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08.00.13 Математические и инструментальные методы экономики (экономические науки)

НЕЧЕТКИЕ И ИНТЕРВАЛЬНЫЕ АДДИТИВНО-МУЛЬТИПЛИКАТИВНЫЕ МОДЕЛИ ОЦЕНКИ РИСКОВ

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Среди математических моделей исследования рисков, разработанных автором, важное место занимают аддитивно-мультипликативные модели оценки рисков. Составляющими таких моделей являются: трехступенчатые иерархические системы рисков (строят для конкретной прикладной ситуации); оценки частных рисков (определяют экспертно для конкретного проекта, продукта и т.п.); показатели весомости конкретных видов частных рисков (находят на основе опроса экспертов в конкретной прикладной области); алгоритмы расчета оценок групповых рисков по оценкам частных рисков и общего риска на основе оценок групповых рисков. В качестве примеров рассмотрены трехступенчатые иерархические системы рисков при выпуске нового инновационного изделия и при выполнении проектов по разработке ракетно-космической техники. Предложен алгоритм аддитивно-мультипликативной модели оценки рисков общего вида. Оценки частных рисков являются произведениями показателей весомости на показатели выраженности, что соответствует известному способу оценки риска в виде произведения среднего ущерба на вероятность нежелательного события. Оценки групповых рисков строятся по оценкам частных рисков аддитивно, а итоговая оценка общего риска рассчитывается по оценкам групповых рисков мультипликативно. Ранее автор рассматривал частный случай аддитивно-мультипликативной модели оценки рисков, в котором, в частности, составляющие модели интерпретировались в терминах теории вероятностей. Предлагается оценки частных рисков и коэффициентов весомости проводить на основе интервальной математики и теории нечеткости. Предложено использовать треугольные нечеткие числа как наиболее соответствующие прикладным задачам. Приведены правила арифметических операций над ними, а также над интервальными числами. Продемонстрировано применение алгоритма аддитивно-мультипликативной модели оценки рисков на основе треугольных нечетких чисел на примере оценки рисков реализации

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08.00.13 Mathematical and instrumental methods of Economics (economic sciences)

FUZZY AND INTERVAL ADDITIVE-MULTIPLICATIVE MODELS OF RISK ESTIMATION

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Among the mathematical models of risk research developed by the author, an important place is occupied by additive-multiplicative models of risk estimation. The components of such models are: three-stage hierarchical systems of risks (built for a specific applied situation); private risk estimators (determined by experts for a specific project, product, etc.); indicators of the weight of specific types of private risks (found on the basis of a survey of experts in a particular application area); algorithms for calculating group risk estimators based on individual risk estimators and general risk estimators based on group risk assessments. As examples, three-stage hierarchical risk systems are considered in the production of a new innovative product and in the implementation of projects for the development of rocket and space technology. An algorithm for an additive-multiplicative model for risk estimation of a general form is proposed. Estimates of particular risks are products of weighting indicators by severity indicators, which corresponds to the well-known method of risk estimation in the form of the product of average damage by the probability of an undesirable event. Group risk estimators are built additively from individual risk estimators, and the final total risk estimator is calculated multiplicatively from group risk estimators. Previously, the author considered a special case of an additive-multiplicative risk estimation model, in which, in particular, the components of the model were interpreted in terms of probability theory. It is proposed to carry out a estimators of particular risks and weight coefficients on the basis of interval mathematics and fuzzy theory. It is proposed to use triangular fuzzy numbers as the most appropriate for applied problems. The rules for arithmetic operations on them, as well as on interval numbers, are given. The application of the algorithm of the additive-multiplicative risk estimation model based on triangular fuzzy numbers is demonstrated using the example of risk estimation t for the implementation of innovative projects. Within the framework of interval mathematics, risk estimators are considered in the implementation of projects for the инновационных проектов. В рамках интервальной математики рассмотрены оценки рисков при выполнении проектов по разработке ракетно-космической техники. Развитый автором подход соответствует основным положениям системной нечеткой интервальной математики и теории устойчивости математических моделей

development of rocket and space technology. The approach developed by the author corresponds to the main provisions of systemic fuzzy interval mathematics and the theory of stability of mathematical models

Ключевые слова: РИСК, ВЕРОЯТНОСТЬ, МАТЕМАТИЧЕСКИЕ МЕТОДЫ ОЦЕНКИ РИСКОВ, ЭКСПЕРТНЫЕ ОЦЕНКИ, АДДИТИВНО-МУЛЬТИПЛИКАТИВНЫЕ МОДЕЛИ, НЕЧЕТКИЕ ЧИСЛА, ИНТЕРВАЛЬНАЯ МАТЕМАТИКА

Keywords: RISK, PROBABILITY, MATHEMATICAL METHODS OF RISK ESTIMATION, EXPERT ESTIMATORS, ADDITIVE-MULTIPLICATIVE MODELS, FUZZY NUMBERS, INTERVAL MATHEMATICS

1. Introduction

Among m of athematic risk research models, an important place is occupied by additive-multiplicative risk assessment models [1]. They are based on three-stage hierarchical systems of risks, in which group assessments are determined by individual risk assessments, and they, in turn, combine the general risk assessment of interest to the researcher. In the additive-multiplicative risk assessment model, we single out the following components.

1) a three-stage hierarchical system of risks (stricty at for a specific applied situation);

2) private risk assessments(determined by experts for a specific project, product, etc.);

3)indicators of weight (importance, weight, materiality, importance) of specific types of private risks (found on the basis of a survey of experts in a particular application area);

4) algorithms for calculating group risk assessments based on individual risk assessments and general risk assessments based on group risk assessments (according to these algorithms, the models of the type under consideration got their name, sinceat the lower level, group risk assessments are built additively from private risk assessments, and at the upper level, the final risk assessment is calculated from group risk assessments using a multiplicative scheme).

In our previous works (see [1, 2] and others), partial risks were estimated with points of 0, 1, 2, 3, 4, 5, and the weighting factors - with real (real) numbers. In this article, we propose a generalized additive-multiplicative model that uses different scoring systems, unambiguous estimates of particular risks and weight coefficients are replaced by their fuzzy counterparts, namely, fuzzy triangular numbers or interval numbers.

2. On the development of works on additive-multiplicative risk assessment models and other sections of risk theory

BUT additive-multiplicative model risk assessment for the implementation of innovative projects was first proposed in 1997 in the report [3] with the aim of analyzing risks in the implementation of an innovative project at a university. The interaction of the scientific team of the project developers, the administration of the university and an external partner was considered. In this setting, further results were obtained in [4].

Then the model of the type under consideration was generalized and applied to assess the risks in the production of a new innovative product at the enterprise [5, 6]. A number of sections of this article are devoted to the development of this model based on the system fuzzy interval mathematics tools [7, 8].

BUT additive-multiplicative model risk assessment turned out to be useful in the development of innovative and investment projects for the creation of rocket and space technology. After discussing this approach at scientific and technical conferences [9, 10], the preliminary results of the development of this area of research were summed up in the article [11]. A series of works in 2017 [12 - 14] is devoted to the further development of the considered approach.

Fundamental work on theory and practice additive-multiplicative model risk assessment is the article [15]. Reports [16, 17] are devoted to the further development of this area of research. In particular, in [17], the need to use fuzzy

(fuzzy. interval) estimates of partial risks and weight indicators is substantiated. This article is devoted to the solution of this problem posed in [17].

Work in this direction took place in a broader context of research on the theory and practice of studying and managing risks in various applied areas. By risk we mean an undesirable opportunity. The antonym to this term is security.

The initial stage of research on environmental safety is reflected in the reports[18, 19]. The article [20] substantiates a methodological statement about three types of mathematical risk models - probabilistic-statistical, fuzzy and interval. A detailed review of the obtained scientific results is included in textbooks [21, 22] and constitutes the main content of monographs [23, 24].

Problems about The report [25] is devoted to the organizational and economic modeling of the management processes of industrial enterprises under the conditions of inflation risks.

During the development of automated system for forecasting and preventing aviation accidents in the organization and production of air transportation [26], a number of problems of risk assessment and management arose. The results obtained are reflected in the works [27 - 31].

The cycle of works is devoted to estimates credit risk for banking structures. They are based on the use of expert technologies [32], in particular, on the new Kemeny median calculation algorithm [33–35].

Much attention was paid to the development of a general theory of risk[36], in particular, the analysis of the diversity of risks [37]. A new direction in controlling was singled out - risk controlling [38]. This managerial innovation was supported at the III International Congress on Controlling [39, 40]. Risk controlling tools are analyzed in [41]. Risk controlling is an important part of the information and methodological support of management [42]. At MSTU im. N.E. Bauman is trained in the discipline "Risk Controlling". Preliminary results of development to risk control as a scientific, practical and educational discipline are summed up in the work[43].

3. Private and group risks for two hierarchical systems

The additive-multiplicative risk assessment model is quite general for applications in various subject areas, but at the same time it is quite simple and adapted for practical applications and calculations. In the terminology of V.V. Nalimov [44], we are talking about a draft model. As an example, consider about risk assessments for the release of a new innovative product [2, sec. 6.3] and when executing projects for the development rocket and space technology [11, 15].

As already noted, at first, an additive-multiplicative model was developed for assessing the risks of implementing innovative projects in universities (with the participation of an external partner)[4]. Then the model of the type under consideration was applied to assess the risks in the release of a new innovative product.

We consider the risk that the release of an innovative product will be disrupted.In accordance with[37] towe classify private risks into production, commercial, financial and global, highlighting the appropriate groups.

To assess the risk that production risks will adversely affect the implementation of the project (thwart its completion on time), we introduce the following particular risks:

R_{eleven}- the risk of defectiveness (in particular, underestimation of the complexity of the organization of production and the technological process, which leads to a high percentage of defective products);

R_{21}- design risk (fundamental design errors, due to which it is impossible to establish production on time and of proper quality);

R_{31}– risk of accidents (including risks of accidents at work);

R_{41}- personnel risk (risks associated with the possible absence (illness, dismissal) of specialists, without which production cannot be established, as well as problems that arise in the process of work associated with other direct participants in the work).

To assess the risk that commercial risks will adversely affect the implementation of the project, we introduce the following partial risks:

R_{12}- supplier risk (risks associated with the activities of suppliers, manifested in the failure to meet delivery dates, failure to meet quality and volume requirements, etc.);

R_{22}– consumer risk (various risks associated with consumers, in particular, the lack of attractiveness of products due to poor marketing, high prices, changes in the market situation, etc.);

R_{32}– competitor's risk (risks associated with the activities of competitors, in particular, the launch of similar products by competitors, collusion between them, etc.);

R_{42}– environmental risk (risks associated with the activities of state and municipal authorities, utilities, public organizations).

To assess the risk that commercial risks will adversely affect the implementation of the project, we introduce the following partial risks:

R_{13}– risk of the legislator (risks associated with unforeseen changes in legislation);

R_{23}- exchange rate risk (risks of fluctuations in exchange rates, stock prices);

R_{33}– the risk of inflation (caused by rising prices).

To assess the risk that global risks will adversely affect the implementation of the project, we introduce the following partial risks:

R_{fourteen}– risk of the state (state and international risks, in particular, wars, revolutions, imposition of sanctions, terrorism, various global risks generated by human activities);

R_{24}– risk of nature (risks of earthquakes, floods, tsunamis, asteroid impact, climate change and other natural risks).

Total we have identified 13 private risks. Each of them can be detailed further, constructing the fourth hierarchical level, the fifth, and so on. However, in order to obtain a preliminary risk assessment, according to our expert assessment, it is sufficient to use three-level hierarchical risk systems.

The additive-multiplicative risk assessment model turned out to be useful in the rocket and space industry as well. We study the risk that the project for the development rocket and space technology will not be completed on time. In the case under consideration, group risks correspond to the following successive stages [11, 15]:

1) preparation of the concept;

2) preparation preliminary design and draft design;

3) development of design and technological documentation;

4) production of a prototype;

5) ground tests;

6) adjustment of documentation based on the results of documentation;

7) flight tests and revision of documentation for production;

8) launch.

For all 8 groups, 44 private risks were identified. All of them are listed in the article.[eleven]. Here, as an example, we give a list of private risks for stage 4 "Production of a prototype";

R_{fourteen}- risk of defectiveness (risk of errors in the manufacture of parts and blocks);

R_{24}- assembly risk (risk of assembly errors);

R_{34}- the risk of lack of resources (machine park, material, personnel, computer, temporary and other resources);

R_{44}- risks of subcontractors (risks associated with non-fulfillment of obligations by subcontractors and subcontractors);

R_{54}- organizational risk (risk of disruption of work due to their poor organization);

R_{64}- risk of suppliers (risk caused by the actions of suppliers of raw materials, components, materials (low quality, violation of deadlines));

R_{74}- external risk (risk for other reasons).

In any particular situation, the creation of an additive-multiplicative risk assessment model begins with the development of a three-level hierarchical risk system.

4. Algorithm additive-multiplicative risk assessment model

We proceed from a three-level hierarchical system of risks, in which *m* risk groups, the j-th of which includes k(j) private risks Rij, where i = 1, 2, ..., k(j), j = 1, 2, ..., m (see examples in the previous section).

Each of the private risks (risk factors) of the second order *Rij* has two indicators - the severity of Xij (shows the frequency of occurrence) and the weight of Aij (how much it affects the risk of a higher level). These indicators can be evaluated on the basis of various models - probabilistic-statistical, interval, fuzzy.

We accept that risk estimate Qij Rij has the form

$$Qij= AijXij, \qquad \text{(one)}$$

where Aij is an indicator of weight (importance), for example, an assessment of economic losses caused by this type of risk, Xij is an indicator of its severity (value). This formula generalizes the well-known risk assessment method as the product of the average damage (the mathematical expectation of damage) by the probability of an undesirable event [1].

Group risk assessment *qi* for group I has the form

$$qi= Q\ i_{one}– Q\ i2 – … – Q\ ik(i) = Ai1Xi1 + Ai2Xi2 + ... + Aik(i)Xik(i),\ i = 1, 2, …, m, \qquad (2)$$

those. the group risk assessment is equal to the sum of the individual risk assessments included in this group.

General Risk *Q* expressed in terms of group risks as follows:

$$Q= 1 - (1 - Q1) (1 - Q2)... (1 - Qm). \qquad (3)$$

Formulas (1) - (3) fully describe the calculation algorithm in additive-multiplicative risk assessment model. Group risk assessments are determined additively from individual risk assessments, and the overall (final) risk assessment is expressed through group risk assessments multiplicatively.

Final overall risk assessment *Q* maybebe used in evaluating the feasibility of project implementation, in determining the priority of project implementation, in planning the allocation of resources for the next planning interval (this is important in case of unsuccessful project implementation). For the purpose of risk management, the assessment of the overall risk Q can be used to identify the influence of the severity of one or another private or group factor on the final assessment Q of the overall risk, optimizing the choice of changes in the values of the factors, taking into account the available resources.

Expert assessments are actively used at all stages of building and using an additive-multiplicative model - when building a hierarchical system of risks, determining the values of the weighting coefficients, and then choosing the values of the coefficients of expression for specific projects.

5. Interpretation of the additive-multiplicative risk assessment model in terms of probability theory

She was used in works [4, 11, 15]. In this approach, the risk score Q is the 1's complement of the probability P of the successful realization of the associated event, i.e. P = 1 - Q. Private risk corresponds to the probability that the corresponding risk event [1] will not occur. Group risk - the probability that the stage of development of rocket and space technology is successfully completed on time. In the case of risk assessments when releasing a new innovative product - the probability that the private risks included in the group will not interfere with the implementation of the project.

The purpose of model development is risk assessment *R* the occurrence of an unwanted event. To calculate this risk, a probabilistic model is often used, according to which the occurrence of an undesirable event B is a random event - a subset of the set of all possible elementary events. The risk (undesirable event) will be denoted by R, its numerical probabilistic assessment Q. Let Q be the probability of the occurrence of an undesirable event R, then $P = 1 – Q$ is the probability that an undesirable event can be avoided. For simplicity, let Q be the probability of failure, then $P = 1 - Q$ is the probability of success, for example, the probability of successful implementation of an innovative investment project to create a product of rocket and space technology (or a certain stage of it). In the further description of the model, the duality of Q and P is used (from the applied point of view, it is important to estimate the risk Q,

If risk events for individual risks are incompatible, then the group risk assessment is given by formula (2). Note that if these events are independent and the corresponding risk estimates Q_{ij} are small, then formula (2) is also valid up to infinitesimals of a higher order. This follows from the fact that

$$P_i = P_{i1} P_{i2} \ldots P_{ik(i)} = (1 - Q_{i1})(1 - Q_{i2}) \ldots (1 - Q_{ik(i)}) = 1 - Q_{i1} - Q_{i2} - \ldots - Q_{ik(i)} \quad (4)$$

up to infinitesimals of a higher (than Q_{ij}) order. Thus, two fundamentally different approaches (inconsistency and independence) give the same numerical value (in the asymptotics), which increases the validity of using formula (2).

Group risk aggregation is based on the assumption that different risk groups act independently, i.e. the corresponding risk events are independent. Then the probability of success is:

$$P = P_1 P_2 \ldots P_t,$$

accordingly, the total risk Q is

$$Q = 1 - P = 1 - P_1 P_2 \ldots P_t.$$

As is known [1], for risk studies use mathematical models and methods of three types - probabilistic-statistical, interval and fuzzy. This statement was substantiated back in 2000 in [20]. The concept of probability is often inappropriate to use in interval and fuzzy models. When developing and applying interval mathematics and fuzzy theory algorithm The additive-multiplicative risk assessment model is based directly on formulas (1) and (3), the quantities included in them have no probabilistic analogues.

6.Building a system for assessing private risks and weighting factors

Let us first discuss the assessment of the severity of Xij. If there is a training sample, then it is advisable to calculate Xij from statistical data (as the frequency of an undesirable event). An alternative approach is the use of one or another technology of expert evaluation. In both approaches, it is natural to give risk assessments using linguistic variables.

In the works [2, 4, 11, 15], particular risks were described by linguistic variables with 6 gradations, each of which was formed in terms of a particular degree of risk severity and was coded using integers from 0 to 5. Namely, it was used, for example, the following system of values:

0 - an almost impossible event (with a probability of no more than 0.000001),

1 - an extremely unlikely event (with a probability of 0.000001 to 0.0005),

2 - unlikely event (probability from 0.0005 to 0.001),

3 - an event with a probability that cannot be neglected (from 0.001 to 0.01),

4 - quite probable event (probability from 0.01 to 0.1),

5 - an event with a noticeable probability (more than 0.1).

The risk scores Xij received from experts are measured on an ordinal scale.

Let us consider various possibilities of generalizing the approach developed in [2, 4, 11, 15] In additive-multiplicative risk assessment models, various other systems of values can be used to assess private risks. Namely, a different number of gradations can be chosen, therefore, the numerical values of risk assessments do not have to be chosen from the set {0, 1, 2, 3, 4, 5}. Grades can be described in various ways. So, in [11], an almost impossible event is an event with a probability of no more than 0.01 (and not an event with a probability of no more than 0.000001, as above).

To apply formulas (1) - (3), numerical risk assessments are required*Xij*for specific objects of expertise (products, projects, etc.). They are obtained as a result of the application of one or another expert technology.[2, 32]. At the same time, experts should be familiar with specific products or projects.

To evaluate indicators of weight (importance)*Aij*(they are the same for all projects) also attract experts, but of a different specialization - those who are familiar with the whole variety of objects of expertise under consideration. The choice of the set of numbers Aij should be consistent with the choice of risk assessment values. So, when using probabilistic-statistical models, the probabilities should be non-negative (ie, risk assessments should not exceed 1). Thus, when using the accepted[2, 4 - 6] in the system of risk assessment values, the maximum risk is achieved when these values are equal to 5. It is natural to assume that the corresponding probability is equal to 0, and therefore the sums Ai1, Ai2,..., Aik(i) for any i = 1, 2, ..., m must equal 1/5.

7.Arithmetic operations on interval and fuzzy numbers

Initial information for applying the algorithm additive-multiplicative risk assessment model isXij severity scores and Aij weighting scores. Risk assessments are calculated using formulas (1) - (3).

In previous works[2, 4, 11, 15] Xij and Aij are numbers. However, it is obvious that in practice the values of Xij and Aij are determined only with some accuracy and have errors. In accordance with the theory of stability of mathematical methods and models [45 - 49], it is advisable to use risk assessment algorithms in which, instead of real numbers, the initial information is interval or fuzzy numbers Xij and Aij. On their use the system fuzzy interval mathematics is based [7, 8], which we consider as the basis of mathematics of the XXI century [50]. Although it is known that interval numbers are a special case of fuzzy numbers, and the theory of fuzzy sets is a part of probability theory [50], in applied research it is advisable to distinguish between probabilistic-statistical, interval and fuzzy models.

The main objective of this article is the development and approbation of algorithms for estimating the fuzziness (error) of the final estimates of the general risk based on the errors in the estimates of particular risks and weight indicators.

To describe the blurring of the initial values, we will use two mathematical tools - interval numbers and triangular fuzzy numbers.

In interval mathematics real numbers are replaced by intervals (a, b), where a < b. The interval number (a, b) can be written as $(c-\Delta, c+\Delta)$ or $c \pm \Delta$, where c = (a + b) / 2 and Δ = (b - a) / 2. Here Δ - error in determining the interval number, i.e. blur indicator.

Arithmetic operations on interval numbers (a, b) and (c, d) are defined as follows. For any real numbers a, b, c, d, the sum and difference are:

$$(a, b) + (c, d) = (a + c, b + d), (a, b) - (c, d) = (a - d, b - c),$$

For non-negative real numbers a, b, c, d, the product and quotient are given by the formulas

$$(a,b)\times(c, d) = (ac, bd), (a, b) / (c, d) = (a / d, b / c).$$

Fuzzy numbers are described by their membership functions. We will use triangular fuzzy numbers, which are given by three real numbers a < b < c, whose membership function is equal to 0 to the left of a, increases linearly from 0 to 1 on the segment [a, b], decreases linearly from 1 to 0 on the segment [b , c] and is equal to 0 to the right of c. Thus, the membership function is defined by a triangle with vertices at the points (a, 0), (b, 1) and (c, 0), which explains its name. The triangular fuzzy number is completely described by the vector (a, b, c).

Note that the interval number (*a*, *b*) can be considered as a fuzzy number with a membership function equal to 0 to the left of a, equal to 1 on the interval [a, b], and equal to 0 to the right of b.

Let us introduce arithmetic operations on triangular fuzzy numbers (a_{one},b_{one}, c_{one}) and (a2, b2, c2). The sum and difference of these numbers are:

$$(a1, b1, c1) + (a2, b2, c2) = (a1 + a2, b1 + b2, c1 + c2),$$

$$(a1, b1, c1) - (a2, b2, c2) = (a1 - a2, b1 - b2, c1 - c2).$$

For non-negative real numbers a1 and a2, the product and quotient of triangular fuzzy numbers are given by the formulas

$$(a1, b1, c1)\times(a2, b2, c2) = (a1a2, b1b2, c1c2),$$

$$(a1, b1, c1) / (a2, b2, c2) = (a1 / c2, b1 / b2, c1 / a2).$$

Of all types of fuzzy numbers, we chose triangular fuzzy numbers for modeling, since they are described by a small number of parameters (three), and the results of arithmetic operations on them do not go beyond the set of triangular fuzzy numbers. In additive-multiplicative risk assessment models, fuzzy numbers with other membership functions can be used, but the calculations and interpretation of their results are much more complicated.

8. ABOUT risk assessment for the release of a new innovative product

Let's demonstrate the application of the algorithm additive-multiplicative risk assessment model based on formulas (1) - (3), for example assessing the risks of implementing innovative projects [2].

Table 1 shows the initial data – estimates private risks for five projects and weighting factors - without taking into account their errors. The private risks used are discussed above, in the section "Private and group risks for two hierarchical systems".

In table. Figures 2 and 3 show risk assessments for the implementation of innovative projects in the case when partial risks and weighting factors are described by triangular fuzzy numbers. Tab. 2 corresponds to the situation when the lower and upper limits for private risk assessments deviate from their average values (see Table 1) by$\pm 0{,}5$, and the weight coefficients - by$\pm 0{,}005$. In table. 3 permissible deviations are 2 times greater - for private risk assessments up to$\pm 1{,}0$, and for weight coefficients up to$\pm 0{,}01$.

Table 1. Initial risk assessments for the implementation of innovative projects.

Initial data	Private risk assessments for five projects				
Weight coefficients	Project 1	Project 2	Project 3	Project 4	Project 5
1. Production risks					
0.08	one	2	0	2	one
0.07	0	one	0	one	one
0.02	0	0	0	0	0
0.03	one	0	0	0	one
Q_{one}	0.11	0.23	0	0.23	0.18
2. Commercial risks					
0.05	0	one	one	one	one
0.07	one	2	five	one	2
0.02	0	one	one	one	0
0.06	one	one	one	one	one
Q_2	0.13	0.27	0.48	0.2	0.25
3. Financial risks					
0.06	0	0	0	0	0
0.07	one	one	one	one	one
0.07	0	0	0	0	0
Q_3	0.07	0.07	0.07	0.07	0.07
4. Global risks					
0.11	one	one	one	one	one

0.09	0	0	0	0	0
Q_4	0.11	0.11	0.11	0.11	0.11
Risk assessments for the implementation of innovative projects					
Q	0.36	0.53	0.57	0.49	0.49

Table 2. Risk assessments for the implementation of innovative projects with triangular fuzzy numbers Ain of the form A = (a - 0.005, a, a + 0.005) and Xin of the form X = (x - 0.5, x, x + 0.5).

Weight coefficients	Private risk assessments for five projects				
	Project 1	Project 2	Project 3	Project 4	Project 5
1. Production risks					
(0.075, 0.08, 0.085)	(0.5, 1, 1.5)	(1.5, 2, 2.5)	(0, 0, 0.5)	(1.5, 2, 2.5)	(0.5, 1, 1.5)
(0.065, 0.07, 0.075)	(0, 0, 0.5)	(0.5, 1, 1.5)	(0, 0, 0.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)
(0.015, 0.02, 0.025)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)
(0.025, 0.03, 0.035)	(0.5, 1, 1.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0.5, 1, 1.5)
Q_{one}	(0.05, 0.11, 0.23)	(0.14, 0.23, 0.35)	(0, 0, 0.11)	(0.14, 0.23, 0.35)	(0.08, 0.18, 0.30)
2. Commercial risks					
(0.045, 0.05, 0.055)	(0, 0, 0.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)
(0.065, 0.07, 0.075)	(0.5, 1, 1.5)	(1.5, 2, 2.5)	(4.5, 5, 5)	(0.5, 1, 1.5)	(1.5, 2, 2.5)
(0.015, 0.02, 0.025)	(0, 0, 0.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0, 0, 0.5)
(0.055, 0.06, 0.065)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)
Q_2	(0.06, 0.13, 0.25)	(0.15, 0.27, 0.40)	(0.35, 0.48, 0.59)	(0.09, 0.20, 0.33)	(0.15, 0.25, 0.38)
3. Financial risks					
(0.055, 0.06, 0.065)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)
(0.065, 0.07, 0.075)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)
(0.065, 0.07, 0.075)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)

Q_3	(0.03, 0.07, 0.18)	(0.03, 0.07, 0.18)	(0.03, 0.07, 0.18)	(0.03, 0.07, 0.18)	(0.03, 0.07, 0.18)
4. Global risks					
(0.105, 0.11, 0.115)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)	(0.5, 1, 1.5)
(0.085, 0.09, 0.095)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)	(0, 0, 0.5)
Q_4	(0.05, 0.11, 0.22)	(0.05, 0.11, 0.22)	(0.05, 0.11, 0.22)	(0, 0.11, 0.34)	(0.05, 0.11, 0.22)
Fuzzy risk assessments for the implementation of innovative projects					
Q	(0.18, 0.36, 0.63)	(0.34, 0.53, 0.76)	(0.40, 0.57, 0.77)	(0.29, 0.49, 0.72)	(0.28, 0.49, 0.73)

Table 3. Risk assessments for the implementation of innovative projects with triangular fuzzy numbers Ain of the form A = (a - 0.01, a, a + 0.01) and Xin of the form X = (x - 1, x, x + 1).

Weight coefficients	Private risk assessments for five projects				
	Project 1	Project 2	Project 3	Project 4	Project 5
1. Production risks					
(0.07, 0.08, 0.09)	(0, 1, 2)	(1, 2, 3)	(0, 0, 1)	(1, 2, 3)	(0, 1, 2)
(0.06, 0.07, 0.08)	(0, 0, 1)	(0, 1, 2)	(0, 0, 1)	(0, 1, 2)	(0, 1, 2)
(0.01, 0.02, 0.03)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)
(0.02, 0.03, 0.04)	(0, 1, 2)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 1, 2)
Q_{one}	(0, 0.11, 0.37)	(0.07, 0.23, 0.50)	(0, 0, 0.24)	(0.07, 0.23, 0.50)	(0, 0.18, 0.45)
2. Commercial risks					
(0.04, 0.05, 0.06)	(0, 0, 1)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)
(0.06, 0.07, 0.08)	(0, 1, 2)	(1, 2, 3)	(4, 5, 5)	(0, 1, 2)	(1, 2, 3)
(0.01, 0.02, 0.03)	(0, 0, 1)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 0, 1)
(0.05, 0.06, 0.07)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)

Q_2	(0, 0.13, 0.39)	(0.06, 0.27, 0.56)	(0.24, 0.48, 0.72)	(0, 0.20, 0.48)	(0.06, 0.25, 0.53)
3. Financial risks					
(0.05, 0.06, 0.07)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)
(0.06, 0.07, 0.08)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)
(0.06, 0.07, 0.08)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)
Q_3	(0, 0.07, 0.31)	(0, 0.07, 0.31)	(0, 0.07, 0.31)	(0, 0.07, 0.31)	(0, 0.07, 0.31)
4. Global risks					
(0.10, 0.11, 0.12)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)	(0, 1, 2)
(0.08, 0.09, 0.10)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)
Q_4	(0, 0.11, 0.34)	(0, 0.11, 0.34)	(0, 0.11, 0.34)	(0, 0.11, 0.34)	(0, 0.11, 0.34)
Fuzzy risk assessments for the implementation of innovative projects					
Q_4	(0, 0.36, 0.82)	(0.13, 0.53, 0.9)	(0.24, 0.57, 0.9)	(0.07, 0.49, 0.88)	(0.06, 0.49, 0.88)

Table data analysis. 1 shows that the risks of implementing the considered innovative projects befor efreely large - from 0.36 to 0.57. Therefore, it is necessary to develop methods to reduce the severity of private risks, as well as to prepare for a possible failure to complete the project on time. The calculated intervals for the total risk (the last rows of Tables 2 and 3) are not small and expand noticeably with an increase in the possible scatter of the values of individual risk assessments and coefficients. We state that it is not advisable to overestimate the accuracy of the conclusions. This statement corresponds to the results of the theory of stability of mathematical models of real phenomena and processes[45 - 49].

9. About risk assessments in the implementation of projects for the development rocket and space technology

We apply the algorithm of the additive-multiplicative risk assessment model based on formulas (1) - (3) to the initial data for two projects in the development of space technology. The three-level hierarchical system of risks is described above, in the section "Private and group risks for two hierarchical systems". The values of the estimates of 44 partial risks and the corresponding weighting factors (without errors) for two projects are given in [11]. We will proceed from the interval analogues of these quantities, which are introduced according to the following rules.

The private risk assessment 0 corresponds to the interval[0; 0.5], estimate 1 - interval [0.5; 1.5], estimate 2 - interval [1.5; 2.5], estimate 3 - interval [2.5; 3.5], estimate 4 - interval [3.5; 4.5], estimate 5 - interval [4.5; 5.0]. Weight coefficients were presented as [A1, A2] = [A - 0.004; A + 0.004], where A are the values for the corresponding partial risk in[eleven].

The calculation results are given in Table. 4, namely, the interval risk estimates of the stages [Qi1, Qi2] and their alternative notations $Q_i \pm \Delta Q_i$, where i = 1, 2, ..., 8, as well as an interval estimate of the total risk.

Table 4. Risk assessments successful implementation projects for the development rocket and space technology (modeling using interval numbers)

Project development stage	Project 1		Project 2	
	[Qi1, Qi2]	$Q_i \pm \Delta Q_i$	[Qi1, Qi2]	$Q_i \pm \Delta Q_i$
1) Concept	[0.126; 0.366]	0.246±0.12	[0.031; 0.178]	0.105± 0.074
2) Project development	[0.075; 0.286]	0.181± 0.106	[0.033; 0.196]	0.115± 0.082
3) Development of	[0.079;	0.193±	[0.035;	0.117±

working documentation	0.306]	0.114	0.198]	0.082
4) Manufacturing of prototypes	[0.140; 0.414]	0.277± 0.137	[0.028; 0.204]	0.116± 0.088
5) Ground mining	[0.209; 0.444]	0.327± 0.118	[0.029; 0.192]	0.111± 0.082
6) Correction of documentation	[0.065; 0.246]	0.156± 0.091	[0.011; 0.148]	0.080± 0.067
7) Flight test	[0.244; 0.532]	0.388± 0.144	[0.024; 0.186]	0.105± 0.081
8) Launch	[0.162; 0.410]	0.289± 0.124	[0.022; 0.174]	0.098± 0.076
Project as a whole	[0.700; 0.979]	0.840± 0.140	[0.195; 0.805]	0.500± 0.305

Accumulating from stage to stage, the numerical risk assessment for project 1 increases to a clearly unacceptable value of 0.840±0.140, at which the error is only 16.67% of the central value. Therefore, project 1 will most likely not be completed on time.

For project 2,accumulating from stage to stage, the total risk estimate reaches 0.500±0.305, respectively, the probability of successful completion of project 2 (ie, on time) is close to the value of 0.5 with an error of 61% of the central value. Therefore, project 2 can be completed on time or not completed with equal probability.

10. Conclusions

In this article, the additive-multiplicative risk assessment model is generalized for the case of describing particular risks and weighting factors by interval and triangular fuzzy numbers. The construction of a system for evaluating particular risks and weighting coefficients is freed from unnecessary assumptions made in the previous works of the author.

As examples, the application of the proposed approach is considered.to assess the risks of implementing innovative projects (modeling using triangular fuzzy numbers) and the risks of successful implementation projects for the development rocket and space technology (modeling using interval numbers).

The problems of assessing the risks of projects in the creation of rocket and space technology based on an additive-multiplicative model are considered in [12 - 15]. This model is included in training courses [2, 52].

Need generalizations additive-multiplicative risk assessment model with the aim of describing private risks and weighting factors by interval and triangular fuzzy numbers is substantiated in [17]. The approach developed in this article corresponds to the main provisions theory of stability of mathematical models of real phenomena and processes [45 - 49] and the results of systemic fuzzy interval mathematics [7, 8, 50].

The generalized additive-multiplicative risk assessment model proposed in this article based on fuzzy and interval initial data can be successfully applied in various application areas for risk assessment and management.

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References

1. Orlov A.I. Mathematical methods for risk research (generalizing article) // Factory laboratory. material diagnostics. 2021. V.87. No. 11. S. 70-80.
2. Orlov A.I. Methods of making managerial decisions. - M.: KNORUS, 2018. - 286 p.
3. Orlov A.I. Orlov A.I., Semenov P.M., Zhikharev V.N., Tsupin V.A. Methodology for assessing the risks of implementing innovative projects // Management of large systems. Proceedings of the International Scientific and Practical Conference (September 22-26, 1997, Moscow, Russia). - M.: SINTEG, 1997. - S. 109-109.
4. Vologzhanina S.A., Orlov A.I. About one approach to risk assessment for small enterprises (on the example of implementation of innovative projects in universities) // Training of specialists in the field of small business in higher education. Collection of scientific articles. - M .: Publishing house of LLC "ELIX +", 2001. P. 40-53.

5. Anisimov S.N. Designing integrated production and corporate structures: efficiency, organization, management / S.N. Anisimov, A.A. Kolobov, I.N. Omelchenko, A.I. Orlov, A.M. Ivanilova, S.V. Krasnov; Ed. A. A. Kolobova, A. I. Orlova. Scientific publication. - M .: Publishing house of MSTU im. N. E. Bauman, 2006. - 728 p.
6. Kolobov A.A., Omelchenko I.N., Orlov A.I. High technology management. Integrated production and corporate structures: organization, economics, management, design, efficiency, sustainability. - M .: Exam, 2008. - 621 p.
7. Orlov A.I., Lutsenko E.V. System fuzzy interval mathematics. - Krasnodar, KubGAU. 2014. - 600 p.
8. Orlov A.I., Lutsenko E.V. Analysis of data, information and knowledge in systemic fuzzy interval mathematics.- Krasnodar: KubGAU, 2022. - 405 p.
9. Orlov A.I., Tsisarsky A.D. Additive-multiplicative risk assessment model and its application in the development of innovative and investment projects for the creation of rocket and space technology // Problems of managing the safety of complex systems: Proceedings of the XXI International Conference. Moscow, December 2013 Ed. N.I. Arkhipova, V.V. Kulby. - M.: RGGU, 2013. - S.394-398.
10. Orlov A.I. Tsisarsky A.D. Features of risk assessment in the implementation of innovation and investment projects in the space industry // Actual problems of Russian cosmonautics. Materials of the XXXVIII Academic Readings on Cosmonautics. Moscow, January2014. / Under the general editorship of A.K. Medvedeva. - M.: Commission of the Russian Academy of Sciences for the development of the scientific heritage of the pioneers of space exploration, 2014. - P. 210-210.
11. Orlov A.I., Tsisarsky A.D. Features of risk assessment when creating rocket and space technology // National interests: priorities and safety. 2013. No. 43(232). pp. 37 - 46.
12. Orlov A.I., Tsisarsky A.D. Method of risk assessment in the creation of rocket and space technology // Bulletin of the Moscow State Technical University. N.E. Bauman, ser. Engineering. 2017. No. 2 (113). pp. 99-107.
13. Orlov A.I., Tsisarsky A.D. Organizational and economic model for project risk assessment // Siberian Journal of Science and Technology. 2017. V.18. No. 2. S. 464-470.
14. Orlov A.I., Tsisarsky A.D. A model for risk assessment of projects in the development of rocket and space technology. Vestnik NPO im. Lavochkin. 2017. №3. pp. 89-94.
15. Orlov A.I. Additive-multiplicative risk assessment model for the creation of rocket and space technology // Scientific journal of KubSAU. 2014. No. 102, pp. 78–111.
16. Orlov A.I. Additive-multiplicative model for assessing the risks of project implementation / Management of scientific and technical projects: mater. Second International sci.-tech. conf. - M.: Publishing house of MSTU im. N.E. Bauman, 2018. - S. 177–182.
17. Orlov A.I. Development of an additive-multiplicative model for assessing the risks of project implementation // Management of scientific and technical projects: materials of the Third International scientific and technical conference, - M .: Publishing house of MSTU im. N.E. Bauman, 2019. - S. 305-310.
18. Arbuzov G.M. Arbuzov G.M., Gorsky V.G., Orlov A.I., Kurochkin V.K. Methodology for identifying hazard priorities in the placement and operation of technically hazardous objects in the region on the basis of expert risk assessment // Proceedings of Scientific and Practical conference "Problems of ensuring the protection of the population and territories in the context of the prospective development of technical activities in the North-West region", St. Petersburg, November 11, 1998

19. Orlov A.I., Timofeev L.P. Problems of public health in the industrial centers of Russia and their solution using the concept of environmental risk // All-Russian Interuniversity Scientific and Practical Conference "Russian University: Personality in the Center of Attention" (Problems of education). Abstracts of reports. Volume 4. - Rostov-on-Don: Don State Technical University, 1999. - S. 190-193.

20. Orlov A.I., Fedoseev V.N. Problems of environmental safety management / Management in Russia and abroad. 2000. No. 6. pp. 78-86.

21. Orlov A.I. and others. Management of industrial and environmental safety: Textbook / A.I. Orlov, V. N. Fedoseev, V. G. Larionov, A. F. Koziakov). — M.: URAO, 2002 (1st ed.), 2003 (2nd ed.). — 220 s.

22. Orlov A.I., Fedoseev V.N. Management in the technosphere. Textbook for universities. - M .: Academy, 2003. - 384 p.

23. Orlov A.I. Problems of environmental safety management. Results of twenty years of scientific research and teaching. – Saarbrücken: Palmarium Academic Publishing. 2012. - 344 p.

24. Orlov A.I. Problems of environmental safety management. - M .: AI Pi Ar Media, 2022. - 224 p.

25. Orlov A.I. Organizational and economic modeling of industrial enterprise management processes under inflation risks // Strategic planning and development of enterprises. Proceedings of the Ninth All-Russian Symposium (Moscow, April 15-16, 2008). Ed. corresponding member RAS G.B. Kleiner. Section 4. - M.: CEMI RAN, 2008. - S. 124–126.

26. Butov A.A. Automated system for forecasting and preventing aviation accidents in the organization and production of air transportation / Butov A.A., Volkov M.A., Makarov V.P., Orlov A.I., Sharov V.D. // Proceedings of the Samara Scientific Center of the Russian Academy of Sciences. 2012. Volume 14. No. 4(2). pp.380-385.

27. Butov A.A. Butov A.A., Sharov V.D., Makarov V.P., Orlov A.I. Flight safety management in an airline based on the prevention of aviation events. // Problems of security management of complex systems: Proceedings of the XX International Conference (Moscow, December 2012). Ed. N.I. Arkhipova, V.V. Kulby. - M.: RGGU, 2012. - S. 272-275.

28. Orlov A.I., Rukhlinsky V.M., Sharov V.D. Economic risk assessment in flight safety management // Proceedings of the I International Conference "Strategic management and controlling in non-profit and public organizations: foundations, universities, municipalities, associations and partnerships": issue No. 1 / Under the scientific. ed. S.L. Baidakova and S.G. Falco. - M.: NP "OK", 2011. - S. 108-114.

29. Volkov M.A. Volkov M.A., Makarov V.P., Orlov A.I., Rukhlinsky V.M., Sannikov I.A., Sharov V. et al. Forecasting flight safety and economic risk assessment / Strategic planning and development of enterprises. D. // Proceedings of the Thirteenth All-Russian Symposium (Moscow, April 10-11, 2012). Ed. corresponding member RAS G.B. Kleiner. Section 5. - M.: CEMI RAN, 2012. - S. 43-45.

30. Sharov V.D., Orlov A.I. Identification of deviations in the controlling system (on the example of monitoring the level of flight safety) / Green Controlling: Proceedings of the III International Congress on Controlling. Under scientific ed. S.G. Falco. - M.: NP "Association of Controllers", 2013. - S. 277–292.

31. Orlov A.I., Sharov V.D. Identification of deviations in controlling (on the example of monitoring the level of flight safety) // Scientific journal of KubSAU. 2014. No. 95. P. 460-469.

32. Orlov A.I. Artificial intelligence: expert assessments. - M .: AI Pi Ar Media, 2022. - 436 p.

33. Zhukov M.S., Orlov A.I. The use of expert rankings in calculating credit risk in a bank // Innovations in management. 2017. No. 1(11). pp. 18-25.

34. Zhukov M.S., Orlov A.I. Using expert rankings when calculating credit risk in a bank // Tenth All-Russian Conference of Young Scientists and Specialists (with international participation) "The Future of Mechanical Engineering in Russia" (September 25-28, 2017, Union of Mechanical Engineers of Russia, Moscow State Technical University named after N.E. Bauman). Collection of reports. - M.: Publishing house of MSTU im. N.E. Bauman, 2017. - S. 646-648.

35. Zhukov M.S., Orlov A.I., Falko S.G. Expert assessments in risks / Controlling. 2017. No. 4 (66). pp. 24-27.

36. Orlov A. I., Pugach O. V. Approaches to the general theory of risk // Management of large systems. Issue. 40. - M.: IPU RAN, 2012. - S. 49-82.

37. Orlov A.I. Variety of risks // Scientific journal of KubSAU. 2015. No. 111. pp. 85–112.

38. Orlov A.I. The current state of risk controlling // Scientific journal of KubSAU. 2014. No. 98. pp. 32–64.

39. Orlov A.I. The current state of risk controlling // Green Controlling: Collection of abstracts of the III International Congress on Controlling. Under scientific ed. S.G. Falco. - M .: NP "Association of Controllers", 2013. - S. 102-104.

40. Orlov A.I. On the current state of risk controlling / Green Controlling: Proceedings of the III International Congress on Controlling. Under scientific ed. S.G. Falco. - M.: NP "Association of Controllers", 2013. - S. 188-197.

41. Orlov A.I. Risk Controlling Tools // Controlling. 2020. No. 78. pp. 56-62.

42. Orlov A.I. Risk Controlling: Information and Methodological Support for Management //Controlling in economics, organization of production and management: information and methodological support of management: a collection of scientific papers of the IX International Conference on Controlling, dedicated to the 190th anniversary of the Moscow State Technical University. N.E. Bauman (Moscow, December 18, 2020) / Under the scientific editorship of Doctor of Economics, Professor S.G. Falko / NP "Association of Controllers". - M.: NP "Association of Controllers", 2020. -S. 192-196.

43. Orlov A.I. Controlling Risks as a Scientific, Practical and Academic Discipline // Scientific Journal of KubSAU. 2021. No. 168. P. 154–185.

44. Nalimov V.V. Theory of experiment. - M.: Nauka, 1971. - 208 p.

45. Orlov A.I. Sustainability in socio-economic models. — M.: Nauka, 1979. — 296 p.

46. Orlov A.I. Sustainable mathematical methods and models / Factory laboratory. material diagnostics. 2010. V.76. No. 3. pp.59-67.

47. Orlov A.I. A new approach to the study of the stability of conclusions in mathematical models // Scientific journal of KubSAU. 2014. No. 100. P. 146-176.

48. Orlov A.I. Properties of the general stability scheme // Scientific journal of KubSAU. 2020. No. 161. pp. 121–149.

49. Orlov A.I. Sustainable economic and mathematical methods and models. — M.: AI Pi Ar Media, 2022. — 337 p.

50. Orlov A.I. System fuzzy interval mathematics - the basis of mathematics of the XXI century // Scientific journal of KubSAU. 2021. No. 165. pp. 111–130.

51. Orlov A.I. The theory of fuzzy sets - part of the theory of probability // Scientific journal of KubSAU. 2013. No. 92. S. 51-60.

52. Orlov A.I. Decision Theory: Textbook. - M .: AI Pi Ar Media, 2022. - 826 p.