1.Introduction

In the current geopolitical and economic conditions, the role of customs authorities in regulating foreign trade and protecting the national interests of the Russian Federation is increasing. Thus, the setted packages of sanctions against Russia require the adoption of adequate and targeted measures to support the national economy and ensure the economic stability of the state. The tasks of the development of the Russian customs service at the moment are primarily related to the maximum mitigation of the impact of sanctions on business, on the Russian economy, and promoting the growth of trade. So, in 2022, according to government support measures, it was possible to generally maintain the volume of priority imports, this applies primarily to food, medicines, and essential goods. For 2023, among the priority tasks of the customs authorities, one can single out ensuring the stability of such supplies, speeding up the processes of declaring goods, and maintaining citizens' access to familiar goods.

The effectiveness of these tasks reflects the effectiveness of the customs authorities activities as a whole. The complexity of the tasks assigned to the customs authorities requires reasonable approaches to assessing their activities.

Since the main function of Customs Authorities is to provide economic security, control and supervision, on the one hand, and to create favourable environment to do business in a foreign trade area , on the other hand, assessing efficiency may occur in various ways.

A strategic goal of developing Federal Customs Service of Russian Federation (hereinafter FCS of Russia) is to create a brand new «smart» customs service , full of «artificial intelligence», fast reconfigurable, having information access to internal and foreign partners, which is not visible for law-abiding business and efficient for the government [20]. It predetermines the way of assessing the activity in the near term.

The issue of assessing Customs Authorities activity in terms of efficiency and efficacy has not been thoroughly researched as an economic concept until now, and it is being evident that these assessment areas should be distinguished.
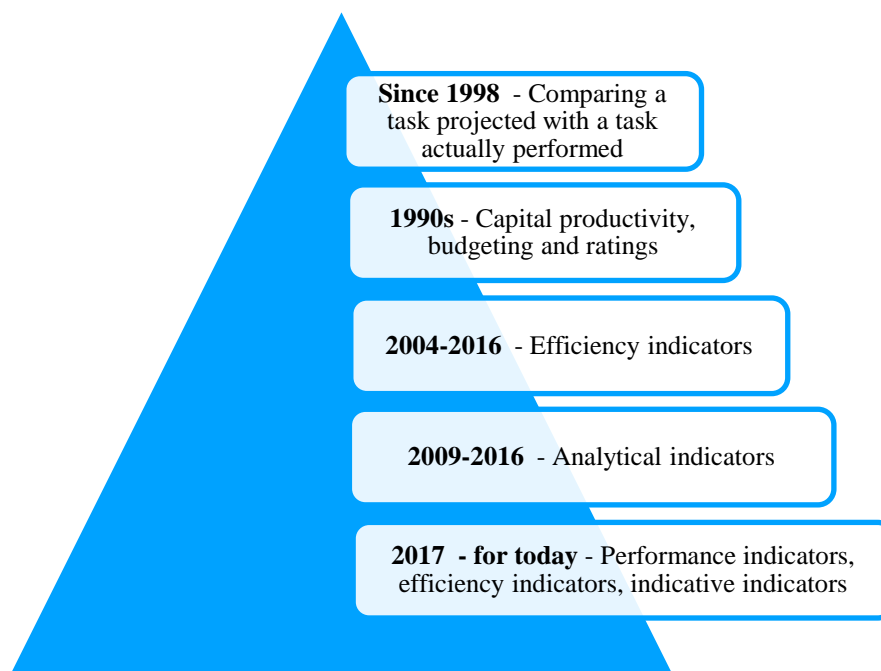
Two key approaches are distinguished in the management theory [for example, 1, 6]: focused approach and cost approach. The focused approach reveals the level of achieving the goals by the business entity, whereas the cost approach - efficiency of tools to transform resources into the outcome of business. Thereunder, when applying to assess Customs Authorities activities, efficiency should be regarded as the relationship between the costs incurred and the results achieved, and efficacy being assessed in terms of the goals achievement rate.

Taking into account the fact, that customs bodies are government agencies with limited state budget funds appropriated, and hence it is hardly possible to compute an accurate amount of their economic benefit as an outcome, so it is necessary to assess the efficiency of Customs Authorities activity.

Modern approaches of assessing customs authorities activity, based on intelligent modelling methods and modern economic-mathematical tools, enable both to monitor the indicators of Customs Authorities development and to create a database for future decision-making.

2. Literature Review

Assessment of Customs Authorities activity in Russia has been evolving for a particular period of time and its genesis is shown in Picture 1.

Since 1998 - Comparing a task projected with a task actually performed

1990s - Capital productivity, budgeting and ratings

2004-2016 - Efficiency indicators

2009-2016 - Analytical indicators

2017 - for today - Performance indicators, efficiency indicators, indicative indicators

Source: author's design

Picture 1- Evolution of the approaches of assessing Customs Authorities activity in Russia

Originally, the efficiency of Customs Authorities activity was assessed by comparing actual data on customs duties paid with a projected task for a particular accounting period.

Picture 1 shows that the system of assessing Customs Authorities activity has gone through a number of development stages. At present, the efficiency of Customs Authorities activity is assessed by a complex of efficiency indicators, performance indicators, indicative indicators. On the one hand, it enables to keep track of evolving results carefully (due to a comprehensive list of indicators) and to reveal the resources for improving the overall quality of the activity.

However, this system has a number of drawbacks, as follows. First, it essentially remained intradepartmental , failing to reflect consumer estimate and overall results of the whole system of Customs Authorities (indicators are computed for distinct links /levels of the system). Second, complex calculation methods preserved and a huge number of figures to compute. And finally, failure to take into account the contribution to achieving the goals by a distinct level of customs system .

Resort to a foreign experience in quantity indicators showed that the assessment system, being an integral part of results-based management, contains such areas as intelligent data analysis, consumer estimates (perceptions index), data monitoring mechanisms [2].

Assessment approaches vary from country to country due to national specificity of customs operations and the level of development of customs services and the country in general.

Thus, the results of the US customs service activity show its efficiency in terms of trade and economic growth, national security, combatting customs offences, protection of the population and efficient customs system administration [17]. And assessment system implies comparing projected (target) values with the ones obtained within a specified period as well as integrating the final values in consolidated assessment areas.

Similar assessment approaches have been developed by Customs Authorities in a number of the developed countries in Europe. For example, Customs Authorities in Finland set the goal of achieving a number of quantity indicators which show the flow of goods and passenger traffic, the number of customs declarations filed in various directions of the flow of goods, the amount of customs duties paid, the rate of customs rules violations etc. In Great Britain the system of assessing Customs Authorities activity is also focused on quantity indicators with particular emphasis on enforcement actions and computerisation of customs procedures.

The strategic goal set by the customs authorities in Australia is to administer the border efficiently, which involves national security, increasing government revenues, minimal limits on legal trade and sufficient statistics on trade transactions [6].

In general, having analysed the available approaches of assessing Customs Authorities activity worldwide, they can be conventionally divided into quantitive (time, cost etc) and qualitative (expert) models, involving combined assessments of various types of government bodies activity.

It is worth noting, that the first approach has been successfully implemented in Russian Federation nowadays, though it is not informative enough to assess managerial decisions. Hence, it is advisable to develop this methodology applying qualitative (expert) modeling for assessing Customs Authorities activity with regard to key assessment areas and strategic perspective of the customs service development. Modern digital transformations of socio-economic and financial relations induce the revision of methodology to apply quantitive methods in economy and finance [4;23]. Considering the metrics of digital economy, R. Bukht and R. Heeks draw the attention to the fact that in the context of dialectic innovations data collection is left behind technological progress [3]. Expert knowledge would be required to measure the economic and financial indicators when facing not stochastic uncertainty resulted from noise pollution and uniqueness of data, the lack of or small amount of statistical surveys [11; 27]. Standard methods of measurement, when using high granularity data, may be unable to be validated. Therefore, methods and models are being transformed into an innovative methodology of intellectual measurement [8;15;16]. S.A Sevastyanova and A.L. Sevastianova point out that «human intelligence transforms information into knowledge as a result of comprehension, systematization, structuring, interpretation» [18, p.51]. When selecting a specific tool which enables to formalise human thinking into knowledge-based systems, a growing number of researchers give preference to fuzzy logic [25].

A technique to implement a combined assessment of Customs Authorities activity as a whole, subject to consumer preferences, is to apply the methods used in accordance with the key standards of customs authorities activity adopted under the Federal Act «On Customs Regulation in Russian Federation and on amending specific Acts of Russian Federation» № 289-ФЗ , dated 03/08/2018 [21].

These approaches seem to be rather significant from the standpoint of assessing comprehensive results and need further development. As has been proven above [5], a system of balanced indicators may be applied as a comprehensive approach which enables to create a system of indicators with regard to the key goals and areas of the Customs Service development.

Thus, consolidating these approaches to assess Customs Authorities activity made it possible to have them classified according to the assessment areas proposed earlier [5] - economic security, finance, clients, training and development. These areas will enable Customs Authorities, Customs Authorities, to assess the efficiency of the key functions of Customs Authorities, namely, their share of economic security , the volume and completeness of the federal budget revenues , the terms of foreign economic activity (hereinafter FEA) and the level of Customs Authorities development based on technology innovations in their activity. Moreover, the methodology proposed herein [5] enables to solve the problem of assessing the share of a particular segment of the Customs system to achieve the goals set.

3. Materials and methods

In order to do modeling let's select the area of «Finance» which shows the efficiency of Customs Authorities in performing their fiscal function. The indicators in this area have been specified in accordance with the Regulation of the Government of RF « On Adoption of the Provision on the system of performance indicators of the Russian Federation Customs Authorities, the order and method of their monitoring» №994, dated 29/09/2012, [22], and include the following 3 indicators:

- Level of compliance with the projected revenues to be contributed to the federal budget by the Customs Authorities when collected from the income administered ,% (indicator 4);

- The share of customs payments refunded to the payors in order to satisfy the complaints of FEA participants against the decision of Customs Authorities or customs officers, their act or omission, in the total amount of customs payments, % (indicator 5);

- The share of customs payments refunded to the payors to execute a court order, which set aside the invalid decisions taken by the Customs Authorities officers in the total amount of customs payments, % (indicator 6);

As has been noted previously, the level of compliance with the projected revenues to be contributed to the federal budget by the Customs Authorities when collected from the income administered,% (indicator 4), was being computed while the system of assessing Customs Authorities activity was evolving , so the empirical basis for this indicator is quite broad. The dynamics of this indicator for the last 23 years is shown in picture 2.
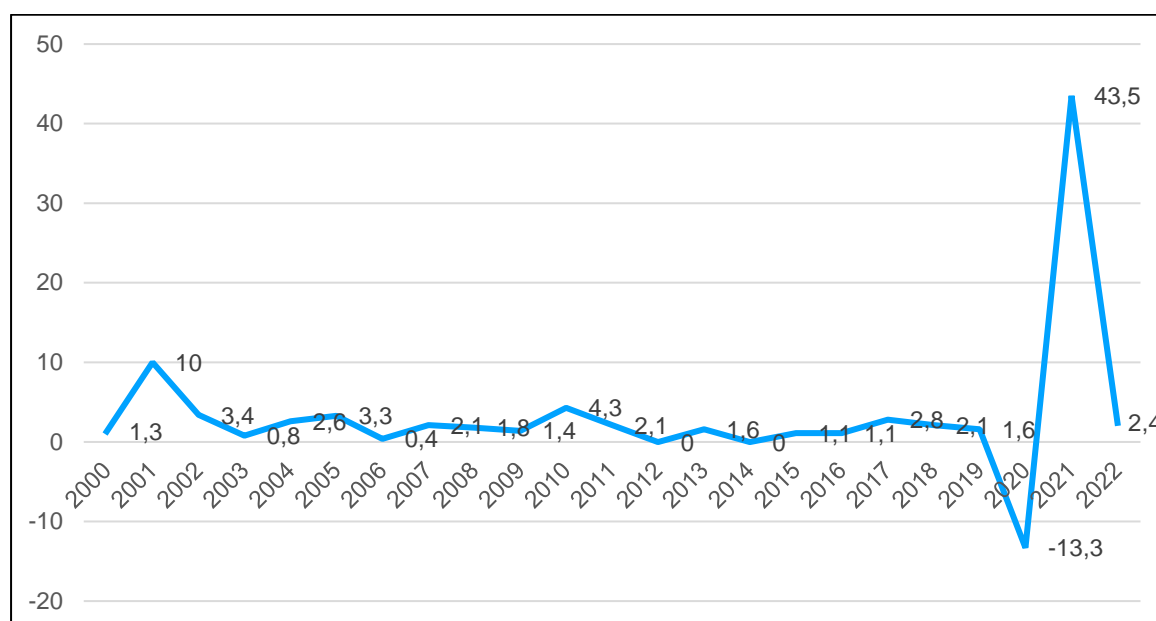
Picture 2 - Dynamics of exceeding the projected revenues to be contributed to the federal budget by the Customs Authorities when collected from the income administered in 2000-2022, %[1]

The indicator reflecting the deviation from the predicted task of transferring customs payments has high amplitude fluctuations. This fluctuation is determined by changes in foreign trade turnover induced by the ongoing global financial crises, changes in current legislation, as well as the impact of difficult to predict factors such as the Covid-19 pandemic, restrictive measures of a financial and trade nature. The most significant impact on the fluctuations in the indicator was the conditions of the pandemic, which led to a sharp reduction in foreign trade turnover and, as a result, a decrease in customs payments in 2020, which resulted in a significant underperformance of the indicator (by 13.31%). This led to the need to revise the forecast values and underestimate the forecast for the next 2021. In addition, the easing of antiquated measures has stimulated business activity in many countries, including among Russia's trading partners. According to the FCS, in 2021, Russian foreign trade turnover increased by 37.9% compared to the previous year and reached $789.4 billion. At the end of 2021, Russia's trade turnover not only exceeded the level of 2020, but also exceeded the results of the pre-pandemic 2018-2019.

As a result, the excess of the forecast in 2021 amounted to 43.5%. It is obvious that the data from 2020-2021 are out of the general trend over the past 23 years and a time period was chosen for the purposes of correct modeling [2000; 2019]. The amount of deviation from the forecast task for the transfer of customs payments at the selected time interval varies from 0 to 10%, which indicates, on the one hand, the high quality of planning these indicators, and on the other hand, the effectiveness of the implementation of the fiscal function by customs authorities.

Empirical data on indicators 5 and 6 (table 1) is uniform, and on the whole provide positive assessment of the activity involving collecting customs payments. Calculation of these indicators has been made since 2013.

Table 1 - Dynamics of indicators 5 and 6 in 2013-2022[2]

YEAR	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Indicator 5, %	0,0075	0,0040	0,0200	0,0100	0,0200	0,0030	0,0002	0,0000	0,0000	0,0000
Indicator 6, %	0,25	0,17	0,15	0,1	0,1	0,06	0,06	0,04	0,13	0,11

The level of achieving the goal in the area of «Finance» shall be measured by means of a knowlege-based technique in the fuzzy logic format, which is a modified class of many-valued logic.

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[1] Compiled by the authors in accordance with the official RF customs statistics.
[2] Compiled by the authors in accordance with the official RF customs statistics.

Experts verbalize the algorithm as fuzzy reasoning. Since modelling is based on expert knowledge , E.Mamdani's algorithm is being used as a modelling one [13]. So production rules defined by the experts as an implication

$$\bigcup_{l=1}^{r_j}\left(\bigcap_{\alpha=1}^{n} x_\alpha = t_\alpha^{\beta l} \quad with \quad weight \quad \omega_{\beta l}\right) \Rightarrow \left(y = d_\beta\right), \beta = \overline{1;m}, \tag{1}$$

where $\left(x_1, x_2, ..., x_n\right)$ – input variables vector;

$t_\alpha^{\beta l}$ – fuzzy term variable x_α in the line numbered βl ($l = \overline{1; r_j}$);

r_j – quantity of rules in the knowledge base;

m – quantity of terms of output parameter y;

$\omega_{\beta l}$ – weight of rule numbered βl ($\omega_{\beta l} \in [0;1]$);

$\bigcup$ – fuzzy disjunction;

$\bigcap$ – fuzzy conjunction,

are considered as fuzzy logic functions or operators rather than as implication rules. Variable models and their linguistic terms are defined and identified. Membership functions are specified per each term of all linguistic variables. A specific numerical value for an output variable is determined by means of defuzzification.

Mathematical modeling of value Y is considered to be the search for the thing described by means of a logic conclusion under the rules with the help of fuzzy implication operator, as follows

$$Y : \left\{\left(x_1; x_2\right)\right\} \rightarrow [0;1], \tag{1}$$

where x_1 – value of deviation from the projected revenues to be contributed to the federal budget by the Customs Authorities when collected from the income administered ;

x_2 – aggregate share of customs payments refunded to the payors to satisfy the complaints of FEA participants against the decision of Customs Authorities , its act or omission, in the total amount of customs payments or set off as future payments to execute a court order, which set aside the invalid decisions taken by the Customs Authorities officers, in the total amount of customs payments;

$\left(x_1; x_2\right)$ – vector of the key efficiency indicators;

To formalize the first model input as a fuzzy set, the dynamics of the deviation value from the projected revenues to be contributed to the federal budget by the Customs Authorities when collected from the income administered in 2000-2019, % (picture 2) has been analyzed, and some noise effect has been discovered which was confirmed by the experts following the logical analysis of the causes thereof. In addition, according to the technique created by Smirnov-Grabbs to find bad

mistakes , maximum observation was checked to find that the excess over projected revenues in 2001 was atypical and can be regarded as an anomalous event (or outlier). Therefore, to obtain a more accurate model it is advisable to exclude 2001 data from the empirical dastabase. Subject to the definitive empirical database and practical experience the range of values [0;5%] has been set for variable x_1 by the experts; three linguistic intervals roughly named zero (AZ), medium positive (MP), big positive (BP), and triangle membership functions. At the same time the experts set the linguistic values with the help f the names containing numerical values: approximately 0%, approximately 1,8 %, much more 1,8 %. Such a combination of linguistic values and fuzzy values complies with the research conducted by J. Kahlert [9] и L.X. Wang [20]. It should be noted that the range of values fails to contain negative values, since in case of failure to implement the plan in accordance with indicator № 4, the level of achieving the goal in the area of "Finance" shall be automatically assessed as unacceptably low (what happened in 2021).

To formalize the second model input as a fuzzy set the data from Table 1has been analyzed. Variable x_2 has been introduced by the experts with a triangle membership function and a universal set [0; 0,2575] (a unit of measurement – per cent). Term-set of variable x_2 was specified as follows : {low (L), medium (M), high (H)}; parameter values respectively: (0; 0; 0,103), (0,039; 0,135; 0,174), (0,144; 0,2575; 0,2575).

The output linguistic variable Y was introduced with a triangular belonging function and a term set {medium (M), above average (AA), high (H)}. To determine the term «medium» a function of the form was used:

$$\mu_M = \begin{cases} -\dfrac{1}{3}x+1, & \text{if} \quad 0 \leq x \leq 3; \\ \\ 0, & \text{if otherwise.} \end{cases}$$

To define the term «above average» – function:

$$\mu_{AA} = \begin{cases} \dfrac{10}{3}x - \dfrac{2}{3}, & \text{if} \quad \dfrac{1}{5} \leq x \leq \dfrac{1}{2}; \\ \\ -\dfrac{10}{3}x + \dfrac{8}{3}, & \text{if} \quad \dfrac{1}{2} < x \leq \dfrac{4}{5}; \\ \\ 0, & \text{if otherwise} \end{cases}$$

The term «high» was determined by experts using the following function:

$$\mu_{\text{H}} = \begin{cases} \dfrac{10}{3}x - \dfrac{7}{3}, & \text{if } \dfrac{7}{10} \le x \le 1; \\ \\ 0, & \text{if otherwise.} \end{cases}$$

Display (1) will be described by means of expert stated production rules on the basis of a summarized fuzzy rule conclusion modus ponens [26], the relationship between antecedents and consequents being represented as a multidimensional matrix shown in Table 3.

Table 2 – Knowledge database (rules) modeling the display (1)

Variable x_1	**Variable** x_2		
	L	**M**	**H**
AZ	M	M	M
MP	M	AA	AA
BP	AA	H	H

The value of a linguistic output variable is shown at the crossing with the values of linguistic input variables . For example, the rule of fuzzy logical conclusion stated in the cell which is located at the crossing of line BP and column M should be interpreted as follows:

IF the deviation from the projected revenues to be contributed to the federal budget by the Customs Authorities when collected from the income administered is more positive (BP) and the aggregate share of customs payments refunded to the payors is medium (M), SO the assessment of achieving the goal in the area of "Finance" is high (H).

If linguistic values are set with the names containing numerical values, the above –mentioned rule of fuzzy logical conclusion may be interpreted as follows:

IF the deviation from the projected revenues to be contributed to the federal budget by the Customs Authorities when collected from the income administered is much higher than 1,8% and the aggregate share of customs payments refunded to the payors is approximately 0,135%, So the assessment of achieving the goal in the area of "Finance" is much more than 0,7.

Knowledge database was verified to comply with the requirements of comprehensiveness and consistency. Comprehensiveness is verified in two ways: whether the database is linguistically comprehensive and whether it is numerically comprehensive. Let's take $(T_{11};T_{12};T_{13})$, $(T_{21};T_{22};T_{23})$ and $(T_1;T_2;T_3)$ denoting linguistic sets of inputs x_1, x_2 and output Y respectively. According to Table 3, each input linguistic state $(T_{1i};T_{2j})$ corresponds with T_k, , where $i = \overline{1;3}$, $j = \overline{1;3}$, $k = \overline{1;3}$ under the rule database. This fact shows that a rule database is linguistically comprehensive. Inconsistency in production knowledge bases can be interpreted differently [15]. In this paper verification of the

knowledge base to find inconsistency was done in order to discover inconsistent rules i.e. the ones having similar antecedents and different consequents [13]. Analysis of Table 3 showed the lack of such rules which enabled to conclude that knowledge base is consistent.

Having found the actual values of the input variables, their minimax normalization was carried out, scaling the values   in such a way that they began to be located in the range from 0 to 1. The disadvantage of minimax normalization, which consists in the presence of abnormal data values   that "stretch" the range, was eliminated by eliminating the 2001 data.

Table 3 shows the normalized values of the power coefficients of triangle membership functions

Table 3 - Normalized values of the power coefficients of triangle membership functions

nx_1			nx_2		
AZ	MP	BP	L	M	H
0	0,08	0,42	0	0,15	0,56
0	0,36	1	0	0,524	1
0,16	0,56	1	0,04	0,676	1

A computerized mathematical model (1)   was designed on the MatLab software system platform with the help of Fuzzy Logic Toolbox software package and interactive module fuzzy.

4. Results

The graphical interface of the computer program for viewing the surface of fuzzy inference for the fuzzy mathematical model (1) is shown in Picture 3.
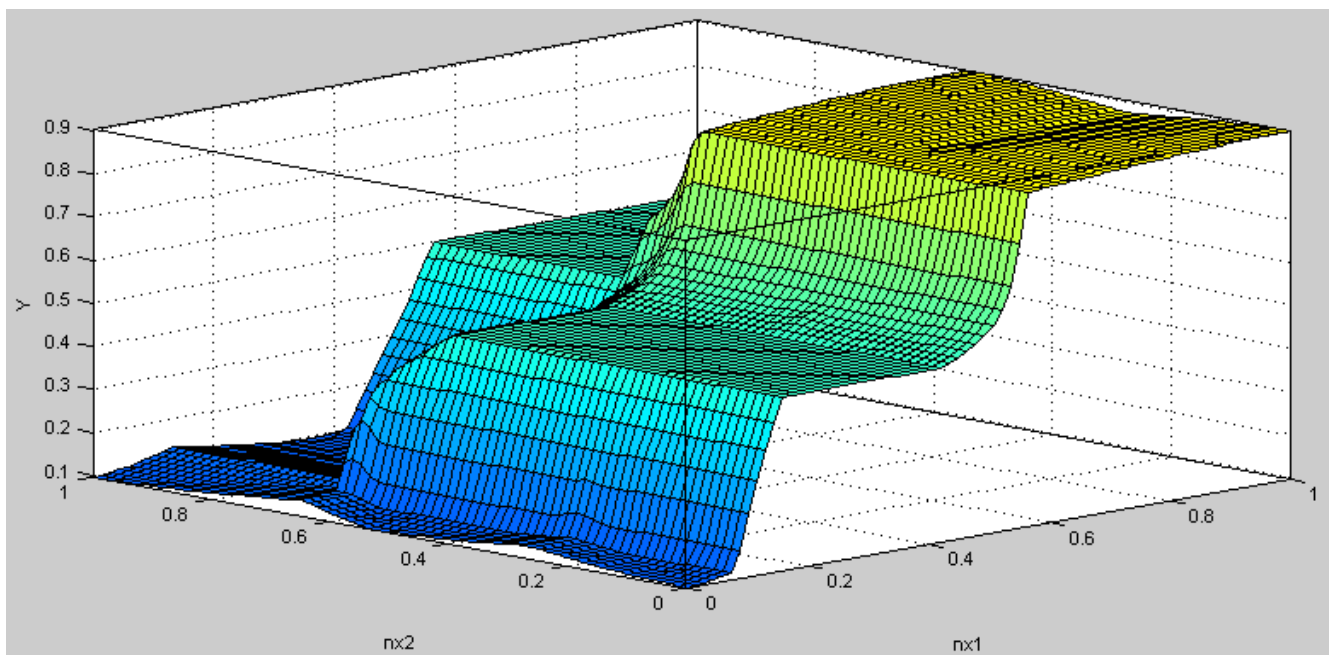
Picture 3 – 3D-Model of assessing the level of achieving the goal in the area "Finance"
(computer image)

As can be seen from Picture 5, any clear input state $\left(nx_1^*; nx_2^*\right)$ has a link to output state Y^*, i.e. input value can be calculated for all entry points. Hence, any clear input state results in activation of at least one rule (consequent), which , in accordance with [13] , defines the knowledge base as numerically complete. Verification of knowledge base is over.

For the final analysis of the created expert system and the completion of the knowledge base verification process, an analysis of the results of fuzzy inference was carried out at various values of input variables. A sample check established a test situation and thereby proved adequacy of the tools used. Picture 4 shows the results of practical application of the model based on input data of 2013-2019.
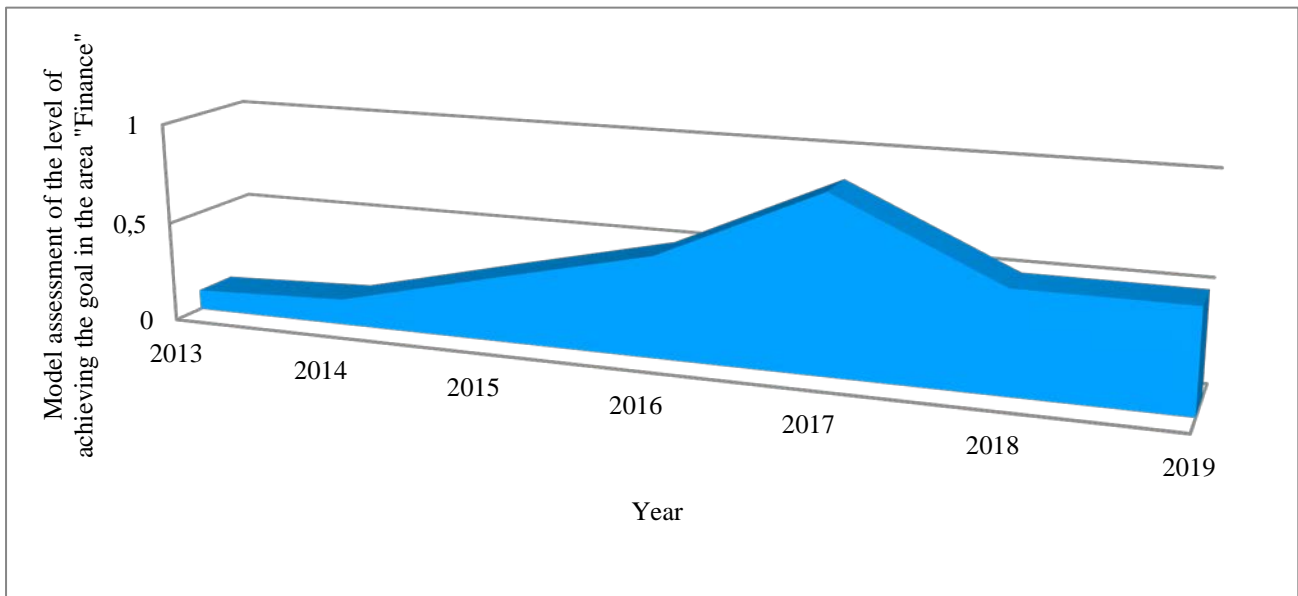
Picture 4 – The display of changing model assessment of the level of achieving the goal in the area "Finance"

In case new data is accumulated, meaningful entries are transformed, requirements of detalizing quality assessment are modified etc., the model may be adjusted, which means modification of the number, type and parameters of the membership function .

5. Discussion

The surface which corresponds to the display of input $x_1; x_2$ into output Y, as Picture 5 shows, is non- linear. Therefore , a fuzzy model designed performs non-linear operations over inputs $x_1; x_2$. From the experience of implementing the systems of fuzzy logic conclusion, at the initial stage expert

practitioners are often interested in a simplified linear model, approximating non-linear correlation caused by a fuzzy model. We shall chose a regressive analysis method as the one to design such a model. This approach is applied, for example, by M.L. Krichevsky, to assess the financial situation of the business [10]. The source data to carry out a multiple regressive analysis is the results of practical application of a fuzzy model. Computed statistics are shown in Table 6.

Table 6- Regressive analysis results

Display of results				
Regressive statistics				
Multiple R	0,973507			
R-square	0,947717			
Normalised R-square	0,943844			
Standard error	0,068115			
Observations	30			
Dispersive analysis				
Indicator	*df*	*SS*	*MS*	*F*
Regression	2	2,270715156	1,135357578	244,7091868
Balance	27	0,125269733	0,00463962	
Total	29	2,39598489		
	coefficients	Standard error	*t-statistics*	*P-Value*
Y-intersecion	0,281067	0,041824444	6,720160231	3,24945E-07
nx_1	0,77266	0,052408572	14,74301375	1,95394E-14
nx_2	-0,25709	0,061119096	-4,206297995	0,000255906

Regression equation (regression equation assessment) looks as follows:

$$Y = 0,281 + 0,772(nx_1) - 0,257(nx_2). \tag{2}$$

Analysis of multicollinearity on the basis of correlation coefficients matrix showed that multicollinear factors are missing. In fact, pair coefficient of correlation $r_{(nx_1)(nx_2)}$, equal (–0,605), on absolute value less than 0,7. To verify the significance of the equation (4) Fisher's F-criteria was applied. According to dispersive analysis F_{osverv}=244,709. Critical value F_{cr} subject to degree of discretion $k_1 = 2$, $k_2 = 27$ and level of significance α=0,05 is equal to 3,37. As inequation $F_{osverv} > F_{cr}$ is done, so co determination coefficient is statistically significant and the equation (4) is statistically reliable. To verify the significance the coefficient of the equation (4) Student's t-criterion was applied. According to a dispersive analysis, $t_{(nx1)}$=14,743; $t_{(nx2)}$= –4,206. Table value of the criterion t_{tabl}=2,373. Therefore the following inequations are done: $t_{(nx1)} > t_{tabl}$; $|t_{(nx2)}| > t_{tabl}$. Thus, coefficients in the equation (2) are statistically significant.

The surface which corresponds to the simplified linear model of assessing the level of achieving the goal in the area "Finance" is shown in Picture 5. This is a plane with a vector of normal (0,772; –0,257), which makes it slope in the coordinate system O(nx_1) (nx_2).
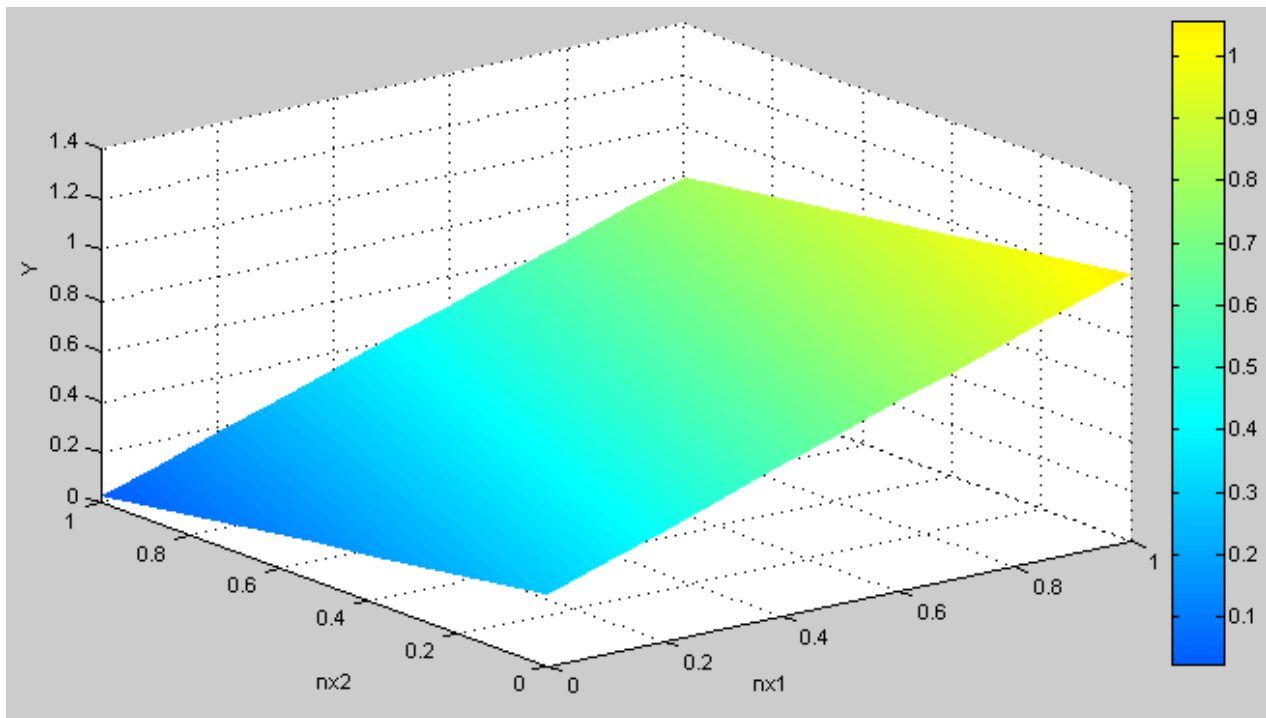
Picture 5 – The plane representing the image of inputs into output for a simplified linear model of assessing the level of achieving the goal in the area "Finance" (computer image)

6. Conclusion

The research made in this article enabled to conclude the following:

1) The methodology of modeling efficiency assessment of Customs Authorities by means of fuzzy logic , suggested herein , enables to make a comprehensive assessment of the key areas of Customs Authorities activity , and obtain the database for taking reasonable managerial decisions;

2) In the conditions of not stochastic uncertainty the intellectual measurement methodology enables to model assessment in other specified by the authors areas of Customs Authorities activity (economic security, clients, tuition and development) thereby make an integral assessment of areas of Customs Authorities activity;

3) The results of the research may be applicable in the activity of National Customs Authorities as an important tool in managerial decision-making and be the basis for reforming the system of assessing Customs Authorities activity.