Artículo de investigación

Creation and development of logistic systems of information support for decision making at the stage of after-sale service

Создание и развитие логистических систем информационной поддержки принятия решений на этапе послепродажного сервисного обслуживания

Creación y desarrollo de sistemas logísticos de apoyo a la información para la toma de decisiones en la etapa del servicio posventa

Recibido: 8 de agosto del 2019 Aceptado: 13 de septiembre del 2019

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Abstract

In this article we discuss about the problematic aspects of constructing logistics systems for decision support information systems used at the stage of after-sales servicing of aircraft, based on an analysis of the modern organization of their design, principles of a systematic approach and fuzzy logic.

Keywords: Aviation, decision-making, fuzzy logic, information support, logistics, multi-agent systems, operational technologies.

Аннотация

В статье рассматриваются проблемные аспекты построения логистических систем информационного обеспечения принятия решений, используемых на этапе послепродажного обслуживания самолетов, на основе анализа современной организации их конструкции, принципы системного подхода и нечеткая логика.

Ключевые слова: авиация, информационная поддержка, логистика, мультиагентные системы, нечеткая логика, операционные технологии, принятие решений.

Resumen

El presente artículo analiza los problemas derivados del desarrollo de procedimientos logísticos para sistemas de información de apoyo a la toma de decisiones utilizados en la etapa de servicio posventa de aeronaves, basado en la lógica difusa, en un análisis de una organización moderna de diseño y en unos principios de enfoque sistemático.

Palabras clave: Aviación, lógica difusa, logística, sistemas de múltiples agentes, soporte de información, tecnologías operacionales, toma de decisiones.

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Introduction

In the impending globalization, the issues of maintaining and expanding the positions in the world market for Russian enterprises become very relevant for manufacturers of aircraft equipment. The aircraft industry has traditionally been fiercely competitive in the global markets of manufacturing countries. Here, an indispensable condition for concluding supply contracts is now meeting the requirements of international standards for integrated logistics support for the supplied products. This situation is confirmed by the intensity of customer requests for information support for the export of civil aircraft (Uskov, Kuzmin, 2004; Minaev, Filimonova, Benameur, 2003; Demidova, Kirakovskiy, Pylkin, 2005).

Considering these circumstances, today in Russia there is a need of development and implementation of effective after-sales service system for aircraft, taking into account the results of summarizing the practical experience of its developers, manufacturers and operators by increasing the efficiency of the processes of “troika” (three organizations): design organizations (DO), aircraft manufacturers (M); operating organizations (OO) (“troika”: “DO-M-OO”) based on the creation of a unified information environment and a set of information and analytical services.

Analysis of the current state and requirements for the development of logistics support for aircraft

Analysis of the current state of creation and application of methods and means of logistics support for aircraft confirms the existence of several problems in the interaction and formation of information and analytical materials for integrated logistics support systems at the stages of the aircraft life cycle:

- Firstly, the world leaders in aircraft manufacturing do not already sell “just planes” and “related services”. They offer customers an integrated and functionally complete set of modern tools, technologies and services for carrying out business in the field of air transportation;
- Secondly, information systems and technologies today are not just tools, they are basic system-forming platforms for the efficient operation and maintenance of modern aviation technology (Kofman, 1982; Orlovsky, 1981).

As a result, external and internal communication interaction of “DO-M-OO” is complicated, which causes additional problems in the organization of distributed control.

These problems and other ones imply the following requirements for the development of an integrated logistics space system:

- Need to consider the dynamics of reducing the values of flight performance (1 - zone of normative design values of the parameters of flight performance, 2 - zone of acceptable reduction of flight performance, 3 - zone of unacceptable reduction of flight performance (Figure 1);
- Purposeful formation of a situational classification of aircraft conditions determined by the alternative composition and values of reliability and airworthiness parameters (Orlovsky, 1981; Pospelov, 1986; Utkin, Shubinskiy, 2000);
- Forecasting, accounting and analysis of the significant composition and values of parameters characterizing the perturbing (negative) or positive factors affecting aircraft: their structure, functions, processes, resources in the temporal and spatial continuum (Novikov, 2017);
- Identification of current and forecasted situations that develop for persons preparing and making decisions, as well as the type and characteristics of disturbing factors.

ISSN 2322- 6307

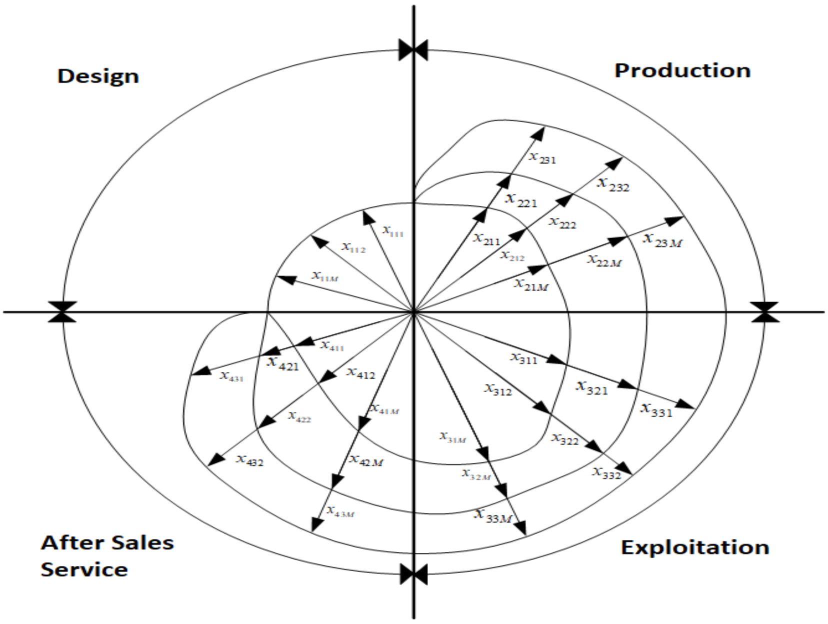

Figure 1. Stages and zones of airworthiness of the aircraft

X_{ijM} is the growth values of deviations of i-th parameters, j-th unit, M-th stage of the aircraft life cycle.

It seems that the fulfillment of these requirements can be most effectively implemented in the services of the system of distributed situational centers of the integrated logistic decision support system containing alternative information support for the formation of relevant answers to questions such as:

- To which class the current state of the objects belongs: <name of the unit, part, system-class of the state of validity>;
- What is the situation for decision makers: <state class - situation class>;
- Why the object is in this state <state of the unit, part, system – reason for decreasing the shelf life level>;
- What is the nature of the influence of parameter x on parameter y: <name and value of parameter x — degree of influence of parameter x on parameter y>;
- Where, what and how is it necessary to implement the selected solution to restore the airworthiness of aircraft: <location of the aircraft - composition of maintenance and repair operations - name of the operational technology for technical inspection and repair>.

Obviously, that one of the significant reasons for reducing the quality and effectiveness of the decision support information system at the after-sales service stage is a violation of the requirements for completeness, efficiency, reliability and relevance of the initial, intermediate and effective analytical information provided to end users (Saati, 1989; Golomazov, 2019).

Another limitation of the construction and application of this system is the limitations associated with the processing and transformation of source information based on deterministic analytical, tabular, graphical, cartographic and multimedia models (Komarova, Zamkovoi, Novikov, 2018; Novikov, 2019).

This fact occurs due to the need to consider the limited (significant) number of variables in such models on the one hand and the partial incorrectness and fuzziness of their relationship on the other. Moreover, the “weights” of these variables sometimes do not correspond to an adequate display of the states of real processes, that is, the variables of the analytical model are not always significant enough than others not included in it (Pamučar, Lukovac, Pejčić-Tarle, 2013). Otherwise, placing them in ranking and variation rows does not meet the Pareto principle and other most preferred criteria. The indicated limitations of the traditional set theory in some cases reduce the analytic level of productive information and, as a result, the quality of the preferred option for information support of decision making. Probabilistic approaches have similar limitations, often due to the lack of representative samples of statistical information, basis of the quality of the results of regression, correlation, analysis of variance and factor analysis (Kruglov, Dli, Golunov, 2001; Liou, Yen, Tzeng, 2008).

Therefore, a multicriteria approach based on the principles of the theory of fuzzy sets has been proposed to build a system of information support for decision making when choosing the preferred operational technology for aircraft (Novikov, Veas Iniesta, 2018).

Several publications note that the availability of input data is not enough to improve the quality of effective informational and analytical materials. You should be able to transform raw data into information useful for decision making (Orlovsky, 1981; Wittbrodt, Paszek, 2015).

This approach, based on the theory of fuzzy sets, has an undeniable advantage over deterministic and probabilistic approaches, which consists in the fact that decision support systems based on it have an increased degree of validity of decisions made (Novikov, 2018). This is due to the fact that both the results obtained on the basis of the deterministic approach and the verbal estimates and conclusions obtained on the basis of the experience and intuition of persons preparing and making decisions fall into the calculation (Dubois, Prade, 1990; Li, Li, 2010; Sheremetov, Contreras, Valencia, 2004).

It seems that with a fuzzy approach, the main task (development of an effective decision support system that collects a significant amount of statistical data) can be solved, takes into account the knowledge of experts and their management, which, in turn, will allow you to make optimal decisions to achieve your goals in conditions of incompleteness and fuzzy states of the subject area and blurring of situations for decision makers (Golomazov, Smirnov, 2016; Mahanta, Chutia, Baruah, 2010; Goswami, Dutta, Baruah, 1997).

Currently, the need for multi-criteria modeling of decision support in planning economic processes at the enterprise is becoming increasingly urgent (Uskov, Kuzmin, 2004; Chutia, Mahanta, Baruah, 2010).

The use of support and decision-making systems based on fuzzy logic for solving voluminous, difficult to formalize problems in various subject areas is characterized, as a rule, by the absence or complexity of formal decision algorithms, the incompleteness and fuzziness of the initial information, the fuzziness of the goals set, and the difficulty of finding a compromise solution in cases of Pareto insolvability of the original problem (Demidova, Kirakovskiy, Pylkin, 2005; Baruah, 2011).

These features lead to the need to use in the process of solving these tasks the knowledge obtained from a human expert in the subject area being studied. Based on them, decision-making support systems are being developed that collect and manage this knowledge, which make it possible to make optimal decisions to achieve goals in the context of incomplete and unclear informational description of the subject area (Minaev, Filimonova, Benameur, 2003; Dubois, Hullermeier, 2007; Feng, Pang, Lodewijks, Li, 2017).

The features of this approach are that fuzzy logic output rule systems can be used in various fields, including for the effective analysis of statistical information in the aviation industry. Such systems are used in determining statistical indicators for identifying and assessing existing and potential threats to adverse situations and in preparing the motivation base for making managerial decisions aimed at improving the effectiveness of measures to eliminate such threats (Li, Guo, Li, 2014; Li, Duan, Liu, 2010; Smirnov, Pashkin, Chilov, Levashova, (2004).

At the same time, based on the knowledge of experts accumulated in the system, we formed a hypothesis of the results of the analysis of the situation is built and concrete recommendations for its resolution.

Algorithm for generating information support and making the choice of the preferred operational technology for maintenance and repair of aircraft

During the study, seven operational technologies were selected, evaluated by an expert on five technological indicators. There is the data on the precedents of operational technologies in the Table 1.

Table 1. Data on operational technology alternatives

	1	2	3	4	5	6	7
Qualification of personnel for maintenance and repair of aircraft	9	12	3	3	11	7	7
Accessibility to maintenance and repair facilities for aircraft	33	35	28	23	31	24	34
Suitability	2	1	1	1	0	0	2
Easy removability	8	8	4	5	6	2	3
Maintainability	56	62	42	54	59	35	40

Next, the first step of the logical conclusion of the solution is implemented, it is fuzzification (determining the type and values of the parameters of membership functions for each operational technology by five indicators of its manufacturability)

For this, it is necessary to set the membership functions corresponding to each indicator of manufacturability of operational technology:

- Qualification of personnel for maintenance and repair of aircraft;
- Accessibility to objects of maintenance and repair of aircraft;
- Control suitability;
- Easy removability;
- Maintainability.

Each indicator of the manufacturability of operational technology is a linguistic variable characterized by a certain finite number of terms (Kumar, Poornaselvan, Sethumadhavan, 2010; Semenova, Smirnova, Tushavin, 2014).

The first linguistic variable is "Qualification of personnel for maintenance and repair of aircraft". The basic term-set of this linguistic variable consists of one fuzzy variable "Corresponds", and the area of reasoning, for example, is in the form $X_1 = [0; 14]$ (1). The membership function in this example is the following:

$$MF(x_1) = exp\left[-\left(\frac{x_1-14}{8}\right)^2\right] \qquad (1)$$

Figure 2 shows the membership function for the linguistic variable "Qualification of personnel for maintenance and repair of aircraft". For all linguistic variables, three values of the terms are conventionally accepted: low (L), medium (M) and high (H).

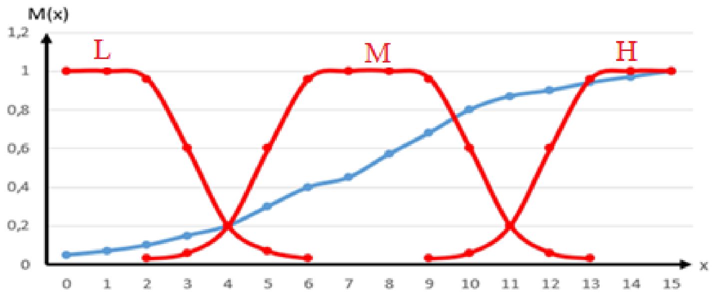

Figure 2. Membership function for the linguistic variable «Qualification of personnel for maintenance and repair of aircraft»

The second linguistic variable is "Accessibility to objects of maintenance and repair of aircraft". The basic term-set also consists of one fuzzy variable "Available", and the area of reasoning is in the form $x_2 = [18; 55]$. The membership function is given by the following formula:

$$MF(x_2) = exp\left[-(\frac{x_2-34}{10})^2\right] \qquad (2)$$

A graphic image of the membership function for the linguistic variable "Accessibility to objects of maintenance and repair of aircraft" is presented in the Figure 3.

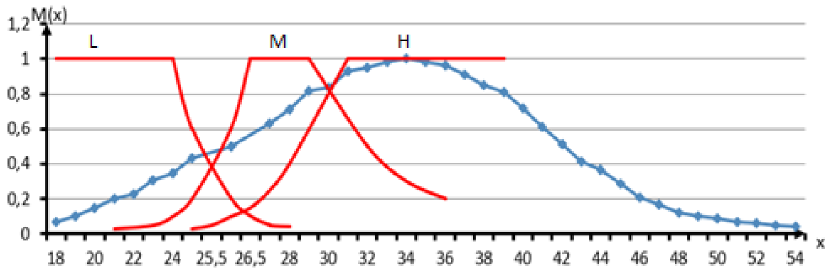

Figure 3. Membership function for the linguistic variable «Accessibility to objects of maintenance and repair of aircraft»

The name of the third linguistic variable is "Suitability". The basic term-set consists of one fuzzy variable "Unsuitable", and the area of reasoning in the form of $x_3 = [0;2]$. piecewise linear membership function is given by the formula:

$$MF(x_3) = \begin{cases} 0, x_3 = 0; \\ 0{,}7, x_3 = 1; \\ 1, x_3 = 2. \end{cases} \tag{3}$$

The name of the fourth linguistic variable is "Easiness". We form a term set for it, which also includes three terms: low, average, high, and the area of reasoning in the form of $x_4 = [0;8]$ The membership function is given by the following formula:

$$MF(x_4) = exp\left[-\left(\frac{x_4-8}{3}\right)^2\right] \tag{4}$$

A graphical representation of the membership function of the linguistic variable "Easiness" is shown in the Figure 4.

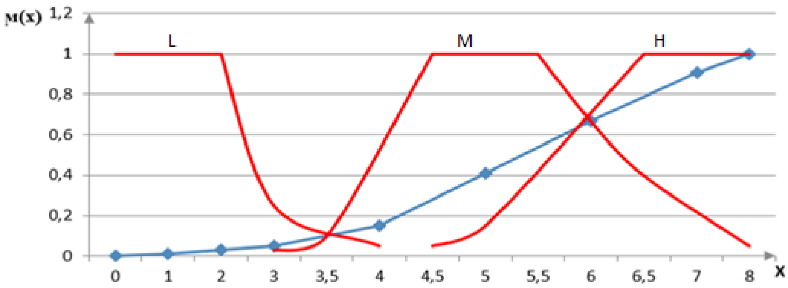

Figure 4. Membership function for the linguistic variable «Easiness»

The name of the fifth linguistic variable is "Maintainability". The basic term-set is represented by the area of reasoning in the form of membership function by formula:

$$MF(x_5) = exp\left[-\left(\frac{x_5-75}{30}\right)^2\right] \tag{5}$$

The graphic image for the linguistic variable "Maintainability" is shown in the Figure 5.

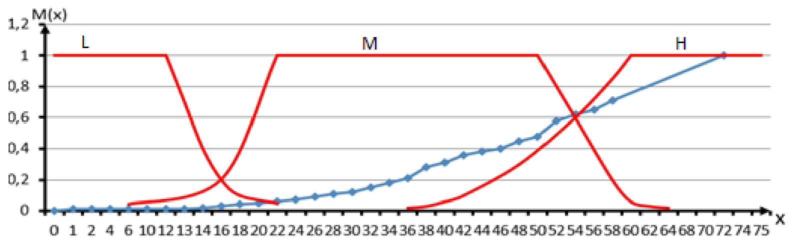

Figure 5. Membership function for the linguistic variable «Maintainability»

ISSN 2322- 6307

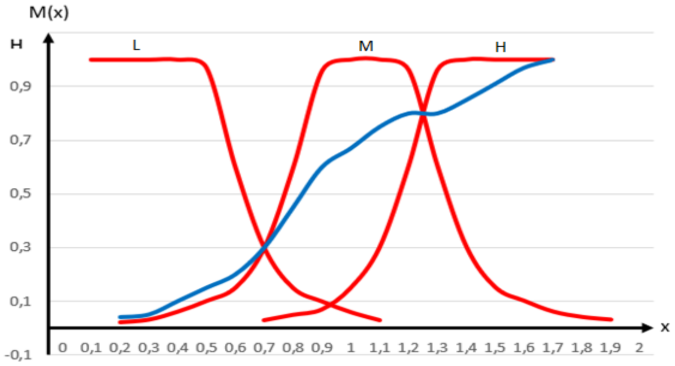

Figure 6. Membership function for the linguistic variable «Suitability»

The usefulness of operational technology obtained on an expert basis for the linguistic variables listed is given in the Table 2.

Table 2. Utility of operational technology

	1	2	3	4	5	6	7
Qualification of maintenance and repair personnel	0,7	0,9	0,2	0,2	0,9	0,5	0,5
Accessibility to maintenance and repair facilities	1,0	1,0	0,7	0,3	0,9	0,4	1,0
Suitability	1,0	0,7	0,7	0,7	0,0	0,0	1,0
Easy removability	1,0	1,0	0,2	0,4	0,6	0,0	0,1
Maintainability	0,7	0,8	0,3	0,6	0,8	0,2	0,3

The next stage of the fuzzy conclusion is the development of fuzzy rules for evaluating the preference of operational technology: analysis of the information fragments allows us to identify six linguistic variables, criteria for choosing operational technology: x_1 is the qualification, x_2 is the availability, x_3 is the suitability, x_4 is the easy removability, x_5 is the maintainability, x_5 is the acceptability or satisfactory.

It is necessary to determine the possible values of x_i and y to formulate the rules, which will be used to evaluate operational technology:

d_1 : «If x_1 = Unsuitable and x_5 = Does not Possess, then y = Unsatisfactory»;

d_2: «If x_1 = Satisfies and x_5= Possesses, then y = Medium satisfactory»;

d_3: «If x_1 = Suitable and x_5 = Possesses and x_3 = Not available, then y = Medium satisfactory»;

d_4: «If x_1 = Suitable and x_2 = Optimum and x_5 = Possesses, then y = Satisfactory»;

d_5: «If x_1 = Suitable and x_2 = Optimum and x_4 = Satisfies, and x_5 = Possesses, then y = Very satisfactory»;

d_6: «If x_1 = Suitable and x_2 = Optimum and x_3 = Available, and x_4 = Satisfies, and x_5=Possesses, then y = Perfect».

The variable y is defined on the set
$J = \{0; 0{,}1; 0{,}2; \ldots 1\}$.

The values of the variable y are set using the following accessory functions:

US = Unsatisfactory defined as:

$\mu_{US}(x) = 1 - x, x \in J;$

MS=Medium satisfactory defined as:

$\mu_{MS}(x) = \sqrt{x}, x \in J;$

S = Satisfactory defined as:

$\mu_S(x) = x, x \in J;$

VS = Very satisfactory defined as:
$\mu_{VS}(x) = x^2, x \in J;$

P = Perfect defined as:

$$\mu_P(x) = \begin{cases} 0, x \in [0; 0{,}9); \\ 1, x \in [0{,}9; 1). \end{cases}$$

Graphic values of the variable Y, specified using membership functions, are presented in the Figure 7.

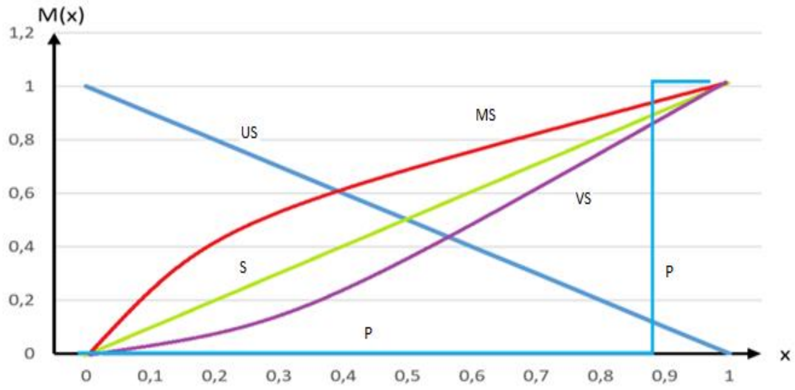

Figure 7. Values of the variable Y, defined using membership functions.

The choice is made from seven operational technologies on a multitude:

$$U = \{u_1, u_2, u_3, u_4, u_5, u_6, u_7\}.$$

Let estimates of alternative operational technologies be given by the following fuzzy sets presented in the Table 3.

Table 3. Evaluation of alternative operational technologies

	u_1	u_2	u_3	u_4	u_5	u_6	u_7
Qualification of maintenance and repair personnel	0,7	0,9	0,2	0,2	0,9	0,5	0,5
Accessibility to maintenance and repair facilities	1,0	1,0	0,7	0,3	0,9	0,0	1,0
Suitability	1,0	0,7	0,7	0,7	0,0	0,0	1,0
Easy removability	1,0	1,0	0,2	0,4	0,6	0,0	0,1
Maintainability	0,7	0,8	0,3	0,6	0,8	0,2	0,3

Considering the introduced notation, the rules are the following:

d_1: «If $X = \overline{A} \wedge \overline{B}$, then $Y = US$»;

d_2: «If $X = D \wedge E$, then $Y = MS$»;

d_3: «If $X = A \wedge E \wedge \overline{C}$, then $Y = MS$»;

d_4: «If $X = A \wedge B \wedge E$, then $Y = S$»;

d_5: «If $X = A \wedge B \wedge D \wedge E$, then $Y = VS$»;

d_6: «If $X = A \wedge B \wedge C \wedge D \wedge E$, then $Y = P$».

If all linguistic variables are equal, their weights are equal.

We calculate the membership function μ_{u_i} for the left parts of the above rules by the formula:

$$\mu_M(u) = \min_{m \in U}(\mu_M(u_1), \mu_M(u_2), \dots, \mu_M(u_n)) \quad (6)$$

We obtain the following values from the Table 4.

Table 4. Values of membership functions μ_{u_i}

d \ u	u_1	u_2	u_3	u_4	u_5	u_6	u_7
For d_1	0,3	0,1	0,7	0,4	0,1	0,5	0,5
For d_2	0,7	0,8	0,2	0,4	0,6	0,0	0,1
For d_3	0,0	0,3	0,2	0,2	0,8	0,2	0,0
For d_4	0,7	0,8	0,2	0,2	0,8	0,2	0,3
For d_6	0,7	0,8	0,2	0,2	0,6	0,0	0,1
For d_7	0,7	0,7	0,2	0,2	0,0	0,0	0,1

The basic rules are the following:

d_1: «If $X = M_1$, then $Y = US$»;

d_2: «If $X = M_2$, then $Y = MS$»;

d_3: «If $X = M_3$, then $Y = MS$»;

d_4: «If $X = M_4$, then $Y = S$»;

d_5: «If $X = M_5$, then $Y = VS$»;

d_6: «If $X = M_6$, then $Y = P$»;

Using to transform rules of the form «If $X = M$, then $Y = Q$» Lukasevich's implication:

$$\mu_D(u, j) = min(1; 1 - \mu_M(u) + \mu_I(j)) \quad (7)$$

For each pair $(u, j) \in U \times J$ we obtain the following fuzzy relations presented in the Table 5.

Table 5. Values of fuzzy relations $D_1, \ldots, D_6$.

D	M	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
	u_1	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9	0,8	0,7
	u_2	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9
	u_3	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,6	0,5	0,4	0,3
	u_4	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9	0,8	0,7	0,6
	u_5	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9
D_1	u_6	1,0	1,0	1,0	1,0	1,0	1,0	0,9	0,8	0,7	0,6	0,5
	u_7	1,0	1,0	1,0	1,0	1,0	1,0	0,9	0,8	0,7	0,6	0,5
	u_1	0,3	0,6	0,8	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_2	0,2	0,5	0,6	0,7	0,8	0,9	0,9	1,0	1,0	1,0	1,0
	u_3	0,8	1,0	1,0	1,0	1,0	0,8	0,8	1,0	1,0	1,0	1,0
	u_4	0,6	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_5	0,4	0,7	0,8	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0
D_2	u_6	1,0	1,0	1,0	1,0	1,0	1,0	0,9	1,0	1,0	1,0	1,0
	u_7	0,9	1,0	1,0	1,0	1,0	1,0	0,9	1,0	1,0	1,0	1,0
	u_1	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_2	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_3	0,8	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_4	0,8	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_5	0,2	0,6	0,7	0,8	0,9	1,0	1,0	1,0	1,0	1,0	1,0
D_3	u_6	0,8	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_1	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,0	1,0	1,0
	u_2	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,0	1,0
	u_3	0,8	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_4	0,8	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0

ISSN 2322- 6307

D_4	u_5	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,0	1,0
	u_6	0,8	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_7	0,7	0,8	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_1	0,3	0,3	0,4	0,4	0,5	0,6	0,7	0,8	1,0	1,0	1,0
	u_2	0,2	0,2	0,2	0,3	0,3	0,4	0,5	0,7	0,8	1,0	1,0
	u_3	0,8	0,9	0,9	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_4	0,8	0,9	0,9	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_5	0,4	0,4	0,4	0,4	0,5	0,6	0,7	0,8	1,0	1,0	1,0
D_5	u_6	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_7	0,9	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_1	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	1,0	1,0
	u_2	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	1,0	1,0
	u_3	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	1,0	1,0
	u_4	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	1,0	1,0
	u_5	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
D_6	u_6	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	u_7	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	1,0	1,0

As a result of the intersection of the relations $D_1, \dots, D_6$ we obtain the general final solution presented in the Table 6.

Table 6. General final decisión

D \ M		0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
	u_1	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,8	0,7
	u_2	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,3	0,3	1,0	0,9
	u_3	0,8	0,8	0,8	0,8	0,8	0,8	0,7	0,6	0,5	0,4	0,3
	u_4	0,6	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,7	0,6
	u_5	0,2	0,3	0,4	0,4	0,6	0,6	0,7	0,8	1,0	1,0	0,9
D_3	u_6	0,8	0,9	1,0	1,0	1,0	1,0	0,9	0,8	0,7	0,6	0,5
	u_7	0,7	0,8	0,9	0,9	0,9	0,9	0,9	0,8	0,7	0,6	0,5

To calculate the measure of satisfaction of each of the alternatives to operational technology, we apply the rule of compositional output in a fuzzy environment:

$E_k = G_k \circ D$,

where E_k is the degree of satisfaction of alternative k,

G_k are the maps alternatives k as a fuzzy subset on U,

D is the general functional solution.

Then

$$\mu_{X_1}(i) = \max_{u \in U}\left(min(\mu_{G_k}(u), \mu_D(u)\right)..$$

The comparison of alternatives is based on point estimates. For a fuzzy subset $E \subset J$ we define an a -level set $(\alpha \in [0,1])$:

$$E_k = i|M_X(i) \geq \alpha \in J$$

The level subsets E_j and the power of such a subset $M(E_j)$ are calculated by the formula:

$$M(E_j) = \frac{\sum_{i-1}^{n} X_i}{n} \quad (8)$$

We find the point estimate E_i by the formula:

$$F(E_i) = \frac{1}{\alpha_{max} \int_0^{M_{max}\int} M} \quad (9)$$

For each alternative, we compute level sets and the power of such a set:

$$0 < a < 0{,}3 \Rightarrow da = 0{,}3:$$

$E_j =$
$\{0; 0{,}1; 0{,}2; 0{,}3; 0{,}4; 0{,}5; 0{,}6; 0{,}8; 0{,}8; 0{,}9; 1\}$,
$M(E_j) = 0{,}5;$

$$0{,}3 < a < 0{,}7 \Rightarrow da = 0{,}4:$$

$$E_j\{0{,}9; 1\}, M(E_j) = 0{,}95$$

$0{,}7 < a < 0{,}8 \Rightarrow da = 0{,}1:$
$E_j = \{0{,}9; 1\}$, $M(E_j) = 0{,}9.$

$$F(E_1) = \frac{1}{0{,}8}(0{,}3 \times 0{,}5 + 0{,}4 \times 0{,}95 + 0{,}1 \times 0{,}9) = 0{,}78.$$

Similarly, we find point estimates for other alternatives to operational technology:

$F(E_1) = 0{,}78;$
$F(E_2) = 0{,}825;$
$F(E_3) = 0{,}41;$
$F(E_4) = 0{,}49;$
$F(E_5) = 0{,}7;$
$F(E_6) = 0{,}44;$
$F(E_7) = 0{,}47.$

As the preferred one, we choose the alternative with the highest point estimate. In this case, this is an alternative to u_2, therefore, it will be the best.

Conclusion

The proposed approach involves the selection and justification of the composition of significant parameters and indicators of the manufacturability of operational technology as the most significant linguistic variables. This is achieved by preliminary selection by methods of mathematical statistics: regression, correlation, variance and factor analysis, which allows you to change the composition and values of the processability indicators of operational technology, as well as the composition of alternative operational parameters. Further, these results provide an increased measure of adaptation of operational technologies to the real conditions of aircraft conditions, maintenance and repair of aircraft at the stage of after-sales service organized by interacting entities "DO-M-OO".

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