----------------
Bij(□) □ (zi(□))/(zjm1□(□))

end.                                                                   (10)
```

□□□ □□□□ □ ^{k1} ^{k2}

Giving the statistical data of the vectors a_1, a_2, a_3, a_4 (1) and the parameters $□_1$ and $□_2$, by means of the above-suggested numerical program we can conduct wider investigations on multivatiant prediction of economic event at uncertainty conditions on the base of 2-component piecewise-linear model in m-dimensional vector space. In the subsequent sections we'll consider concrete special variants and examples.

Development of software for computer modeling and multi-variant prediction of economic event at uncertainty conditions on the base of 2-component piecewise-linear economic-mathematical models in 3dimensional vector space

2.3. Action algorithm for computer modeling by constructing 2-component piecewise-linear economicmathematical models in 3-dimensional vector space

On the base of Matlab we suggest an algorithm and numerical method of calculation for numerical construction of 2-component piecewise-linear economic-mathematical model with regard to unaccounted factors influence in 3-dimensional space of a vector function, and also to consider a concrete numerical example. For the case of 2-component piecewise-linear vector-function in 3-dimensional vector space we write the main equations and mathematical expressions that are subjected to numerical programming.

□

Let in 3-dimensional space R_3 a statistical table in the form of the points (vectors) $\{a_n\}$ set describing some economic process be given. Let these points be represented in the form of the points set of adjacent 2-component piecewise-linear vector equation of the form [1,2,5,7,10,12,13-17]:

□ □ □□□

$z_1 □ a_1 □ \mu_1(a_2 - a_1)$ (2.3.1)

$z□_2 □ z□□_1^{k1} □ \mu_2 (a□_3 - z□_1^{k1})$ (2.3.2)

□ □ □ □

where $z_1 □ z_1(z_{11}, z_{12}, z_{13})$ and $z_2 □ z_2(z_{21}, z_{22}, z_{23})$ are the equations of the first and second piecewise-linear

□ □ □

straight lines in 3-dimensional vector space. The vectors $a_1(a_{11},a_{12},a_{13})$, a_2 □ $a_2(a_{21},a_{22},a_{23})$ and □ □□a_3 □ $a_3(a_{31},a_{32},a_{33})$ are the given points (vectors) in 3-dimensional space of the form:

□ □ □

□□a1 □ a11i1 □a12i2 □a13i 3

□ □ □ □

a_2 □ $a_{21}i_1$ □$a_{22}i_2$ □$a_{23}i_3$ (2.3.3)

□ □ □ □

a3 □ a31i1 □a32i2 □a33i 3

□

Here $\mu_1 \geq 0$ and $\mu_2 \geq 0$ are arbitrary parameters, z_1^{k1} is the intersection point of the straight lines $z□_1$ and $z□_2$.

□□□ □

The goal of the investigation is the following. Giving the approximative point a_1 , a_2 , a_3 and also the value of the parameters μ_1^{k1} □ μ_1^* and μk_2^2 □μ^*_2 , develop a computer calculation algorithm for the following equations and mathematical expressions: □□ *z*1 *k*1 □ *a*□□1 □□1*k*1 (*a*□2 -*a*□1)

□□ □*k* 2

(*a*

□1*k*2 □□1*k*1 □□2*k*2 (*a*□3 □ 3*k*1□)(*za*1□12)□*a*□1)

*z*1

□

*z*1 *k*2 □ *a*□□1 □□1*k*2 (*a*□2 -*a*□1)

□□*z k* (*a*)

2 2 □ *z*□1*k*1 □(□1*k*2 □□1*k*1) (*a* □3 □□*z*□□3 1*k*□1)(*z* □1*a*□*k*13 □2 *a*1) (*a*□3 □ *z*□1*k*1)

(*z*□□1*k*2 -*z*□1*k*1)(*z*□1*k*2 -*z*□1 *k*1) *cos*□1,2 □ *z* □*k*2 -*z*□1*k*1 *z*□1*k*2 *z*□1 *k*1

1

a□2 -*a*□1 *z*□□1*k*1 -*a*□□1

A □ (□1*k*1 -□1*k*2) *z*□1 *k*2 (*z*□1*k*1 -*a*□1)

□2*k*2 *z*□□1*k*2 -*z*□1*k*1 *a*□3 -*z*□1k 1 *z*□1*k*2 (*z*□1*k*1 -*a*□1)

□2 □ □1 *k*1 -□2*k*2 □ *z*□1*k*2 (*z*□1*k*2 -*z*□1*k*1) □ *a*□2 -*a*□1 *z*□1k 1 -*a*□1

□2 (□2,□1,2) □□2*cos*□1,2

□ □□*k*2{1□ *A*[1□□2 (□2,□1,2)]} *z*2 □ *z*1

□ □ □□□

*z*1 □ *a*1 □□1 (*a*2 -*a*1)

(*a* □2 □ (□1 □□ 11 □ □3 □(*a*□*z*□□3 1k□1)(*z*□1 *a*□k12)□2 *a*□1)

k)

*k*1) *a*□2*z*□1-(*a*□*z*□11*k*1*z*□□□1k1*a*□-1) *a*□1

A(□1) □ (□1 □□1

(□1) □ □1 *k*□1 -2□1 □ *z*□1*z*□-1*z*□□(1*kz*□1 1 -*a*□*z*3□1*k*-1*z*□)1k 1 □ *a*□2*z*□1-(*a*□*z*□11*k*1*z*□1-k 1*a*□1-) *a*□1 □2

□(□1) □□2 (□1) *cos*□1

□ □

z_2 (□$_1$) □ z_1{1□ A (□$_1$)[1□ □$_2$ (□$_1$)]} (2.3.4)

Introduce the following denotation:

□ □ □□ □^{k_1} $m1k1$; a_1 □$a1$; a_2 □$a2$; a_3 □$a3$; □$_1$ □$m1$; □$_1$ □ k $m1k2$ □□□1 2 □ ; $z1k1$ □$z1k1$; z□$1k2$ □$z1k2$; z□$2k2$ □ $z2k2$; □□ □^{k_2} $m2k2$; A(□$_1$) □$Am1$; z_1 □ $z1$; □$_2$ □ $m2$; □$_2$ □

□$_2$ □ $La2$; □$_2$ (□$_1$) □$La2m1$;

□$_2$ (□$_2$,□$_{12}$) □□$_2$ (□$_1$) □$w2m1$;

□□ □□

z_2 □$z2$; z_2 (□$_1$) □$z2m1$ (2.3.5)

Using the introduced denotation (2.3.5), the appropriate computer algorithm for the system (2.3.4) for numerical construction of 2-component piecewise-linear economic-mathematical models with regard to unaccounted factors influence in 3-dimensional vector space, in the Matlab program will look like:

```
a1=[a11  a12  a13] a2=[a21  a22  a23] a3=[a31  a32  a33] m1k1=(m1)* m2k2=(m2)*
for m1=J1: J2 :J3 z1k1=a1+m1k1*(a2-a1);
m1k2=m1k1+m2k2*((a3-z1k1)*(a3-z1k1)')/((a3-z1k1)*(a2-a1)'); z1k2=a1+m1k2*(a2-a1);
z2k2=z1k1+(m1k2-m1k1)*((a3-z1k1)*(a2-a1)')/((a3-z1k1)*(a3-z1k1)')*(a3-z1k1);
cosa12=((z1k2-z1k1)*(z2k2-z1k1)')/(sqrt((z1k2-z1k1)*(z1k2-z1k1)')*sqrt((z2k2-z1k1)*(z2k2-z1k1)'))
A=(m1k1-m1k2)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1k2*(z1k1-a1)');
p1=m2k2/(m1k1-m1k2);
p2=(sqrt((z1k2-z1k1)*(z1k2-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1k2*(z1k2-z1k1)');
p3=(z1k2*(z1k1-a1)')/(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'));          La2=p1*p2*p3;
w2=La2*cosa12; z2=z1k2*(1+A*(1+w2)); z1=a1+m1*(a2-a1)
m2=(m1-m1k1)*(((a3-z1k1)*(a2-a1)')/((a3-z1k1)*
(a3-z1k1)'))
Am1=(m1k1-m1)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1*(z1k1-a1)')   p1m1=m2/(m1k1-
m1);
p2m1=(sqrt((z1-z1k1)*(z1-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1*(z1-z1k1)');          p3m1=(z1*(z1k1-
a1)')/(sqrt((a2-a1)*(a2-1)')*sqrt((z1k1-a1)*(z1k1-a1)'));
La2m1=p1m1*p2m1*p3m1; w2m1=La2m1*cosa12
 z2m1=z1*(1+Am1*(1+w2m1)) end                                        (2.3.6)
```

□ □ □

3. Example: As an example we give the following table of statistical data. Let the vectors a_1 , a_2 , a_3 and the parameters $\mu_1^{k_1}$ and $\mu^{k}_2{}^2$ have the following numerical values:

a1=[1 1 1]; a2=[3 2 4, 5]; a3=[6 4 7]; m1k1=1.5 m2k2=2

for m1=1,5:0,5:8

The task of the investigation is to represent the points of the second piecewise-linear straight line depending □ on the first piecewise-linear vector-function z_1 (□$_1$) and unaccounted factors influence function □$_2$ (□$_2$,□$_{1,2}$) for arbitrary values of the parameter □$_1$ changing in the interval $\mu_1^{k_1}$ □1,5 □ μ_1 □ μ_1^* □8, in the form:

□ □□z_2 (□$_1$) □z_1 (□$_1$){1□A(□$_1$)[1□□$_2$ (□$_1$)]}

Applying the above-stated numerical program to the given problem, we numerically define the points of the □ second piecewise-linear straight line z_2 (□$_1$) depending on the parameter □$_1$ □1,5, that are represented in the form

□□of the following table. It should be noted that the numerically constructed vectors z_2 (□$_1$) for different values of the parameter 1,5□□$_1$ □8 completely coincide with numerical results obtained earlier in the by developing theory of construction of piecewise-linear economic-mathematical models at uncertainty conditions in finite dimensional vector space stated in [1,2,7,13-15]. Below is a link to the table in the book [15]

Table 5.1.

Numerical values of the points (vectors) of the second piecewise-linear straight line $\Xi_2(\mu_1)$ depending on the parameter $\mu_1 \geq 1{,}5$ in 3-dimensional vector space, defined by the formula: $\Xi_2(\mu_1) = \Xi_1(\mu_1)\{1 + A(\mu_1)[1 + \omega_2(\mu_1)]\}$, calculated for the following given values of the vectors $\vec{a}_1 = \vec{i}_1 + \vec{i}_2 + \vec{i}_3$, $\vec{a}_2 = 3\vec{i}_1 + 2\vec{i}_2 + 4{,}5\vec{i}_3$, $\vec{a}_3 = 6\vec{i}_1 + 4\vec{i}_2 + 7\vec{i}_3$, and parameters: $\mu_1^{k_1} = 1{,}5$ и $\mu_2^{k_2} = 2$

N	μ_1	μ_2	$A(\mu_1)$	$\omega_2(\mu_1)$	$\Xi_1(\mu_1) = \vec{a}_1 + \mu_1(\vec{a}_2 - \vec{a}_1)$	$\Xi_2(\mu_1) = \Xi_1(\mu_1)\{1 + A(\mu_1)[1 + \omega_2(\mu_1)]\}$
1	1,5	0	0	0	Ξ_1(1,5) =[4 2,5 6,25]	Ξ_2(1,5) =[4 2,5 6,25]
2	2	0,5963	-0,2104	-0,5618	Ξ_1(2) =[5 3 8]	Ξ_2(2) =[4,539 2,7234 7,2625]
3	2,5	1,1927	-0,3476	-0,5618	Ξ_1(2,5) =[6 3,5 9,75]	Ξ_2(2,5) =[5,086 2,9668 8,2647]
4	3	1,789	-0,4442	-0,5618	Ξ_1(3) =[7 4 11,5]	Ξ_2(3) =[5,6372 3,2213 9,2613]
5	3,1769	2	-0,4719	-0,5618	Ξ_1(3,1769) =[7,3538 4,1769 12,1192]	Ξ_2(3,1769) =[5,8331 3,3132 9,613]
6	3,5	2,3853	-0,5159	-0,5618	Ξ_1(3,5) =[8 4,5 13,25]	Ξ_2(3,5) =[6,1913 3,4826 10,2544]
7	4	2,9817	-0,5712	-0,5618	Ξ_1(4) =[9 5 15]	Ξ_2(4) =[6,7471 3,7484 11,2452]
8	4,5	3,578	-0,6152	-0,5618	Ξ_1(4,5) =[10 5,5 16,75]	Ξ_2(4,5) =[7,3041 4,0173 12,2344]
9	5	4,1743	-0,6509	-0,5618	Ξ_1(5) =[11 6 18,5]	Ξ_2(5) =[7,862 4,2884 13,2225]
10	5,5	4,7706	-0,6806	-0,5618	Ξ_1(5,5) =[12 6,5 20,25]	Ξ_2(5,5) =[8,4206 4,5612 14,2098]
11	6	5,3670	-0,7057	-0,5618	Ξ_1(6) =[13 7 22]	Ξ_2(6) =[8,9796 4,8352 15,1963]
12	6,5	5,9633	-0,7271	-0,5618	Ξ_1(6,5) =[14 7,5 23,75]	Ξ_2(6,5) =[9,5391 5,1102 16,1824]
13	7	6,5596	-0,7456	-0,5618	Ξ_1(7) =[15 8 25,5]	Ξ_2(7) =[10,0989 5,3861 17,1681]
14	7,5	7,1560	-0,7617	-0,5618	Ξ_1(7,5) =[16 8,5 27,25]	Ξ_2(7,5) =[10,6589 5,6625 18,1534]
15	8	7,7523	-0,7760	-0,5618	Ξ_1(8) =[17 9 29]	Ξ_2(8) =[11,2191 5,9395 19,1385]

…continued

2.4. Algorithm of multi-variant computer modeling of prediction variables of economic event on the base of **2-component piecewise-linear economic-mathematical models in 3-dimensional vector space**

In this section, based around the Matlab program, we suggest an algorithm and numerical programe for multi-variant prediction of economic event at uncertainty conditions on the vase of 2-component piecewise-linear model in 3-dimenaionl vector space.

According to the theory [1,2,7,13-15]. for the case of a 2-component piecewise-linear vector-function at uncertainty conditions in three-dimensional vector space for a multi-variant prediction of economic event we have the following equations and expressions:

z□□1k1 □a□1 □□1k1 (a□2 -a□1)

2 1 2 (a □ □□k1)2

□1k □□1k □□2k (a□□□ z □3 k□1)(z1a□2 □a□1)

3 1

z□□1k2 □a□1 □□1k2 (a□2 -a□1)

□ □□ □□ □(a - z k)(a□□-a□□) □ □k)

3 1 2 1 -

$(a - z^{k_1})$

3 1

z2k2=z□1k1 □(μ1k2 -μ1k1) 1 2 (a3 z 1 1

$$\cos\alpha_{1,2} = \frac{(\vec{z}_1^{k_2} - \vec{z}_1^{k_1})(\vec{z}_2^{k_2} - \vec{z}_1^{k_1})}{\left|\vec{z}_1^{k_2} - \vec{z}_1^{k_1}\right| \cdot \left|\vec{z}_2^{k_2} - \vec{z}_1^{k_1}\right|}$$

$$A(\mu_1^{k_2}) = A = (\mu_1^{k_1} - \mu_1^{k_2}) \frac{\left|\vec{a}_2 - \vec{a}_1\right| \left|\vec{z}_1^{k_1} - \vec{a}_1\right|}{\vec{z}_1^{k_2}(\vec{z}_1^{k_1} - \vec{a}_1)}$$

$$\lambda_2(\mu_1^{k_2}) = \lambda_2^{k_2} = \frac{\mu_2^{k_2}}{\mu_1^{k_1} - \mu_1^{k_2}} \cdot \frac{\left|\vec{z}_1^{k_2} - \vec{z}_1^{k_1}\right| \left|\vec{a}_3 - \vec{z}_1^{k_1}\right|}{\vec{z}_1^{k_2}(\vec{z}_1^{k_2} - \vec{z}_1^{k_1})} \cdot \frac{\vec{z}_1^{k_2}(\vec{z}_1^{k_1} - \vec{a}_1)}{\left|\vec{a}_2 - \vec{a}_1\right| \vec{z}_1^{k_1} - \vec{a}_1}$$

□2 (□k22 ,□1,2) □□k22cos□1,2

z□□2 (□1k2)□ z□2=z□1k2{1+A [1+ω2 (λ2k2 ,α1,2)]}

□ □ □ □□□

z1(□1)□ z1 □ a1 □□1(a2 -a1)

□ □□ (a z k)(a□□□

(□1 □□1k1)□ 3 □(a□□1□1 z □k12)□2 a1)

□2 □

3 1

□□□□□

k1 -□1) a2z□1-(az □1k1z -1k1a□1-)a□1

A(□1) □ (□1

1

(□1) □ □ k□1 -2□1 □ z□1z□-1z□□(1zk□1 1 -a□z□31k-1z□)1k1 □ a□2z□1-

(a□z□11k1z□-1k1a□1-) a□1

□2

1

□2 (□2 (□1),□12) □□2 (□1) □□2 (□1) cos□1,2

□ □

z2 (□1)=z1{1+A (□1)[1+ω2 (□1)]}

a42(1) □ (a□4)2 □ z22k2 □ a 22 □a 12 (a41(1)□ z21k2) a21 □a 11

□ k2 a 23 □a 13 (a41□1□□ z21k2)

a43□1□□ (a4)3 □ z23 □

a21 □a 11

□ □□□ □□k1)
(a q1 □ 2 (□a□a1□)(□a1 k31□)2z1 z

3

(a□3 □ z□□1k1)(a□4 (1)□ z□□2k2)

q2 □ (a□4 (1)□ z□2 k2) 2

□3 □ (□1 □□1k2)q1q 2 z□2 (□1)□ z□□2k2 □ a□4 (1)□ z□2k2
q 3 □ z□1(z□2 (□1)□ z□2k2)
z□1(z□□1k1 □a□□1)
q4 □a□2 □a□1 □ z□1k 1 □ a □1

1□ 3 q3 □q 4
□3(□1) □ k □
□1 □□1
(z□2 (□1)□ z□□2k2)□(a□4 (1)□ z□2k2)
cos□2,3 □ z□□(z □k2 a□4 (1) □ z□2k2 2 □1)□ 2
a□2 □a□1 □ z□□1k1 □a□□1
A3 (□1) □ (□1k1 □□1)□ z□1(z□1k1 □ a□1)

□3(□3(□1),□2,3) □□3(□1) □cos□2,3
□ □
Z3(□1) □ z1{1□ A3(□1)[1□□2 (□1)□□3(□3,□2,3)]} (2.3.7) a□1, a□2 , a□3 , a□□4 (1) and also the values of the parameters □1k1 □□1* and
Give the approximation points
□2k2 □□2* . Here a□4 (1) is the given value of one of the coordinates of the vector a□4 . For that we introduce the following denotation:
□ □ □ □
a1 □a1; a2 □a2; a3 □a3; (a4)1 □a4(1) ;
□1 □m1; □1k1 □ m1k1; □1k2 □ m1k2 ; □2 □m2 ; □2k2 □m2k2; z1k1 □z1k1; z1k2 □z1k2; z2k2 □ z2k2 ; cos□12 □cosa12; A(□1k2) □ A□A; □2 (□1k2) □□k22 □La2;
□2 (□k22 ,□12) □w2; z□2 (□1k2) □z2; z□1(□1) □z1;
□
z1(□1) □ z1M ; A(□1) □Am1; □2 (□1) □La2m1;
□
□2 (□2 (□1),□12) □w2m1; z2 (□1) □z2m1;
□ □ □
z2 (□1) □ z2m1M ; (a4)2 □a4(2); (a4)3 □a4(3);
q1 □ q1; q2 □ q2; □3 □m3; □3(□1) □La3m; q3 □ q3;
q4 □ q4; cos□23 □cosa23; A3(□1) □ Am1p;
□
□3(□3(□1),□23) □w3mp; Z3(□1) □ z3m1p; □
Z3(□1)□ z3m1pM ;
□ □
z1(□1)/Z3(□1) □(z1M)/(z3m1pM) □ B 1;
□ □
z2 (□1)/Z3(□1) □(z2m1M)/(z3m1pM) □ B 2 ;

□ □

$z_1(\square_1)/$ $z_2(\square_1) \square (z1M)/(z2m1M) \square B_3$;

□ □□ □

$z_1(1)/Z_3(1) \square (z1(1))/(z3m1p(1)) \square B_4$; $z_2(1)/Z_3(1) \square (z2m1(1))/(z3m1p(1)) \square B_5$;

□ □

$z_1(1)/z_2(1) \square (z1(1))/(z2m1(1)) \square B_6$;

□ □

$z_1(2)/Z_3(2) \square (z1(2))/(z3m1p(2)) \square B_7$;

□ □

$z_2(2)/Z_3(2) \square (z2m1(2))/(z3m1p(2)) \square B_8$;

□ □

$z_1(2)/z_2(2) \square (z1(2))/(z2m1(2)) \square B_9$;

□ □

$z_1(3)/Z_3(3) \square (z1(3))/(z3m1p(3)) \square B_{10}$;

□ □

$z_2(3)/Z_3(3) \square (z2m1(3))/(z3m1p(3)) \square B_{11}$;

□ □

$z_1(3)/z_2(3) \square (z1(3))/(z2m1(3)) \square B_{12}$ (2.3.8)

Using the introduced denotation, an algorithm and appropriate numerical program for the system (2.3.8) in the Matlab language will be represented in the form:

a1=[a11 a12 a13] a2=[a21 a22 a23] a3=[a31 a32 a33] m1k1=(m1)* m2k2=(m2)* a4(1)=a4(1)* for m1=J1:J2:J3 z1k1=a1+m1k1*(a2-a1);
m1k2=m1k1+m2k2*((a3-z1k1)*(a3-z1k1)')/((a3-z1k1)*(a2-a1)'); z1k2=a1+m1k2*(a2-a1);
z2k2=z1k1+(m1k2-m1k1)*((a3-z1k1)*(a2-a1)')/((a3-z1k1)*(a3-z1k1)')*(a3-z1k1);
cosa12=((z1k2-z1k1)*(z2k2-z1k1)')/(sqrt((z1k2-z1k1)*(z1k2-z1k1)')*sqrt((z2k2-z1k1)*(z2k2-z1k1)'));
A=(m1k1-m1k2)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1k2*(z1k1-a1)');
p1=m2k2/(m1k1-m1k2);
p2=(sqrt((z1k2-z1k1)*(z1k2-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1k2*(z1k2-z1k1)');
p3=(z1k2*(z1k1-a1)')/(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)')); La2=p1*p2*p3;
w2=La2*cosa12; z2=z1k2*(1+A*(1+w2)) z1=a1+m1*(a2-a1) z1M=sqrt((z1)*(z1)')
m2=(m1-m1k1)*(((a3-z1k1)*(a2-a1)')/((a3-z1k1)*(a3-z1k1)'))
Am1=(m1k1-m1)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1*(z1k1-a1)'); p1m1=m2/(m1k1-m1);
p2m1=(sqrt((z1-z1k1)*(z1-z1k1)')*sqrt((a3-z1k1)*(a3-z1k1)'))/(z1*(z1-z1k1)'); p3m1=(z1*(z1k1-a1)')/(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'));
La2m1=p1m1*p2m1*p3m1; w2m1=La2m1*cosa12; z2m1=z1*(1+Am1*(1+w2m1)) z2m1M=sqrt((z2m1)*(z2m1)')
a4(2)=z2k2(2)+[(a2(2)-a1(2))/(a2(1)-a1(1))]*(a4(1)-z2k2(1)); a4(3)=z2k2(3)+[(a2(3)-a1(3))/(a2(1)-a1(1))]*(a4(1)-z2k2(1)); q1=[(a2-a1)*(a3-z1k1)']/[(a3-z1k1)*(a3-z1k1)'];
q2=((a3-z1k1)*(a4-z2k2)')/((a4-z2k2)*(a4-z2k2)');
m3=(m1-m1k2)*q1*q2
q3=(sqrt((z2m1-z2k2)*(z2m1-z2k2)')*sqrt((a4-z2k2)*(a4-z2k2)'))/(z1*(z2m1-z2k2)'); q4=[z1*(z1k1-a1)']/[sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)')]; La3m=[m3/(m1k1-m1)]*q3*q4;
cosa23=((z2m1-z2k2)*(a4-z2k2)')/[sqrt((z2m1-z2k2)*(z2m1-z2k2)')*sqrt((a4-z2k2)*(a4-z2k2)')];
Am1p=(m1k1-m1)*(sqrt((a2-a1)*(a2-a1)')*sqrt((z1k1-a1)*(z1k1-a1)'))/(z1*(z1k1-a1)');
w3mp=La3m*cosa23; z3m1p=z1*[1+Am1p*(1+w2m1+w3mp)] z3m1pM=sqrt((z3m1p)*(z3m1p)')
B1=(z1M)/(z3m1pM)
B2=(z2m1M/(z3m1pM))
B3=(z1M)/(z2m1M)

B4=(z1(1))/(z3m1p(1))
B5=(z2m1(1))/(z3m1p(1))
B6=(z1(1))/(z2m1(1))
B7=(z1(2))/(z3m1p(2))
B8=(z2m1(2))/(z3m1p(2))
B9=(z1(2))/(z2m1(2))
B10=(z1(3))/(z3m1p(3))
B11=(z2m1(3))/(z3m1p(3)) B12=(z1(3))/(z2m1(3))
end. (2.3.9)

□□□ □□□□ □^{k1} $k2$

Giving the statistical data of the vectors a_1, a_2, a_3, a_4 (1) and the parameters □$_1$ and □$_2$ by means of the above suggested numerical program we can conduct wider investigations on multivariant prediction of economic event at uncertainty condition on the base of 2-component piecewise-linear model in 3-dimensional vector space. □□□ □ □

Example. As an example consider the case with the following given statistical vectors a_1, a_2, a_3, a_4 (1) and parameters □$_1^{k1}$ and □$_2^{k2}$:

a1=[1 1 1] a2=[3 2 4.5] a3=[6 4 7] m1k1=1.5 m2k2=2
a4(1)=10 for m1=1,5:0,5:8

Conduct the following numerical calculation on estabment of all possible variants of prediction numerical values of economic event on the subsequent stage represented in tables 5.2 and 5.3.

Table 5.2 (Below is a link to the table in the book [15])

Numerical values of modulus and appropriate coordinates of predictable points-vectors for different values of parameters 3,1769,□□1 □8 and 0 □□3 □ 2,7094

N	Numerical values of the vectors □□□ z_1, z_2, z□$_3$ and their module	□$_1$	□$_2$	□$_3$
1	□□z_1(□$_1$)=[7,3538 4,1769 12,1769] □□z_2(□$_1$) =[5,8331 3,3132 9,6130] □□Z_3(□$_1$)=[5,8331 3,3132 9,6190] □□z_1(□$_1$) =14,8257 □□z_2(□$_1$) =11,7223 □ Z_3(□$_1$) =11,7227	3,1769	2	0
	□□z_1(□$_1$)=[8 4,5 13,25]			

□
□

Table 5.3 (Below is a link to the table in the book [15])

Numerical values of the ratios of module and appropriate coordinates of predictable points-vectors for different values of parameters 3,1769,□□1 □8 and 0 □□3 □ 2,7094

□ □ □

	1,0984	0,7851	1,3991

	□ □ $z_1(1)/Z_3(1)$ ----------------- -- 1,0984	□ □ $z_2(1)/Z_3(1)$ ----------------- -- 0,7851	□ □ $z_1(1)/ z_2(1)$ --------------- - 1,3991
	□ □ $z_1(2)/Z_3(2)$ ----------------- -- 1,0984	□ □ $z_2(2)/Z_3(2)$ ----------------- -- 0,7851	□ □ $z_1(2)/ z_2(2)$ --------------- - 1,3991
	□ □ $z_1(3)/Z_3(3)$ ----------------- -- 1,0984	□ □ $z_2(3)/Z_3(3)$ ----------------- -- 0,7851	□ □ $z_1(3)/ z_2(3)$ --------------- - 1,3991

□□□□□□□□□□□

□ □ □ □ □ □
□□ □□ □ □ □

The data of tables 5.2 and 5.3 allow to conduct deep quality and quantity analysis on prediction of economic event, i.e. to work out numerically all possible variants of prediction data of economic state on the subsequent stage

□ □ □

both by total indices on the whole, i.e. by the coordinates of the vectors z_1(□$_1$), z_2(□$_1$), Z_3(□$_1$) and by separate

□ □ □

economic factors, i.e. by the coordinates of the vectors z_1(□$_1$), z_2(□$_1$), z_3(□$_1$). Furthermore, it is possible to compare prediction values of economic event by three criteria 1) by the results of calculations on linear criterion; 2) by the results of calculations according to continuation of the points of the second piecewise-linear vector-function; 3) by the results of calculations of a vector function with regard to uncertainty factors influence. The scheme of comparison of predictable variants are graphically represented in fig. .1, and in numerical form in tables 5.2 and 5.2. Here for any

value of an arbitrary parameter □$_1$, changing in the interval □$_1^{k_2}$ □□$_1$ □□* we have appropriate numerical values

$\vec{z}_1$(□$_1$), $\vec{z}_2$(□$_1$), $\vec{Z}_3$(□$_1$), $|\vec{z}_1$(□$_1$)$|$, $|\vec{z}_2$(□$_1$)$|$, $|\vec{Z}_3$(□$_1$)$|$.

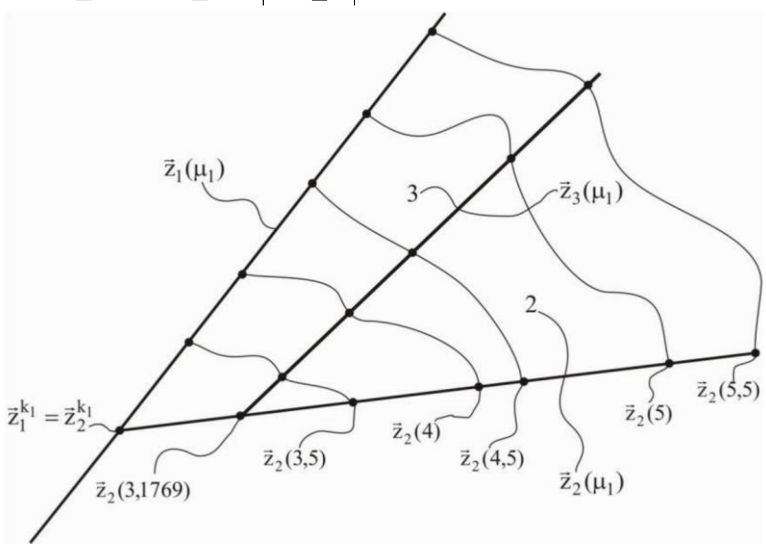

Fig. 1. The graph of numerical values and appropriate coordinates of predictable points-vectors for the values of the parameters 3,1769 □□$_1$ □8 and 0 □□$_3$ □ 2,7094 calculated by different criteria.

For visuality as an example we take the value of the parameter □$_1$ □ 5.

□ □ □

Take into attention the denotation of appropriate ratios of coordinates of vectors z_1(□$_1$) z_2(□$_1$) Z_3(□$_1$) in the form:

□ □ □

z□$^1(i)$ □ x^{1i}, z□$^2(i)$ □ x^{2i}, □$z^1(i)$ □ x^{1i} ` (2.3.10) $Z3(i)$ $X\,3i$ $Z3(i)$ $X\,3i$ $z2(i)$ $x\,2$

In these denotations, compose their percentage ratio (for i=1, 2, 3):

□

$n1i$ □ z□□$1(i)$ 100% □ $x\,1i$ 100%,

$\overline{Z3(i)}$ $X\,3i$

□

$n2i \square z\square\square 2 (i)100\% \square x 2i 100\%$,

$\overline{Z3}(i) \quad X 3i$

$n_{3i} \square \square z^1(i)100\% \square x^{1i} 100\%, n_4 \square z\square^1(\square 1) 100\%, z2(i) \quad x2i \quad Z3(\square 1)$

$n_5 \square z\square^2(\square 1) 100\%, n_6 \square \square^{z1}(\square 1) 100\%$ (2.3.11) $Z_3(\square_1) \quad z_2(\square_1)$

According to formula (2.3.11), tables 5.2 and 5.3, we numerically establish the percentage ratio of the coordinates of the vectors $z_1(\square_1)$ and $z_2(\square_1)$, i.e. x_{1i} and x_{2i} from the appropriate coordinates of the predicting function $Z_3(\square_1)$ with regard to uncertainty factors influence, in the form:

$n_{11} \square n_{12} \square n_{13} \square 109{,}84\%$ (2.3.12)

$n_{21} \square n_{22} \square n_{23} \square 78{,}51\%$ (2.3.13)

$n_{31} \square n_{32} \square n_{33} \square 139{,}91\%$ (2.3.14) $n_4 \square 1{,}0984$, $n_5 \square 0{,}7851$, $n_6 \square 1{,}3991$ (2.3.15)

III. Results

Numerical value (2.3.12) shows that the values of the coordinates of prediction variables calculated by linear criterion is higher by 9,84% than the appropriate prediction coordinates calculated according to the vector function with regard to uncertainty factors influence;

- numerical value (2.3.13) shows that the values of coordinate prediction variables calculated by means of the second piecewise-linear vector function is lower by 21,49% than the appropriate prediction coordinates calculated according to the vector-function with regard to uncertainty factors influence;
- numerical value (2.3.14) shows that the values of coordinates of prediction variables calculated by linear criterion is higher by 39,91% than the appropriate prediction coordinates calculated by means of the second piecewise-linear vector-function;
- numerical value (2.3.15) show the percentage ratio of total indices of vector-functions, i.e. by modules of the vectors $z_1(\square_1)$, $z_2(\square_1)$, $Z_3(\square_1)$, calculated according to different criteria.

It should be noted that by means of numerical data of table 5.3 it is easy to establish the dependence of coordinates of prediction vector-function depending on the parameter $\square_1$, i.e. $z_1(i) \sim \square_1$, $z_2(i) \sim \square_1$ and $Z_3(i) \sim \square_1$.

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