https://doi.org/10.31891/csit-2022-2-10
UDC 004.023

Vasyl PRYIMAK, Svitlana PRYIMA, Olga HOLUBNYK
Ivan Franko National University of Lviv, Lviv, Ukraine

FUZZY TECHNOLOGIES IN THE MANAGEMENT OF SOCIO-ECONOMIC PROCESSES

The purpose of the article is to analyze the course of socio-economic processes in Ukraine over the past eight years to make recommendations for improving their management policy. The complexity of the task was that the development of the studied processes is characterized by not one but several primary factors, the simultaneous analysis of which is not a trivial task. Among these factors are not only quantitative but also qualitative indicators, which makes our task poorly structured.

In the analysis were used statistical and expert data that characterize socio-economic processes. This made it possible to consider the Russian military aggression against Ukraine and the situation with COVID-19 when making calculations. The use of qualitative information in the analysis makes it impossible to use methods of multidimensional statistics. To perform this task, it is proposed to use the theory of fuzzy logic and fuzzy sets. To describe the linguistic terms of fuzzy sets are used trapezoidal membership functions, the parameters of which are determined by experts. The constructed model of approximation of a nonlinear object with linguistic expressions allows finding the desired result faster and easier in comparison with the classical procedure of similar calculations.

Using the considered approach in the article the tendencies of the development of social and economic processes in Ukraine from 2013 to 2020 are analyzed. The result of the calculations is the value of the generalized indicator, the value of which characterizes the level of development of socio-economic processes in the year. The obtained calculations showed that the value of this indicator was the highest in 2013. Over the next two years, this figure decreased and then began to grow slowly. The increase lasted until 2019, and in 2020 the value decreased again. However, in none of the years, 2014-2020 did the figure reach 2013. In our opinion, the main reason for the decrease in the level of development of socio-economic processes in 2014 and 2015 was Russia's annexation of the Autonomous Republic of Crimea and the war in eastern Ukraine, and in 2020 - the effects of the COVID-19 pandemic.

Keywords: socio-economic processes, fuzzy set, linguistic variable, trapezoidal membership function, qualitative indicator, generalized indicator.

Василь ПРИЙМАК, Світлана ПРИЙМА, Ольга ГОЛУБНИК
Львівський національний університет

НЕЧІТКІ ТЕХНОЛОГІЇ В УПРАВЛІННІ СОЦІАЛЬНО-ЕКОНОМІЧНИМИ ПРОЦЕСАМИ

Метою статті було виконання аналізу перебігу соціально-економічних процесів в Україні протягом останніх восьми років для вироблення рекомендацій щодо удосконалення політики управління ними. Складність поставленого завдання полягала у тому, що розвиток досліджуваних процесів характеризується не одним, а декількома первинними чинниками, одночасний аналіз яких не є тривіальним завданням. Серед цих чинників є не тільки кількісні, а й якісні показники, що робить нашу задачу слабоструктурованою.

У роботі при виконанні аналізу було використано статистичні й експертні дані, які характеризують соціально-економічні процеси. Це дало змогу при проведенні розрахунків урахувати російську військову агресію проти України і ситуацію з COVID-19. Використання якісної інформації при проведенні аналізу унеможливлює застосування методів багатовимірної статистики. Для виконання цього завдання пропонується використовувати теорію нечіткої логіки і нечітких множин. Для опису лінгвістичних термів нечітких множин запропоновано скористатися трапецієподібними функціями належності, параметри яких визначені експертами. Побудована модель апроксимації нелінійного об'єкта з лінгвістичними висловлюваннями дозволяє швидше та легше знайти потрібний результат порівняно з класичною процедурою подібних обчислень.

Використовуючи розглянутий підхід у статті проаналізовано тенденції розвитку соціально-економічних процесів в Україні протягом 2013-2020 років. Результатом виконаних розрахунків є значення узагальненого показника, величина якого характеризує рівень розвитку соціально-економічних процесів у відповідному році. Отримані розрахунки показали, що величина цього показника була найбільшою у 2013 році. В наступних двох роках ця величина зменшувалась, а далі почала повільно зростати. Збільшення відбувалось аж до 2019 року, а в 2020 р. величина показника знову зменшилася. Проте в жодному з 2014-2020 років показник не досяг величини, яка була у 2013 році. На нашу думку, головною причиною зменшення величини рівня розвитку соціально-економічних процесів у 2014 і 2015 роках була анексія Росією Автономної республіки Крим і війна на сході України, а в 2020 р. – наслідки пандемії COVID-19.

Ключові слова: соціально-економічні процеси, нечітка множина, лінгвістична змінна, трапецієподібна функція належності, якісний показник, узагальнений показник.

Introduction

The development of the world economy is constantly accompanied by a contradiction between its capitalization and socialization. Earlier, the economy's capitalization won in this contradiction, the transformation of an arbitrary resource into capital. Currently, the priorities have changed. There is an awareness that the increase of capital is impossible without the economy's socialization and humanization. The goal of economic progress, its basic capital, is man. Instead of saving on people, they are looking for ways to invest in it, to develop it comprehensively. Investments in people pay off quickly and are effective in accelerating economic development. The formation and development of human capital are impossible without its involvement in production. This indicates the

interdependence and intertwining of social and economic processes. Therefore, they need to be studied together, which indicates the relevance of research to assess the development of socio-economic processes.

It is necessary to study the development of socio-economic processes in order to develop an effective socio-economic policy. It is not possible to make the right decision to manage a particular object or process without precise information about it. The adopted management actions will achieve the goal in the case of available information about the reaction of the system to previous management actions. This once again confirms the relevance of the procedure for analyzing the development of socio-economic processes.

Assessing the development of socio-economic processes is associated with certain difficulties. The first thing to emphasize is that the development of socio-economic processes is characterized not by one but by several primary factors, the simultaneous analysis of which is not a trivial task. The second thing that complicates the analysis - among the factors could be not only quantitative but also qualitative indicators. In the case of only quantitative primary factors, the procedure is simplified. Then you can use the methods and algorithms of multidimensional statistics to perform the analysis. Depending on the task, you can organize the studied processes according to the level of their development by time or region, find the best or worst of them or perform their clustering. A sufficient number of statistical methods and software products have been developed to date to implement these procedures.

The considered task is sharply complicated in case of a choice for the analysis, as primary, at least one qualitative indicator. Then the use of multidimensional statistics is impossible. We need to use fuzzy set theory, which solves poorly structured problems present in our case.

In this paper, we have analyzed the development of socio-economic processes in Ukraine in recent years using quantitative and qualitative indicators.

Related works

Several publications are devoted to the coverage of the results of scientific research on socio-economic processes and their management. In particular, the scientific works [1]-[3] consider the mechanisms of public management of these processes at the regional level. Works [4]-[5] investigated the socio-economic development management issues, respectively, of the municipality and the united territorial communities. But the effectiveness of management of socio-economic processes depends on accurate and reliable information about the state of these processes and their response to previous management actions. Therefore, it is necessary periodically to diagnose socio-economic processes and assess their condition. It is impossible to perform such an assessment with the help of any one primary indicator, as several primary partial indicators characterize these processes.

It is possible to estimate the dynamics of socio-economic processes and their intensity by analyzing all such primary partial indicators or to build on their basis one generalized integrated indicator and based on its value to draw certain conclusions. For example, the results of a study of most international rankings and indices, as well as some primary partial indicators of Ukraine's economy allowed the author of a scientific article [6] to develop certain recommendations, the implementation of which will ensure stable socio-economic development in the country. In [7], a comparative analysis of socio-economic processes in the regions of Poland used an algorithm for constructing Hellwig's taxonomic integral index. The extension of this method was used by the authors of scientific work [8] to study education in the countries of the European Union.

However, in the specified scientific works for estimation of social and economic processes only quantitative primary partial indicators and the method of multidimensional statistics are used. If high-quality primary information is taken into account, it isn't possible to use this method. In this case, it is advisable to use the methods of fuzzy set theory and fuzzy logic. This theory operates with so-called «soft» or otherwise «fuzzy» data typical of many economic problems and control systems in general. These tasks are associated with the uncertainty that cannot be accurately and unambiguously disclosed.

The fuzzy sets theory makes it possible to apply a linguistic description of weakly structured processes and formalize linguistic variables in decision making information systems [9].

The fuzzy sets theory was developed and used by foreign and Ukrainian scientists [10]-[12] and many others. The main concepts in this theory are the concept of fuzzy set and linguistic variable.

In more detail, a fuzzy set is defined as a set of pairs of the following type:

$$Y = \{(x, \mu_Y(x)),\ x \in X\}, \tag{1}$$

where Y is a fuzzy (blurred) set; X is the base scale or, in other words, the universal set; $\mu_Y(x)$ is a function of the membership of the set Y to the universal set X. This function can take values from the interval [0, 1] and be discrete or continuous. It determines the subjective measure of the expert's confidence that a given specific value of the base scale corresponds to a fuzzy set. It cannot be identified with probability, because the distribution function is unknown, there is no repetition of experiments [10].

Thus, taking into account the study of socio-economic processes of qualitative primary indicators that characterize these processes requires the use of fuzzy set theory elements. Thus, it is necessary to construct an integral indicator in a multidimensional fuzzy statement. Scientists have developed a method of constructing such

indicators, which generally characterize the studied processes. It is called a method of constructing a classical «model of approximation of a nonlinear object according to linguistic statements». The specified model displays an object with n inputs and one output:

$$y = f_y(x_1, x_2, \dots, x_N), \tag{2}$$

where y і x_i $\left(i = \overline{1, N}\right)$ – respectively, the output and input variables, which can be both quantitative and qualitative. It is assumed that for quantitative variables, the domains of their change are known, and for qualitative variables - sets of all their possible values.

This method of constructing a fuzzy model of the object of economic analysis has been developed in detail. Scientists widely use it to make recommendations for decision-making in poorly structured situations in various human activity areas. In short, its essence can be described as follows. The first stage of the considered technique, called the fuzzification of variables, is to translate the primary data into a fuzzy format. At this stage, determine the linguistic estimates of variables and necessary for their membership function's formalization. At the next stage, using the available expert information, a matrix of knowledge is built, and on its basis - a base of fuzzy knowledge. Here, if necessary, perform sampling of the continuous output y. Next, using this information, a system of logical equations is derived, which is used to perform calculations of fuzzy initial values of y. The last stage of this technique, called defuzzification of variables, is to convert the obtained initial values into a «clear» format. As a result, we get the desired value of the generalized indicator, which characterizes the studied socio-economic processes in a country or its region for a certain period of time, such as a year.

Despite the widespread use of this technique by scientists, its application is associated with significant difficulties. The fact is that the procedure of building a knowledge base with a large enough sample of primary data is quite time-consuming. This requires a significant amount of expert time. This complicates the use of this technique to assess the development of socio-economic processes.

To solve this problem in qualitative primary indicators, you can also use a simplified method of calculating the value of this integrated indicator [12]. This technique also consists of three steps: fuzzification of input data, processing of the received information, and its defuzzification. Simultaneously, it is not necessary to develop a knowledge base, and defuzzification is performed according to the approximate algorithm, which is convenient in calculations. Therefore, to assess the development of socio-economic processes in Ukraine, we will use this approach.

Research method

Suppose that to assess the development of socio-economic processes in Ukraine, we selected n primary indicators $X_1, X_2, \dots, X_n$, which are sufficient for this study. The values of these indicators for a certain period of time, such as a year, are denoted by $x_1, x_2, \dots, x_n$. They can be quantitative, determined based on statistical data, or qualitative, obtained from experts. The task is to determine the type of function.

$$Q = f_Q(X_1, X_2, \dots, X_n), \tag{3}$$

the value of which determines the level of development of the studied socio-economic processes in the country. The larger the value of the function (3), the higher this level. Moreover, for a better structure of our problem, we will look for this function in the normalized form ($Q \in [0,1]$)).

The set of states C of socio-economic processes is divided into several fuzzy subsets, which correspond to certain development levels. To represent the membership functions of these subsets, we use trapezoidal numbers:

$$\gamma = (b_1, b_2, b_3, b_4), \tag{4}$$

where numbers b_1, b_2, b_3, b_4 abscissas of the vertices of the trapezoid $OABC$ with coordinates $O(b_1, 0)$, $A(b_2, 1), B(b_3, 1), C(b_4, 0)$ in the Cartesian coordinate system (X, μ).

The number of these subsets can be arbitrary. In our research, we will use five subsets of C_1, C_2, C_3, C_4, C_5. These subsets intersect. Each of these subsets means, respectively, low, satisfactory, medium, good, and high level of socio-economic processes. Using the formula (4), the membership functions of these subsets are given in the form:

$$\begin{gathered}\theta_1(Q) = \gamma_1 = (0{,}0; 0{,}0; 0{,}15; 0{,}25);\\ \theta_2(Q) = \gamma_2 = (0{,}15; 0{,}25; 0{,}35; 0{,}45);\\ \theta_3(Q) = \gamma_3 = (0{,}35; 0{,}45; 0{,}55; 0{,}65);\\ \theta_4(Q) = \gamma_4 = (0{,}55; 0{,}65; 0{,}75; 0{,}85);\\ \theta_5(Q) = \gamma_5 = (0{,}75; 0{,}85; 1{,}0; 1{,}0).\end{gathered} \tag{5}$$

To perform calculations, you need to choose the primary factors, the number of which should not be large, but their total informativeness should be sufficient to reflect all aspects of the studied processes. At the same time, it is possible to consider their priority. Besides, they should be divided into two groups. The first group is stimulators, and the second - destimulators. The first of them include indicators, the increase in the value of which leads to an increase in the level of development of processes. The second of these groups includes indicators, the increase in the value of which leads to a decrease in the level of development of the studied processes.

Next, similarly to the initial indicator, it is necessary to determine the sets of states of each input indicator $X_i\ (i = \overline{1,n})$ with the involvement of experts. That is, for each of these indicators, it is necessary to specify the linguistic variable "The value of the indicator X_i" and its term set. Besides, you need to specify fuzzy subsets of the domain of this indicator $D(X_i)$, as well as their membership functions.

These term sets may have different, or the same number of terms, and these terms may be different. For simplicity, let's focus on random ones, where all term sets have five elements. Moreover, the terms have names: the value of the indicator $X_i\ (i = \overline{1,n})$"very bad", "bad", "average", "good" and "very good".

Denote by $D_{ij}\ (i = \overline{1,n}, j = \overline{1,5})$ fuzzy set, which corresponds to the j-th term $(j = \overline{1,5})$ of the indicator$X_i\ (i = \overline{1,n})$. We determine the membership functions of these sets with the help of experts in the form of trapezoidal numbers (4) so that they intersect for each $X_i\ (i = \overline{1,n})$ Denote them by $\lambda_j(x_i) = \lambda_{ij}\ (i = \overline{1,n}, j = \overline{1,5})$.

At the first stage of calculations, ie at the stage of fuzzification of indicators $X_i\ (i = \overline{1,n})$ for each of them, you need to specify the trapezoidal numbers of these membership functions, and then the algorithms for determining these functions themselves. It is possible to take into account the affiliation of each of these indicators to the classification group of stimulators or destimulators at this or the next stage. Let's do this at this stage.

Let us illustrate the actions of the first stage of the considered approach on the example of the indicator-destimulator X_1, which we will call "Force majeure". This is a qualitative indicator determined expertly for each period (year) of the study on a scale with a gradation from zero to ten points. The higher the number of points for this indicator, the worse the corresponding socio-economic process. The survey of experts showed that the membership functions $\lambda_j(j = \overline{1,5})$ of the corresponding fuzzy subsets $D_j\ (j = \overline{1,5})$ of this indicator have the form:

$$\lambda_1 = (8{,}0; 8{,}5; 10{,}0; 10{,}0);\ \lambda_2 = (6{,}0; 6{,}5; 8{,}0; 8{,}5);$$
$$\lambda_3 = (4{,}0; 4{,}5; 6{,}0; 6{,}5);\ \lambda_4 = (2{,}0; 2{,}5; 4{,}0; 4{,}5);$$
$$\lambda_5 = (0{,}0; 0{,}0; 2{,}0; 2{,}5); \qquad (6)$$

The algorithm for calculating the corresponding terms and values of the membership function of fuzzy sets of this indicator is given in the table. 1.

Table 1

Classification of values of the indicator-destimulator "Force majeure"

The name of the indicator	Value range	Classification group of the indicator's value	Degree of assessed confidence (membership function)
Force majeure circumstances (designation of the indicator) – X_1, of the value – K_1)	$8{,}5 \le K_1 \le 10$	"Very bad"	$\lambda_1 = 1$
	$8 < K_1 < 8{,}5$	"Very bad"	$\lambda_1 = 2 \cdot (K_1 - 8)$
	$8 < K_1 < 8{,}5$	"Bad"	$\lambda_2 = 1 - \lambda_1$
	$6{,}5 \le K_1 \le 8$	"Bad"	$\lambda_2 = 1$
	$6 < K_1 < 6{,}5$	"Bad"	$\lambda_2 = 2 \cdot (K_1 - 6)$
	$6 < K_1 < 6{,}5$	"Average"	$\lambda_3 = 1 - \lambda_2$
	$4{,}5 \le K_1 \le 6$	"Average"	$\lambda_3 = 1$
	$4 < K_1 < 4{,}5$	"Average"	$\lambda_3 = 2 \cdot (K_1 - 4)$
	$4 < K_1 < 4{,}5$	"Good"	$\lambda_4 = 1 - \lambda_3$
	$2{,}5 \le K_1 \le 4$	"Good"	$\lambda_4 = 1$
	$2 < K_1 < 2{,}5$	"Good"	$\lambda_4 = 2 \cdot (K_1 - 2)$
	$2 < K_1 < 2{,}5$	"Very good"	$\lambda_5 = 1 - \lambda_4$
	$0 \le K_1 \le 2$	"Very good"	$\lambda_5 = 1$

For all other input indicators $X_i\ (i = \overline{2,n})$ it is necessary to develop similar algorithms for determining the corresponding terms and values of membership functions $\lambda_{ij}\ (i = \overline{2,n}, j = \overline{1,5})$ on the basis of a survey of experts.) of their fuzzy sets $D_{ij}\ (i = \overline{2,n}, j = \overline{1,5})$. At the same time, immediately consider whether the indicator is a stimulant or a disincentive.

The second step in determining the desired result is to determine the fuzzy number Q. It can be calculated by the formula [12]:

$$Q = (q_1, q_2, q_3, q_4, q_5) = \sum_{j=1}^{5} Z_j \otimes \gamma_j \quad (7)$$

in which the values of $Z_j\left(j = \overline{1,5}\right)$ are calculated by the following formulas:

$$Z_j = \left(\sum_{i=1}^{N} p_i \cdot \lambda_{ij}\right) / \left(\sum_{i=1}^{N} p_i\right) \ \left(j = \overline{1,5}\right) \quad (8)$$

where the sign "⊗" means the operation of multiplying the real number Z_j by the fuzzy number y_j, which is given by formula (5), the value of p_i is the priority factor of the indicator X_i $(i = \overline{1,\ N})$.

At the last stage of our calculations, we defuzzification the obtained fuzzy number $\underline{Q}$ into a "clear" format. The belonging of the trapezoidal interval Q to one of the fuzzy subsets {C} of the development level of socio-economic processes can be determined using the formulas of section and union of fuzzy sets. The degree of belonging S of the level of development to one of the states C_j is determined using the area Δ of a figure by the formula [12]:

$$S = [\Delta(Q \cap C_j)] / [\Delta(Q \cup C_j)] \quad (9)$$

where Δ is defined as the corresponding area bounded by trapezoidal curves of membership functions.

Given the significant difficulties in the calculations by formula (9), according to [12] we will find the approximate value of immediately "clear" generalized indicator of the level of development of socio-economic processes by the formula:

$$Z = 0{,}075 \cdot Z_1 + 0.3 \cdot Z_2 + 0.5 \cdot Z_3 + 0.7 \cdot Z_4 + \ +0.925 \cdot Z_5, \quad (10)$$

where $Z_j\ \left(j = \overline{1,5}\right)$ are determined by formulas (8).

If necessary, for the value of this generalized exponent Z found by formula (10), it is possible to determine the corresponding terms and values of the membership function of fuzzy sets that correspond to them. To do this, use the algorithm given in the table. 2, which is constructed using formulas (5).

Table 2

Algorithm for finding terms and corresponding values of membership functions of the generalized indicator of the level of development of socio-economic processes

The name of the indicator	Value range	Level of development (classification group, term)	Degree of assessed confidence (membership function)
The development level of socio-economic processes	$0 \le Z \le 0{,}15$	"low"	$\gamma_1 = 1$
	$0{,}15 < Z < 0{,}25$	"low"	$\gamma\_1 = 10 \cdot (0{,}25 - Z)$
	$0{,}15 < Z < 0{,}25$	"satisfactory"	$\gamma_2 = 1 - \gamma_1$
	$0{,}25 \le Z \le 0{,}35$	"satisfactory"	$\gamma_2 = 1$
	$0{,}35 < Z < 0{,}45$	"satisfactory"	$\gamma_2 = 10 \cdot (0{,}45 - Z)$
	$0{,}35 < Z < 0{,}45$	"average"	$\gamma_3 = 1 - \gamma_2$
	$0{,}45 \le Z \le 0{,}55$	"average"	$\gamma_3 = 1$
	$0{,}55 < Z < 0{,}65$	"average"	$\gamma_3 = 10 \cdot (0{,}65 - Z)$
	$0{,}55 < Z < 0{,}65$	"good"	$\gamma_4 = 1 - \gamma_3$
	$0{,}65 \le Z \le 0{,}75$	"good"	$\gamma_4 = 1$
	$0{,}75 < Z < 0{,}85$	"good"	$\gamma_4 = 10 \cdot (0{,}85 - Z)$
	$0{,}75 < Z < 0{,}85$	"high"	$\gamma_5 = 1 - \gamma_4$
	$0{,}85 \le Z \le 1$	"high"	$\gamma_5 = 1$

Results of numerical calculations

We use the considered method of constructing a generalized indicator to assess the development of socio-economic processes in Ukraine during 2013-2020. As primary indicators, we take 8 (n=8) indicators: force majeure (X_1), gross domestic product (GDP) (X_2), the volume of sold innovative products to the total volume of sold industrial products (X_3), average wages (X_4), unemployment rate (X_5), consolidated budget expenditures on education (X_6), consolidated budget expenditures on health care (X_7), and consumer price index (X_8), All these primary indicators are given in annual terms. Moreover, X_1, X_5, X_8 are destimulators, and all others are stimulators. Experts on a ten-point scale determine the value of the first of these indicators. All other indicators are statistical.

GDP and consolidated budget expenditures on education and health care are presented in UAH billion. The third and fourth indicators are expressed in parts and UAH, respectively. The unemployment rate and consumer price index are given as a percentage. The values of all cost indicators are indicated in the prices of 2013. As a result, the following initial data were used for calculations (Table 3).

Table 3

The value of input indicators to determine the level of development of socio-economic processes in Ukraine for 2013-2020

Indiator	Year							
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
X_1	4,5	9,8	8,7	7,8	7,5	6,9	7,1	9,2
X_2	1454,9	1351,8	1229,6	1264,2	1295,9	1339,8	1384,2	1327,3
X_3	3,3	2,5	1,4	1,05	0,7	0,8	1,3	1,9
X_4	3273,8	2994,0	2613,5	2751,7	3087,0	3338,3	3658,1	3669,8
X_5	7,7	9,7	9,5	9,7	9,9	9,1	8,6	9,9
X_6	101561	86376	70934	68661	77296	79071	83151	79836
X_7	61 568	61261	46842	54315	50330	48331	61222	55630
X_8	100,5	124,9	143,3	112,4	113,7	109,8	104,1	105

Based on the expert survey's processed results for each of the considered input indicators, the trapezoidal membership functions of the type (4) of the considered linguistic variables were determined, which are given in the table. 4. In the process of forming this table, the belonging of the primary indicators X_i $(i = \overline{1,\ 8})$ to stimulators or destimulators is immediately taken into account.

Table 4

Functions of belonging of input indicators

Indicator	Trapezoidal numbers for the values of the linguistic variable "The value of the indicator X_i"				
	"Very bad"	**"Bad"**	**"Average"**	**"Good"**	**"Very good"**
X_1	(8; 8,5; 10; 10)	(6; 6,5; 8; 8,5)	(4; 4,5; 6; 6,5)	(2; 2,5; 4; 4,5)	(0; 0; 2; 2,5)
X_2	(0; 0; 1200; 1250)	(1200; 1250; 1300; 1350)	(1300; 1350; 1400; 1450)	(1400; 1450; 1500; 1550)	(1500;1550; $+\infty$; $+\infty$)
X_3	(0; 0; 0,5; 1)	(0,5; 1; 1,5; 2)	(1,5; 2; 2,5; 3)	(2,5; 3; 3,5; 4)	(3,5; 4; 20; 20)
X_4	(0; 0; 2600; 2800)	(2600; 2800; 3000; 3200)	(3000; 3200; 3400; 3600)	(3400; 3600; 3800; 4000)	(3800;4000; $+\infty$; $+\infty$)
X_5	(9,5; 10; 100; 100)	(8; 8,5; 9,5; 10)	(6,5; 7; 8; 8,5)	(5; 5,5; 6,5; 7)	(0; 0; 5; 5,5)
X_6	(0; 0; 60; 65)	(60; 65; 75; 80)	(75; 80; 90; 95)	(90; 95; 105; 110)	(105; 110; $+\infty$; $+\infty$)
X_7	(0; 0; 42,5; 45)	(42,5; 45; 50; 52,5)	(50; 52,5; 57,5; 60)	(57,5; 60; 65; 67,5)	(65; 67,5; $+\infty$; $+\infty$)
X_8	(130; 135; 500; 500)	(120; 125; 130; 135)	(110; 115; 120; 125)	(100; 105; 110; 115)	(0; 0; 100; 105)

Based on the table. 4 for each of the primary indicators X_i $(i = \overline{2,8})$ were developed similar to the table. 1 for indicator X_1 algorithms for fuzzification of these indicators. That is, algorithms for determining the terms and membership functions of the corresponding fuzzy subsets were developed for each primary indicator. Using these algorithms based on those given in the table. 3 initial data for all primary indicators X_i $(i = \overline{1,8})$ and each of the studied years from 2013 to 2020 were calculated specific values of membership functions $\lambda_j(x_i) = \lambda_{ij}$ $\left(i = \overline{1,8}, j = \overline{1,5}\right)$ fuzzy subsets of D_{ij} $\left(i = \overline{1,8}, j = \overline{1,5}\right)$. Using the formula (8), the values of Z_j $\left(j = \overline{1,5}\right)$ are also determined for each of these years. The calculations were performed under the same priority of all primary indicators. The obtained results of these calculations showed that for 2020 these variables have the following values (see table 5).

Table 5

Values {λ} і z_j for the level of the generalized indicator of socio-economic processes in 2020

$\{\theta\}$	λ_{i1}	λ_{i2}	λ_{i3}	λ_{i4}	λ_{i5}
X_1	1	0	0	0	0
X_2	0	0,454	0,546	1	0
X_3	0	0,2	0,8	0	0
X_4	0	0	1	0	0
X_5	0,8	0,2	0	0	0
X_6	0	0,08	0,92	0	0
X_7	0	0	1	0	0
X_8	0	0	0	1	0
Z_j	0,225	0,11675	0,53325	0,125	0

Using formula (10) and the calculated values of $Z_j\ (j=\overline{1,5})$ from table. 5 we get the value of the generalized indicator Z for 2020,

$$Z = 0{,}075 \cdot 0{,}225 + 0.3 \cdot 0{,}11675 + 0.5 \cdot 0{,}53325 + 0.7 \cdot 0{,}125 + 0.925 \cdot 0 = 0{,}406$$

We use the calculated value of this integral exponent to find the number of the corresponding fuzzy set $C_j\ (j=\overline{1,5})$ and its membership function $\gamma_j(j=\overline{1,5})$. Using the algorithm given in table. 2 we obtain that $\gamma_2 = 0{,}44\ \gamma_3 = 0{,}56$, and $\gamma_j = 0\ \ (j=1,4,5)$. That is, with a high degree of compliance it can be argued that in 2020 the level of development of socio-economic processes in Ukraine was "average" and with a lower degree - satisfactory.

The considered values for all studied years are given in the table. 6.

Table 6

The complex indicator values are the level of development of socio-economic processes in Ukraine *Z* and the membership function $y_j(Z)$ of the set of its states in 2013-2020

Year	Z	$\gamma_j(Z)$				
		γ_1	γ_2	γ_3	γ_4	γ_5
2013	0,6503	0	0	0	1	0
2014	0,3361	0	1	0	0	0
2015	0,1956	0,544	0,456	0	0	0
2016	0,2918	0	1	0	0	0
2017	0,3089	0	1	0	0	0
2018	0,3884	0	0,616	0,384	0	0
2019	0,4517	0	0	1	0	0
2020	0,4060	0	0,440	0,560	0	0

This table shows that the value of the integrated indicator, the level of development of socio-economic processes in Ukraine, was the highest in 2013. However, in the next two years, this value decreased and then began to grow slowly. The increase lasted until 2019, and in 2020 the value of this indicator decreased again. In our opinion, the main reason for the decrease in this indicator in 2014 and 2015 was Russia's annexation of the Autonomous Republic of Crimea and the war in eastern Ukraine, and the 2020 - COVID-19 pandemic.

Conclusions

The study showed that to assess the development of socio-economic processes, it is advisable to use the theory of fuzzy sets. Moreover, the problem can be solved by a simplified method, which consists of constructing a generalized indicator of the level of development of socio-economic processes, measured in the order scale. The performed calculations show that the level of development of socio-economic processes in Ukraine was the highest in 2013. Over the next two years, this level decreased, and then gradually increased until 2019. In 2020, the value of this indicator decreased again.

References

1. Kachnyj O.S. Formation and implementation of effective mechanisms of public administration of socio-economic processes at the regional level. *Investments: practice and experience*. № 5. 2018. pp. 64-66.
2. Skyba M.V. Conceptual principles of public management of socio-economic development of the region / *Regional economy*, 2020. №3. pp. 35-45.
3. Tofanjuk O. V. State regulation of socio-economic development of the regions of Ukraine / O.V. Tofanjuk, A.S. Zinchuk // *Black Sea Economic Studies*, 2018. Vol. 33, pp. 159-165.
4. Kutsenko T., Pintelei, I. "Management of socio-economic development of the municipality: strategy, analysis and tools for efficiency evaluation (on the example of kalush city in ivano-frankivsk oblast)", *Efficient economy.* [Online], 2021. vol. 7, available at: http://www.economy.nayka.com.ua/?op=1&z=9049 (Accessed 21 Jun 2022). DOI: 10.32702/2307-2105-2021.7.72)
5. Korchynsjka O. O. Management of socio-economic development of united territorial communities / *Visnyk of the National University "Lviv Polytechnic*". Series Problems of Economics and Management. Vol. 7, № 4(2). 2019. pp. 81-88.
6. Ghordej O. D., Myrkun B. A. The current state of social and economic development of Ukraine / Business Inform № 10. 2019. pp. 151-157.
7. Malina A. Analiza przestrzennego zróżnicowania poziomu rozwoju społeczno-gospodarczego województw Polski w latach 20052017 / *Social Inequalities and Economic Growth*, №61 (1/2020), pp. 138-155.
8. Roszkowska E. Measuring Sustainable Development Using an Extended Hellwig Method: A Case Study of Education / Ewa Roszkowska, Marzena Filipowicz-Chomko. *Social Indicators Research.* January 2021. 153(3):1-24. URL: https://www.researchgate.net/publication/344348425
9. Olenych I., Nechypor Yu., Olenych Yu., Gukaliuk A. Optimization of Transport Routes by Fuzzy Logic Methods, International Scientific and Practical Conference "*Electronics and Information Technologies*", 2018. Issue 10, Pages: A-147-A-150.
10. Siavavko M.S., Rybytska O.M. Mathematical modeling under uncertainty. Lviv: SPF "Ukrainian Technologies". 2000. 319 p.
11. Hrytsenko K.H. Using the theory of fuzzy sets for assessing the level. Visnyk bank security from cyber frauds) / *Priazovsky Economic Herald* . Vol. 1(12) 2019. pp. 214-219.
12. Pryimak V. I., Holubnyk O. R., Ucieklak-Jeż P., Kubicka J., Urbańska K., Babczuk A. Fuzzy Technologies Modeling the Level of Welfare of the Population in the System of Effective Management. *EuropeanResearch Studies Journal.* Piraeus, Greece. 2021. Volume XXIV, Issue 3. P. 749-762.