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ORIGINAL RESEARCH PAPER

Estimation level of public welfare on the basis of methods of intellectual analysis

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ABSTRACT

In the context of globalization of economic development processes, the issue of determining the level of public welfare of economic agents is particularly burning. The object of ehis study is the process of assessing welfare of the economic entities system. The subject of the study is the instrumental and mathematical aspects of modeling and measuring the public welfare. The aim of the work is to develop the mathematical model for measuring the welfare of Ukraine using methods of intellectual analysis, namely, the theory of fuzzy sets. The output of the study is a new approach to objective estimation of public welfare of the state. It is proposed to assess the level of public welfare of the state on the basis of a mathematical model developed on the basis of the theory of fuzzy sets. Input factors of the model are international indices and indicators, such as Index of Economic Freedom, Global Peace Index, Democracy Index, Corruption Perceptions Index, Human Development Index, Prosperity Index, Global Competitiveness Index as well as an indicator that reflects the characteristic property of the Ukrainian economy, namely the minimum living wage. Developed mathematical model for assessment of the level of public welfare of Ukraine and made a prediction of the indicator by 2024 on the basis of the above indices. The results of the study allowed us to establish that the level of public welfare (units) in Ukraine on a scale from 0 to 100 will be equal to 25, 17, 32, 26, and 28 in 2020, 2021, 2022, 2023, and 2024, accordingly.

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INTRODUCTION

The problem of assessment of the subjective public welfare has gained momentum for a number of reasons. The main one is that deficit motivation has ceased to be a determining factor in behavior for the population of developed countries, since satisfying basic needs is no longer a global challenge for modern society (Diener *et al., 2002*). Living standards are taking precedence over indicators of economic growth; the subjective perception of welfare is becoming more important because of greater attention to individualism (Easterlin, 2001). The theory of subjective welfare has recently received a new impetus to development. Frey and Stutzer (2002) assert: "The economics have faced a major breakthrough: happiness was instrumentally measured and many of its determinants were identified." These authors suggest that the economics traditionally paid little attention to issues of happiness. Griffin (1998) states the following: "Over the past few years, the situation has changed: many economists have discovered prospects in measuring subjective welfare through own perception of individuals." Understanding of the fact that public policy should be aimed (at least partly) at increasing the public welfare has firmly rooted in modern economic science. The solution of the problem of assessing the public welfare seems to be impossible without knowledge of the natural basic characteristics of human thinking. Recently, the economic circles have come to understanding that the subject of economic science lies in the field of a complex system of economic and social relations, and many aspects inherent in humans influence economic decision-making. Consideration of these factors, their estimation is a key factor for development of the state`s economy, improving the welfare of its citizens. It is possible to solve this problem using modern methods of intellectual analysis, which simulate human thinking, allow analyzing both quantitative and qualitative indicators, and predicting the value of the indicator of interest with a high level of reliability. The most suitable way for solving this problem seems to be the methods of the fuzzy set theory, which have been successfully tested on managing similar economic problems (Kozlovskyi *et al.*, 2018). The practical significance and insufficient scientific elaboration of the issues of assessing public welfare precondition the topicality of the study. Assessment of public welfare on the basis of indicators and rating scores provided by international organizations with due account to the internal indicator of economic development of Ukraine on the basis of intellectual analysis methods is a completely new scientific problem, the solution of which will be presented in this article. The aim of the work is to develop a mathematical model for measuring public welfare using the method of intellectual analysis, namely, the theory of fuzzy sets (FS). The implementation of this goal will contribute to arriving at strategic benchmarks for social and economic development of Ukraine, improvement of welfarel of its citizens. This study was conducted in Ukraine (Eastern Europe) as part of the scientific and practical research of the Vasyl' Stus Donetsk National University (Vinnytsia) in 2018-2019. The uniqueness of the study consists of the development and estimation of an integral indicator, the level of public welfare, which can be represented linguistically and involves both quantitative and qualitative indicators of influence. The practical significance of the study lies in the development of a general algorithm for modeling using methods of intellectual analysis that can be used for estimating and predicting other economic phenomena and processes.

Literature review

The welfare theory as welfare economics (WE) is a system of thought in economic science regarding the economic optimum and ways to achieve it through instruments of the state economic policy. Like any other scientific concept, the welfare theory operates its own suppositions and assumptions, which constitute its scientific basis. The category of optimality, the ratio of individual and social utility, and even definition of term "welfare" may be attributed to this basis. Since it seems to be impossible to verify the truth of these basic concepts at the present stage of scientific development, the welfare theory is considered a normative one. The main task of the welfare theory is to answer the question what instruments of economic policy should be used to bring the society to a new, more preferable condition. However, to develop optimal regulatory tools, it is necessary to measure welfare in order to compare different options. The best-known work in the field of economic theory of welfare is a treatise by Pareto (1935). The Pareto`s concept is called the "New Economic Theory of Welfare." This theory is considered

new because it gives its own ingenious answer to the question of interpersonal commensurability of usefulness. According to the Pareto`s criterion (also known as the "criterion of public welfare growth"), a situation is not optimal until the resources are distributed is such a way that an increase in the welfare of at least one person is possible without compromising the welfare of any other individual. However, such a criterion, is not always acceptable, since its application requires an initially equitable distribution of resources and a priori knowledge of all possible distribution options and related usefulness. That is why alternative approaches to determining the optimum public welfare have gained popularity (Babajanian, 2008). It is worthwhile to distinguish individually a representative of the Cambridge school Pigou (1932). It is rightfully considered that he completed creation of the neoclassical theory of welfare. A. Pigou proposed using a "national dividend" as a practical tool for measuring public welfare. For A. Pigou, the concept of individual welfare is broader than just absolute economic aspects of that term. Therefore, it is reasonable to distinguish between public and individual welfare. Accordingly, it is impossible to directly compare various options for economic development of society against the criterion of welfare (Banerjee *et al.,* 2016). The fact that no truly significant positive results have been obtained since the times of V. Pareto and A. Pigou makes the theory of economic welfare particularly attractive. Basically, all that was achieved within the framework of this paradigm reduces to refutation of previously stated hypotheses. This should include the irreducibility of personal good to a general one - the paradox "Condorcet" (List and Goodin, 2001) and the theorem by Arrow (1951) "On the impossibility of collective choice" (Arrow, 1951). The reason for the theory status may be that relatively recently, the welfare has started to be considered through the prism of human perception, that is, a mental image that reflects human consciousness. Without this knowledge, further study of the welfare does not make sense. In the work by Smith (1776), "An Inquiry into the Nature and Causes of the Welfare of Nations", it is possible to note his understanding of the principles of the welfare theory. Firstly, there is a presumption of selfish interest as the main motivating factor in human decision making. Secondly, it is the "invisible hand" of the market, which is a natural tool for coordinating public and individual benefits (the public welfare, according to A. Smith, is the welfare of the people). Therefore, A. Smith believed that the state's economic policy should not use any tools to achieve the highest possible level of welfare. Only a policy of non-interference will allow market forces and self-interest to achieve the optimal balance, which will determine the optimal welfare of all business entities. Developing the definition of welfare, modern economists have created two basic approaches: the resource- and consumer-oriented ones. The first approach, represented by Rimashevskaia (2008), assesses welfare against availability of economic entities in the system of resources for meeting the needs. To estimate the value of resources, and therefore, the welfare, the values of national income and consumption fund are used. In turn, the explanatory factors depend on the level of social production and on the optimality of its structure. In this regard, the work of Pezzey (1992), who proposed a methodology of calculating so-called "indicator of life self-worth" in his article has also to be mentioned. The consumer-oriented approach is presented by Pezzey (1992), who considers individual consumption in the final cycle of expanded reproduction an indicator of welfare. Welfare is assessed against the actual level of goods and services consumption by the society, as well as a degree of satisfaction of socially recognized needs. It can be stated that welfare is contemplated through a prism of the social production function. The welfare category occupies a passive position; i.e. it is just an outcome of economic development. It is basically because of the fact that welfare elements that characterize social consumption - level and structure – prevail (Thompson *et al.,* 2017). Despite a number of attractive features of traditional economic indicators of welfare, the most important of which Campbell *et al.* (1976) considered to be the ease of calculation and generally accepted scale of measurements, he also made a stress on their inadequacy. A. Campbell said that rapid economic development, as a rule, was not associated with a comparable increment of welfare. Following him, the authors of the Human Development Report, published as part of the United Nations Development Program (UNDP), wrote: "Studying the rise and fall of national income, economists often lost the sight of human welfare as a real goal of social development. Economic

growth is just a tool, perhaps an important one, for achieving this goal" (Human Development Report, 2004). In this case, the emphasis on welfare as a true development goal is quite obvious. The UNDP adds that "welfare does not only depend on economic growth and national income. It also depends on how these resources are used — whether to develop weapons or produce food, build palaces or provide clean water" (Human Development Report, 2004). Modern works related to the welfare theory stand at the crossroad of economics and a number of social sciences. For example, methodological principles and methods of social philosophy underlie the normative problems of the welfare theory (WT). Neurobiology and psychology give us tools for empirical verification of the provisions of the welfare theory by A. Lerner.

The trend towards multidisciplinarity is preconditioned by understanding of the fallacy of relying entirely on achievements of the neuroeconomics in measuring welfare, and not taking social concepts of philosophy into account, as well as vice versa (Kibler *et al.,* 2018). The investment of welfare assessment was proposed by Chatterjee *et al.* (2018). This approach shows that the level of investment in the country's economy should be correlated with investment in infrastructure. These investments lead to the compromise in the growth of public welfare, in case the gross domestic product grows by more than 4%. A study by Disney and Luo (2017) proposed an approach to assessing the social welfare of a population through an assessment of the cost of buying apartments. The authors analyzed the housing purchase market in the UK and found the dependence of the level of public welfare on the growth of this market. In this study, classical methods of statistical analysis are applied. Oueslati (2015) considers the growth of welfare as a result of environmental tax reform and an increase in government expenditures on the social sector. In a study by Lundberg *et al.* (2015) a description of methodological approaches to assessing social welfare is proposed. These authors propose using indicators such as the level of unemployment benefits and the level of longevity of the population to assess public welfare. This approach is a social approach and cannot fully characterize all population groups. From a social development perspective, welfare assessment is presented by Michalik (2011). In this study, the assessment of social welfare is based on factors that estimate the costs of medicine and social transfers in Europe. The study concluded that a key factor in improving wealth is also the level of wages. Summarizing this review, it can be concluded that the problem posed, namely estimation of public welfare, has not yet been fully investigated, has some controversial and not completely resolved problems. One of the options for solving this problem is an interdisciplinary approach to studying this problem. This approach was supported in the 2018 Club of Rome Report (Weizsacker and Wijkman, 2018). Following this research philosophy, methods of intellectual analysis will be used to solve the problem posed.

MATERIALS AND METHODS

The research is based on the method of intellectual analysis of complex processes, in particular, the tools of the mathematical apparatus of the theory of fuzzy sets have been adapted. In the process of research, theoretical and methodological achievements of domestic and foreign economic science and experience in solving problems of a market economy were applied. The work uses algorithms and methods of mathematical modeling and mathematical statistics. In the course of the study, software tools (MS Excel 2010, Matlab 2019 with the use of Image Toolbox) and computer technology were used. The statistical and informational-factual basis of the study was made up of statistical reports, reviews of the state and dynamics of the economic situation of leading state and non-state agencies. In addition, the support of the study is based on the work of domestic and foreign economists. Classical methods of economic modeling are not quite suitable for analyzing and forecasting the development of systems operating in conditions of significant uncertainty. The traditional methods of economic modeling are based primarily on binary logic (Yousuf *et al.,* 2019), which is not correct for dealing with inaccuracies and uncertainty occurring in financial and economic systems. For this purpose, the need to develop new methods that would be based on "soft" computing, mainly on fuzzy sets and neurocomputing occurred. It is the fuzzy sets that represents the system of calculations in which objects of calculations are objects with vague boundaries. In the areas of finance and economics, such modeling techniques are rather common than exceptional. The advantages of the theory of fuzzy

sets (Nikolenko *et al.*, 2018) in comparison with other mathematical methods to solve the research problem are shown in Table 1.

The theory of fuzzy sets allows to consider and analyze both qualitative and quantitative indicators. The use of this mathematical apparatus has been successfully tested in solving similar economic problems (Kozlovskyi *et al.*, 2018; Kozlovskyi *et al.*, 2019) and can be applied to achieve the purpose of this work. The advantages of the theory of fuzzy sets in comparison with other mathematical methods are given in (Kozlovskyi *et al.*, 2018), which one more time confirms the effectiveness of the use of the theory of fuzzy sets to solve the research problem. A common modeling methodology based on fuzzy sets theory involves the step-by-step solution of the following tasks: identification of the main factors of influence that characterize the level of public welfare in Ukraine (factual and analytical information on the state of economic, economic, global and political situations); formalizing the relationship between the factors of influence in a generalized form; definition and formalization of linguistic assessments of factors of influence; building a fuzzy knowledge base that identifies relationships between factors of influence; inference of fuzzy logical equations on the basis of

Table 1: Methodological analysis of the choice of mathematical apparatus for solving the study problem

Characteristics considered	Approaches to considering factors of uncertainty					
	multitasking logic	probability theory	the theory of errors	the theory of interval mean	theory of subjective probabilities	the theory of fuzzy lsets
1. Considering the physical numerical uncertainty	-	+	+	+	+	+
2. Considering the physical non-numerical uncertainty	+	+	-	+	+	+
3. Considering non-numeric linguistic uncertainty	+	-	-	-	+	+
4. Dependence of the error of the final result on the accuracy of the input data	unacceptable	Increases rapidly		increases		does not surpass
5. Ability to take into account the semantic modality of information	+	+	-	-	+	+
6. Ability to take into account the level (quantification) of uncertainty	-	+	-	-	+	+
7. Taking into account expert qualifications (more than, significantly, very, etc.)	+	-	-	-	-	+
8. Ability to take into account the contradiction between accuracy and uncertainty	+	-	-	+	+	+
9. Efficiency of formalization of complete ignorance	+	-	+	+	+	+
10. Absence of a requirement for a clear task of a complete list of events	+	-	+	+	-	+
11. Possibility of effective consideration of the mutual influence of uncertainties in the processing of information	+	-	-	-	-	+
12. Possibility of simultaneous reception of pessimistic and optimistic assessments and the level of trust in them	-	+	-	+	+	+
13. Unified approach to presenting accurate, uncertain, incomplete, fuzzy parameter values	-	-	-	-	-	+
14. Ability to implement algorithms for processing information	+	+	+	+	+	+
15. Ability to work in the professional language of the user	+	-	-	-	-	+
16. Simplicity of obtaining expert opinions (statements)	+	-	+	+	-	+
17. Ability to work with uncertain information based on small statistical samples	+	-	+	+	-	+
18. Visibility of the results obtained for the calculation and risk assessment	-	-	-	-	-	+
19. Effective and rapid adjustment of the model	-	-	+	+	-	+

linguistic assessments and fuzzy knowledge base; optimization of fuzzy model parameters. The basic principles of fuzzy set theory and fuzzy logic, which are needed for further study, were provided by Panoshichen and Kozachko (2010); Rotshtein and Shtovba (2009).

RESULTS AND DISCUSSION

It is worth to note that Ukraine has not yet developed a uniform concept of economic development of the country. Near the only theoretical basis for development of Ukraine's economy in the post-Soviet period was implementation of the principle of "invisible hand of the market" according to the theory of market economy of Adam Smith, "... based on the principle of "laissez faire", (*French - let act, do not interfere*). The essence of this concept is an admission that the natural order, based on the liberal economic idea of free enterprise and non-interference of the state in economic activity, should not be disturbed by any external influences. The benefits of a market-based self-regulation mechanism are realized only under the condition that "everyone, as long as he or she does not violate the laws of justice, is allowed to act freely at his/her own discretion and compete with his labor and capital" (Kirilenko *et al.*, 2007). As a result of implementation of this theoretical approach, an oligarchic model of economy emerged in Ukraine, which contributed to "... creation of closed oligarchic groups based on state-monopolistic ownership and oriented on the priority development of export-oriented and resource-based economy" (Kropivko, 2016). The consequence of this model is, first and foremost, a decline in living standards of the majority of country's population, including household members. Despite rather positive processes attributed to implementation of reforms by central and local governments, these measures cannot be considered comprehensive. In the last two years Ukraine has implemented 75 legislative acts aimed at reforms in various sectors of economy and governance (Law of Ukraine, 2017). However, these activities can be described as implementing some legislative acts of the European Union in response to financial and political pressure of the European community and part of Ukraine's society. Accordingly, the results of such measures have had minor financial and social effects. According to Byrdyn (2008), the quality of life of the population is improved by results of social and economic development, which include:

- Higher income, improving the health of the population and its education level
- Creation of conditions that contribute to the growth of self-esteem of people as a result of shaping social, political, economic and institutional systems focused on respect for human dignity
- More freedom to people, in particular the economic one.

The traditional indicator of welfare in the country is gross domestic product (GDP) per capita and the Human Development Ratio (otherwise called the Human Development Index), which is calculated taking into account GDP per capita, average life expectancy and education level (literacy) of population. However, since recently politicians and scholars have questioned the use of such indicator for measuring welfare of the population. Poverty indicator is partly considered the indicator of welfare of the state population. Michalik (2011) defines poverty as inability to maintain living standards inherent in a particular society over certain period of time. The well-known scientist Bell (1976) formulated 12 main criteria (indicators) that help compare the "quality of life" of different societies. These include: health care, development and improvement of personality in the process of education, jobs and quality of time in employment, organization of leisure, distribution of goods and services, physical environment, personal security, justice, an opportunity to take part in social activities, etc. According to the Global Welfare Rating defined by the LPI (2008), Ukraine ranks 68-th out of 104 countries. Among European countries, only Belarus (78-th place) and Moldova (83-rd place) were lower on this scale. In terms of purchasing power index, Ukraine ranks 39-th, the penultimate place in Europe. Only Moldova has lower purchasing power. According to experts, the average income spent in Ukraine in 2008 was 1688 euro (EUR), while the average purchasing power per person in Europe reached 12.5 thousand EUR. The purchasing power of Ukrainians is only 13.5% of the European average level. According to the Human Development Index (HDI), in 2008, Ukraine ranked as low as 76-th place in the world (HDI value = 0.788). The HDI consists of three components, one of which is GDP per capita in terms of purchasing power parity. In 2007, Ukraine

ranked 85-th among 174 countries of the world. According to United Nations (UN) estimates, Ukraine belongs to the category of countries with average level of development (low GDP per capita is compensated by high level of education and moderate average life expectancy). The average life expectancy in Ukraine in 2009 was 68.5 years (in 1990 - 70.5), while in Europe it was 79.13 years. The average healthy life expectancy in Ukraine in 2009 was 59.2 years, and in EU countries - 67 years. The mortality rate in Ukraine is 16.3 cases per 1000 population. This figure has increased by one third compared to 1990, and now Ukraine ranks the tenth in the world in terms of this rate. The scientist Hafer (2017) draws attention to such indicator as the minimum subsistence level, which is actually a dynamic social and economic category reflecting the lower boundary of socially necessary standard of living under certain conditions and is used for general assessment of living standards of the population. According to Hafer (2017), the minimum subsistence level is influenced by prices, inflation, quantitative assessment of a set of consumer goods and services. It should be noted that this indicator in Ukraine is determined in the normative way, by setting the value of the minimum subsistence level as the cost of minimum month consumer basket per person. At the same time, the indicator is calculated under differential approach depending on the age criterion or social and demographic group to which belongs an individual: for children under 6 years of age; for children from 6 to 18 years of age; for able-bodied persons; for disabled persons (Law of Ukraine, 2017). Imperfection of the methodology for calculating and applying this indicator to determine citizens' eligibility for social assistance and setting standards for social services is evidenced by vigorous annual debate in the press and in the political community that accompanies adoption of this indicator at the legislative level. It is bureaucratization of the methodology for calculating the social well-being and its application for measuring the level of public welfare which leads to over-politicization of the issue. In order to identify the main factors of influence on the welfare level in Ukraine, an expert survey was conducted on the territory of Ukraine by the experts of the state authorities of Ukraine, and experts of the Ministry for Development of Economy, Trade and Agriculture of Ukraine. According to the interview, the main factors and indicators are identified. On the basis of it we can estimate the state of public welfare in Ukraine. It is concluded that to determine the level of public welfare in Ukraine, it is advisable to use the following indicators:

1. The Index of Economic Freedom (IEF). The index takes into account 12 degrees of freedom - from property rights to financial freedom (Fig. 1). Ukraine is in the group of countries with mostly not free economy. This is the fourth category in the graduation. In addition to the countries with mostly not free economy, there are countries with free economy, mostly free economy, moderately free economy and depressed economy. Ukraine is ranked last among 44 European countries, and its position is lower than the regional ones according to the world parameters. It is noted that Ukraine, whose economy has been severely affected by the events of recent

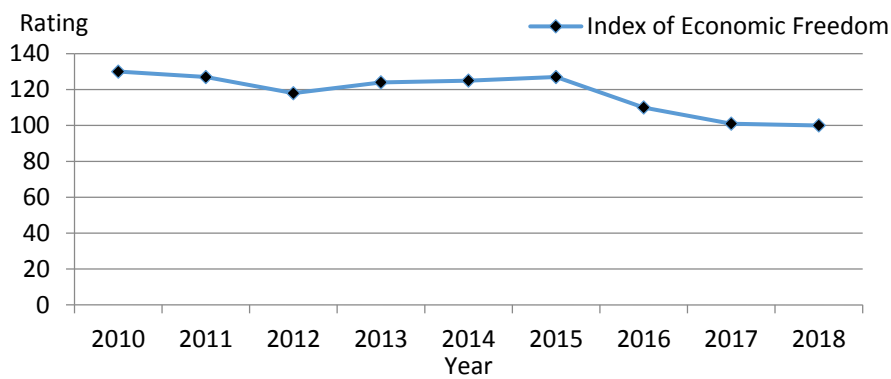

Fig. 1: The Index of Economic Freedom (UIR, 2019)

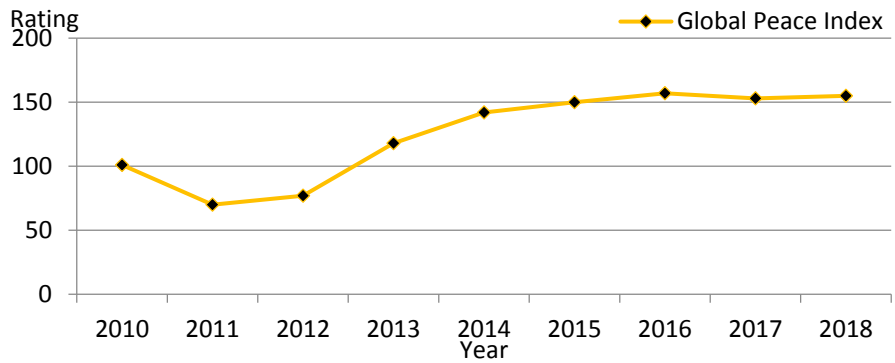

Fig. 2: Global Peace Index of Ukraine (UIR, 2019)

years - annexation of Crimea and armed conflict in Donbass - has made significant progress in reforming and has become democratic and transparent state. However, the center's researchers emphasize the need to fight corruption, develop capital markets, privatize state-owned enterprises and improve the legislation and rule of law.

2. Global Peace Index (GPI). It is a methodology for determining the level of tension/peace in countries and regions. Ukraine is in the group of ten countries with the lowest scores in terms of the Global Peace Index. In addition, according to the report, Ukraine ranks second among the countries where the peace situation has worsened most in the last year (Fig. 2). The annual Peace Index is determined under 23 components (Koziuk *et al.,* 2018), including cases of violent crime, the level of militarization of the country and import of weapons.

3. The Democracy Index (DI). Ukraine ranked 83 out of 167 in the Democracy Index 2018 measured by the Economist Intelligence Unit. The classification takes into account 60 different indicators, grouped in 5 categories: elections and pluralism, civil liberties, government activities, political engagement of the population and political culture (Fig. 3). Ukraine was classified as a "hybrid regime." The report also covered a press freedom rating for 2018. According to it, Ukraine received 6 points out of 10 and was assigned to countries with "mostly not free" press.

4. The Corruption Perceptions Index (CPI). It is the annual rating of world countries, which has been measured by Transparency International since 1995. Countries are ranked by the level of corruption based on the estimates of entrepreneurs and analysts.

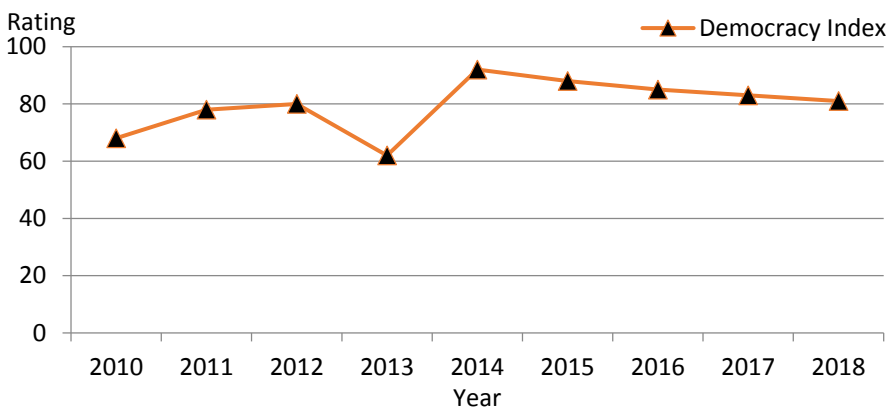

Fig. 3: The Democracy Index of Ukraine (Democracy Index, 2017)

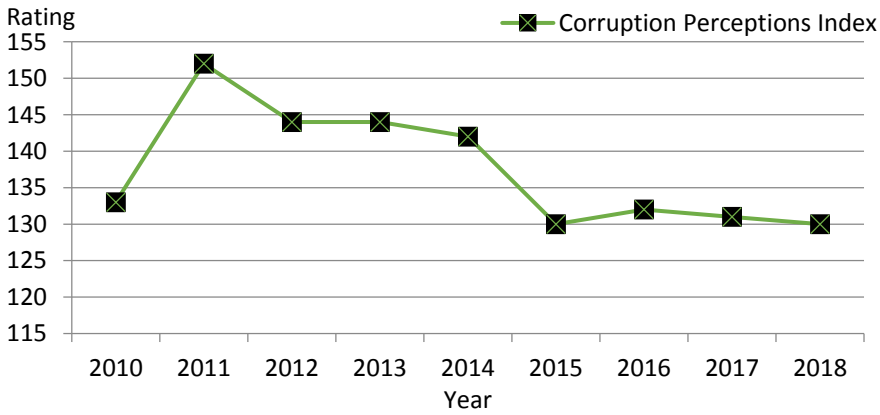

Fig. 4: The Corruption Perceptions Index of Ukraine (UIR, 2019)

In 2017, Ukraine received only 30 points out of possible 100. Ukraine's neighbors in the ranking are Gambia, Iran, and Myanmar. According to experts of the organization, a slight improvement of Ukraine's position in the rating was achieved due to the fact that in 2017 the Ukrainian anti-corruption authorities: Specialized anti-corruption prosecutor's (SAP) and National anti-corruption bureau (NABU) brought the first cases of suspected corruption of high-ranking officials to court. Among the reasons that also contributed to the slight improvement of Ukraine's position in the rating are the gas market reform, operation of the register of electronic declarations, the first year of public procurement and the using the system public procurement ProZorro (ProZorro) (Fig. 4). At the same time, the slow growth of the Ukrainian index is explained by the lack of political will of the country's leadership to fight corruption and a low level of confidence in Ukrainian courts and prosecutors.

5. The Human Development Index (HDI) is an index for comparative assessment of poverty, literacy, education, life expectancy, health, social protection, longevity, ecology, crime, human rights and GDP per capita (Stukalo *et al.,* 2019). The UN has published a Human Development Indices and Indicators report, in which Ukraine ranked 88-th among 189 countries (Fig. 5). According to the UN rating, the Human Development Index in Ukraine is 0.751, life expectancy is 72 years, the expected length

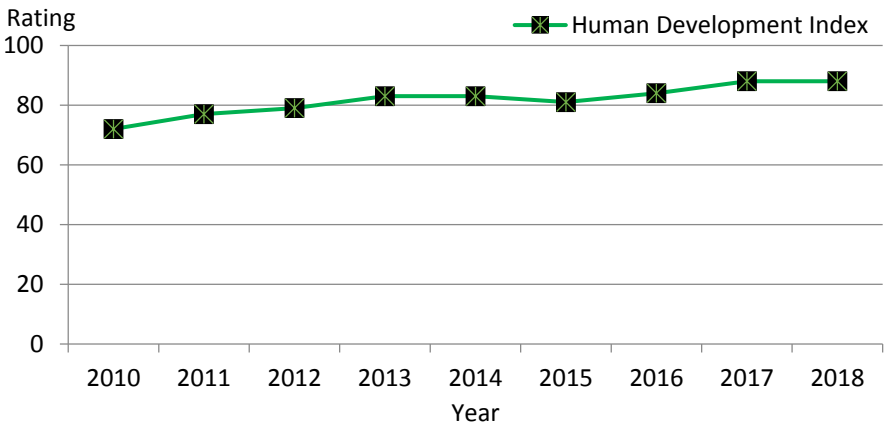

Fig. 5: The Human Development Index of Ukraine (HDII, 2018)

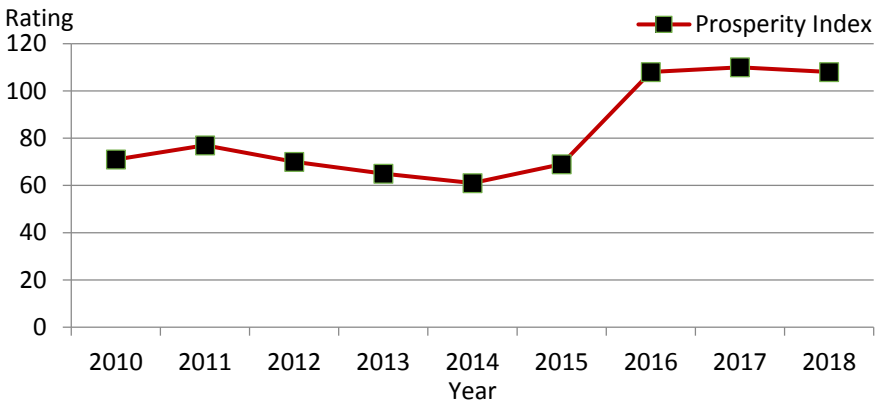

Fig. 6: The Prosperity Index of Ukraine (LPI, 2018)

of education is 15 years, while the average one is 11.3 years.

6. The Prosperity Index (PI) is an estimation of world wealth and welfare. It has been calculated by Legatum Institute with headquarters in London since 2008. The rating is based on a complex methodology for calculating weighted indices. According to the report of the above-mentioned organization Ukraine has risen in the Global Prosperity Index from 112^{-th} to 111^{-th} position among 149 countries, (Fig. 6). This year Ukraine has shown the best results in the field of personal freedom and education. However, the health care rating of Ukraine is still on the low 137^{-th} position.

7. The Global Competitiveness Index (GCI). It is a result of global study and its accompanying ranking of countries in terms of economic competitiveness. It is calculated according to the methodology of the World Economic Forum (WEF), based on a combination of publicly available statistics and the results of a global survey of corporate executives, which is a large annual survey conducted by WEF together with a network of partner organizations - leading research institutes and organizations of the participating countries. In 2018, Ukraine ranked 83^{-d} in the Global Competitiveness List made by experts of the WEF, (Fig. 7). This year, the indicator reflects the situation in 140 countries or territories. According to the list, Ukraine ranks 77^{-th} in technology adaptation, 110^{-th} in development of state institutions, 131^{-st} in macroeconomic stability, 94^{-th} in health care performance, 58^{-th} in innovation opportunities, 46^{-th} in education, and 66^{-th} in the employment market.

8. Minimum subsistence level (Living Wage: LW*). It* is a valuation of the consumer basket, which includes the minimum sets of food products, non-food goods

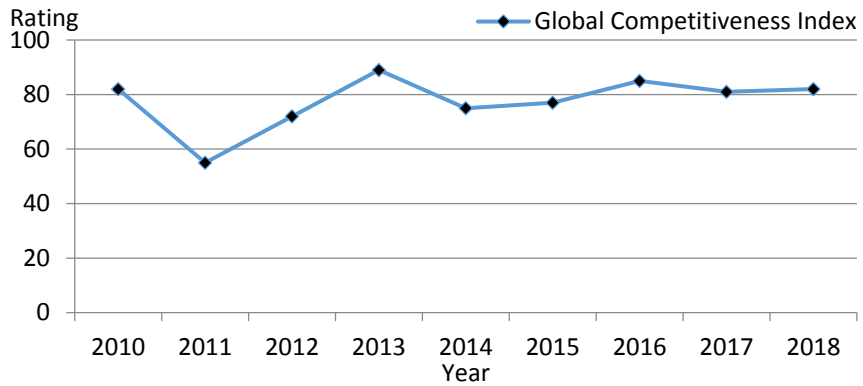

Fig. 7: The Global Competitiveness Index of Ukraine (WEF, 2019)

and services necessary to preserve human health and ensure the vital functions. The Fig. 8 shows that the average level of the minimum subsistence level in Ukraine in 2018 is 5 US dollars per person per day (Fig. 8). This is the minimum value that makes the country one of the poorest in the world.

The lack of adequate and compact models for estimation of public welfare is the main prerequisite for development of integrated indicator that reflects the estimation of public welfare that meets the following methodological requirements:

1) universality - the indicator should reflect the most characteristic essential parameters of public welfare (Menegaki and Tugcu, 2017). Fulfillment of this requirement will ensure the possibility of applying such indicator to solving most social and economic problems associated with the analysis of welfare of various systems of economic entities
2) reliability - calculation of the indicator should be based on regularly recorded statistical indicators, which will ensure the quality and validity of the model
3) standardization - the scale for measuring the indicator should be common for various options of implementation of model calculating. This requirement is dictated by a need to measure the results of various studies using the model
4) sensitivity - the measurement scale division value of the indicator should ensure the ability of the model to capture changes in the social welfare of various degrees of expressiveness
5) objectivity - the independence of the indicator from the subject working with the model to prevent falsification of results
6) the integral assessment of the system must take into account the joint functioning of subsystems, i.e. the effect of synergy (Carley and Johnston, 1981).

To determine and scale the level of public welfare, the authors proposes to use a comprehensive indicator, since the essence of the index consists in characterizing changes in the totality of certain values. This indicator is identified as "Welfare Index" (hereinafter - WI). To determine the value of the indicator (WI), the mathematical technique will be used, namely the theory of fuzzy sets. This approach demonstrates high effectiveness in solving such problems (Kozlovskyi *et al.*, 2018; Kozlovskyi *et al.*, 2019). Fig. 9 presents the inputs of the model: Economic Freedom Rating (IEF), Global Peace Index (GPI), Democracy Index (DI), Corruption Perception Index (CPI), Human Development Index (HDI), Prosperity Index (PI), Global Competitiveness Index (GCI), the Living Wage (LW). In fact, Fig. 9 represents a structure of the public welfare model of Ukraine.

Generalization of the mathematical values of the input and output indexes, the range of parameter changes and the values of the parameters of the

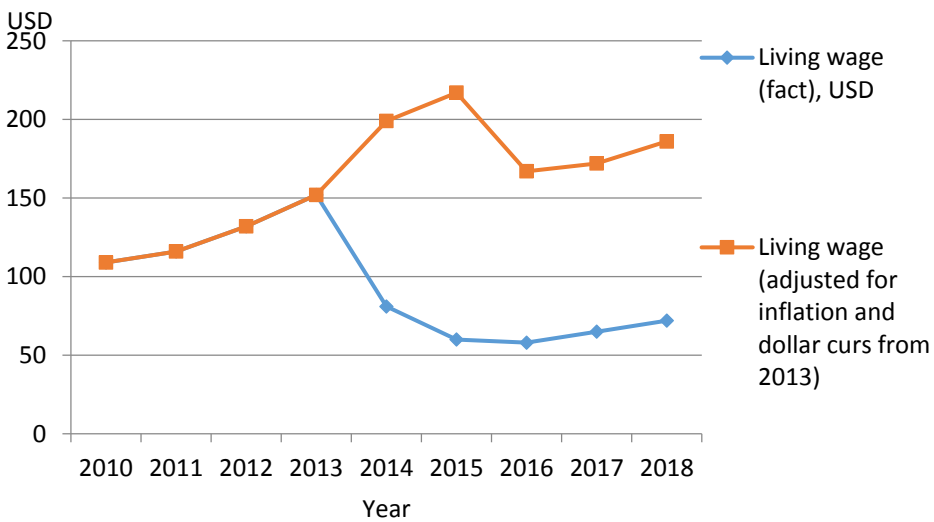

Fig. 8: Minimum subsistence level (Living Wage) (factual and adjusted) in Ukraine (Minfin, 2019)

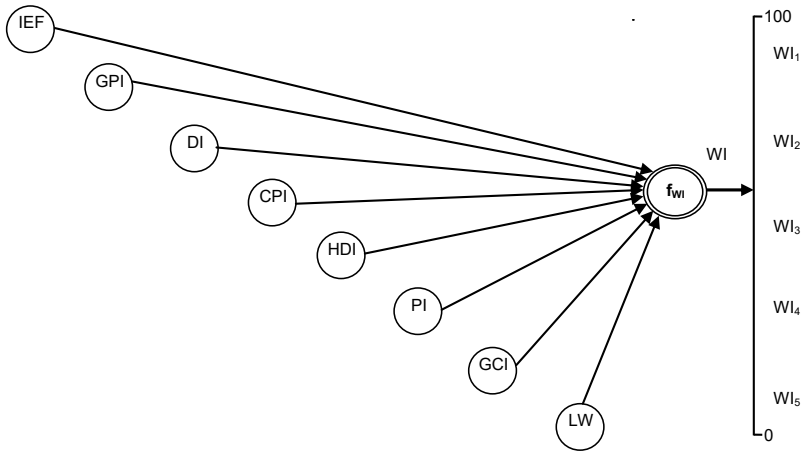

Fig. 9: The structural model of estimation of the level of public welfare of Ukraine

membership functions (μ) (according to the general method of modeling by means of fuzzy set theory (Kozlovskyi *et al.*, 2019; Rotshtein and Shtovba, 2009) are given in Table. 1. Model parameters are described linguistically and presented as terms. These terms are presented as a function of membership and based on using Eq. 1.

$$\mu^{T}(x) = \frac{1}{1+\left[\frac{x-b}{c}\right]^{2}}, \quad (1)$$

where b i c – parameters of membership function (MF)

b – maximum function coordinate (b);
c – stretching concentration factor (c).

The values of the coefficients b and c for the input parameters and output value are also given in Table 2.

The input parameter of WI (the level of public welfare of Ukraine) can be determined by using Eq. 2.

$$WI = f_{wi}(IEF, GPI, D'I, CPI, HDI, PI, GCI, LW) \quad (2)$$

The graph of the membership function of WI (mWI) in accordance with the values of Table 2 and Eq. 2 is shown in Fig. 10.

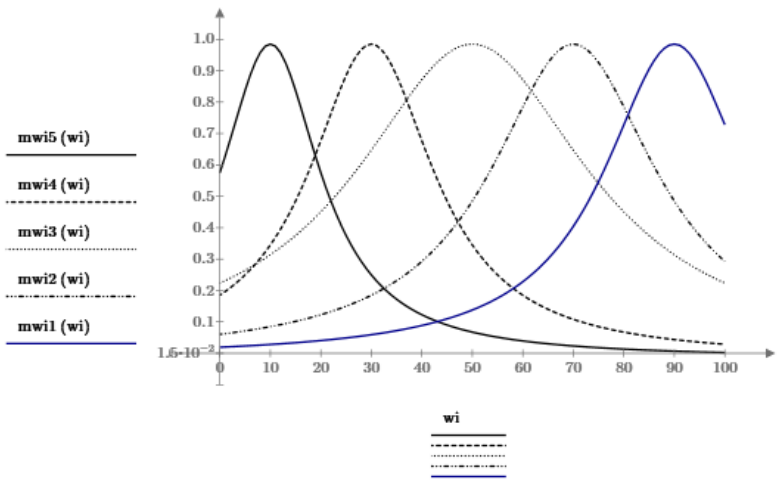

Fig. 10: The membership function for parameter WI

Table 2: Generalized values of indicators of the model of estimation of level of public welfare of Ukraine

Indicator (factor)	Marking	Change range	Linguistic evaluation of parameters (terms) and the range of their changes	Values of parameters b and c of the membership function of the variables	
				b	c
Economic Freedom Index	IEF	0…180	Low (L), 101…180	130	80
			Average (A), 51…100	75	50
			High (H), 0…50	25	20
Global Peace Index	GPI	0…180	Low (L), 101…180	130	80
			Average (A), 51…100	75	55
			High (H), 0…50	25	23
Democracy Index	DI	0…180	Low (L), 101…180	135	75
			Average (A), 51…100	70	55
			High (H), 0…50	20	30
Corruption Perceptions Index	CPI	0…180	Low (L), 0…50	22	35
			Average (A), 51…100	70	55
			High (H), 101…180	130	90
Human Development Index	HDI	0…180	Low (L), 0…50	22	35
			Average (A), 51…100	70	55
			High (H), 101…180	130	90
Prosperity Index	PI	0…150	Low (L), 0…50	22	35
			Average (A), 51…100	70	55
			High (H), 101…150	120	70
Global Competitiveness Index	GCI	0…140	Low (L), 101…140	110	50
			Average (A), 51…100	75	50
			High (H), 0…50	25	20
Living wage	LW	50…1000 USD	Low (L), 50…300	20	10
			Average (A), 301…800	500	120
			High (H), 801…1000	900	150
Welfare index	WI	0…100	Very Low, (WI_5), 0…20	10	12
			Low (WI_4), 21…40	30	15
			Average (WI_3), 41…60	50	28
			Above Average (WI_2), 61…80	70	20
			High (WI_1), 81…100	90	17

The next step in modeling is to build a hierarchical knowledge base, that is, to determine the impact of input parameters on the output one. The information from international organizations was used to build the knowledge base (WEF, 2018). The knowledge base for dependence of WI on IEF, GPI, DI, CPI, HDI, PI, GCI, LW is given in Table 3.

Proceeding from of the resulted knowledge base (Table 3), we develop the fuzzy logical equations of the model. These will be the initial equations of the Ukraine public welfare assessment model (Eq. 3).

$$\mu^{WI1}(WI) = \begin{bmatrix} \mu^{\mathrm{H}}(IEF) \cdot \mu^{\mathrm{H}}(GPI) \cdot \mu^{\mathrm{H}}(DI) \cdot \mu^{L}(CPI) \cdot \\ \mu^{L}(HDI) \cdot \mu^{H}(PI) \cdot \mu^{H}(GCI) \cdot \mu^{H}(LW) \end{bmatrix} \vee$$

$$\begin{bmatrix} \mu^{\mathrm{H}}(IEF) \cdot \mu^{L}(GPI) \cdot \mu^{\mathrm{H}}(DI) \cdot \mu^{A}(CPI) \cdot \\ \mu^{A}(HDI) \cdot \mu^{A}(PI) \cdot \mu^{A}(GCI) \cdot \mu^{A}(LW) \end{bmatrix};$$

$$\mu^{WI2}(WI) = \begin{bmatrix} \mu^{A}(IEF) \cdot \mu^{\mathrm{H}}(GPI) \cdot \mu^{A}(DI) \cdot \mu^{L}(CPI) \cdot \\ \mu^{A}(HDI) \cdot \mu^{H}(PI) \cdot \mu^{A}(GCI) \cdot \mu^{A}(LW) \end{bmatrix} \vee$$

$$\begin{bmatrix} \mu^{\mathrm{H}}(IEF) \cdot \mu^{A}(GPI) \cdot \mu^{A}(DI) \cdot \mu^{A}(CPI) \cdot \\ \mu^{H}(HDI) \cdot \mu^{A}(PI) \cdot \mu^{A}(GCI) \cdot \mu^{H}(LW) \end{bmatrix};$$

$$\mu^{WI3}(WI) = \begin{bmatrix} \mu^{A}(IEF) \cdot \mu^{\mathrm{H}}(GPI) \cdot \mu^{L}(DI) \cdot \mu^{A}(CPI) \cdot \\ \mu^{A}(HDI) \cdot \mu^{L}(PI) \cdot \mu^{A}(GCI) \cdot \mu^{A}(LW) \end{bmatrix} \vee$$

$$\begin{bmatrix} \mu^{L}(IEF) \cdot \mu^{H}(GPI) \cdot \mu^{\mathrm{H}}(DI) \cdot \mu^{L}(CPI) \cdot \\ \mu^{H}(HDI) \cdot \mu^{H}(PI) \cdot \mu^{H}(GCI) \cdot \mu^{L}(LW) \end{bmatrix};$$

$$\mu^{WI4}(WI) = \begin{bmatrix} \mu^{A}(IEF) \cdot \mu^{L}(GPI) \cdot \mu^{\mathrm{H}}(DI) \cdot \mu^{H}(CPI) \cdot \\ \mu^{L}(HDI) \cdot \mu^{L}(PI) \cdot \mu^{H}(GCI) \cdot \mu^{A}(LW) \end{bmatrix} \vee$$

$$\begin{bmatrix} \mu^{L}(IEF) \cdot \mu^{L}(GPI) \cdot \mu^{\mathrm{H}}(DI) \cdot \mu^{A}(CPI) \cdot \\ \mu^{A}(HDI) \cdot \mu^{A}(PI) \cdot \mu^{L}(GCI) \cdot \mu^{L}(LW) \end{bmatrix};$$

$$\mu^{WI5}(WI) = \begin{bmatrix} \mu^A(IEF) \cdot \mu^L(GPI) \cdot \mu^A(DI) \cdot \mu^L(CPI) \cdot \\ \mu^A(HDI) \cdot \mu^L(PI) \cdot \mu^A(GCI) \cdot \mu^A(LW) \end{bmatrix}^{\vee}$$

$$\begin{bmatrix} \mu^L(IEF) \cdot \mu^L(GPI) \cdot \mu^L(DI) \cdot \mu^H(CPI) \cdot \\ \mu^L(HDI) \cdot \mu^L(PI) \cdot \mu^L(GCI) \cdot \mu^L(LW) \end{bmatrix}. \quad (3)$$

The values of membership functions in Eq. 3 are calculated from the fuzzy knowledge base presented in Table 3.

The dephasification procedure is the last stage of simulation and is the inverse transformation of the found fuzzy logic result (Eq. 3) into output estimate or forecast. To solve this equation, a method of dephasing, called the "extended center of gravity method" Rotshtein and Shtovba (2009), consisted in solving the Eq. 4.

$$\mathrm{WI} = \frac{\sum_{i=1}^{n}\left[\mathrm{WI_E} + (i-1)\cdot\frac{\mathrm{WI_A}-\mathrm{WI_E}}{n-1}\right]\cdot\mu^{\mathrm{WI_i}}}{\sum_{i=1}^{n}\mu^{\mathrm{WI_i}}} \quad (4)$$

where n – the number (discrete values) of variable terms «WI»

$WI_E(WI_A)$ – the lower (upper) limit of the variable range «WI»

μ^{WI_i} – membership function of variable «WI» to fuzzy term «WI_i».

There was an experiment with the use of the above method in the mathematical package Matlab 6.1. The result of estimation and prediction of the level of public welfare in Ukraine till 2024 are in Fig. 11.

According to the analytical results, the following prediction should be made: by 2024, public welfare would be at a low WI4 level. In general, that indicates rather negative trend in the Ukrainian economy's development. Under the aforementioned conditions, it is necessary to determine the most significant indicator, regarding the level of public welfare in Ukraine. Figs. 12 and 13 represent the WI output dependent on a pair of factors (GCI, LW) and (GPI, CPI). The simulation was made with Matlab 2019 and the Image Toolbox. The mentioned Figs. 12 and 13 depict the impact of those indicators on the level of public welfare in Ukraine. Moreover, LW (Living Wage) and GCI (Global Competitiveness Index) should be mentioned among the crucial factors reducing the level of public welfare in Ukraine.

Until now, individual macro-social indicators related to the welfare of society have been investigated when studying the level of public welfare. It is related to the fact that, first of all, it was necessary to conduct an analytical study of indices and manifestations of sensations of individuals forming social integrity. However, this makes it difficult to evaluate the basic processes of the social trends in the affective sphere of social life, especially given the complicated and fuzzy relationships of parameters. For example, most of the indicators analyzed above have correlation relationships, often with unobvious cause-and-effect nature. The mathematical solution in this case became possible due to the use of methods of intellectual analysis, namely, methods of the fuzzy set theory. The issues of measuring and ensuring public welfare are always largely politicized because of differing views on the nature of the social problems. As scientist Pezzey (1992) points out that social welfare policies are always in debate about what counts as "benefit" and "value", how to identify needs, whose needs should be given preferences, to what extent the government is able to be rational in terms of choosing mechanisms

Table 3: Knowledge base of Welfare Index

IEF	GPI	DI	CPI	HDI	PI	GCI	LW	WI
H	H	H	L	L	H	H	H	WI_1
H	L	H	A	A	A	A	A	WI_1
A	H	A	L	A	H	A	A	WI_2
H	A	A	A	H	A	A	H	WI_2
A	H	L	A	A	L	A	A	WI_3
L	H	H	L	H	H	H	L	WI_3
A	L	H	H	L	L	H	A	WI_4
L	L	H	A	A	A	L	L	WI_4
A	L	A	L	A	L	A	A	WI_5
L	L	L	H	L	L	L	L	WI_5

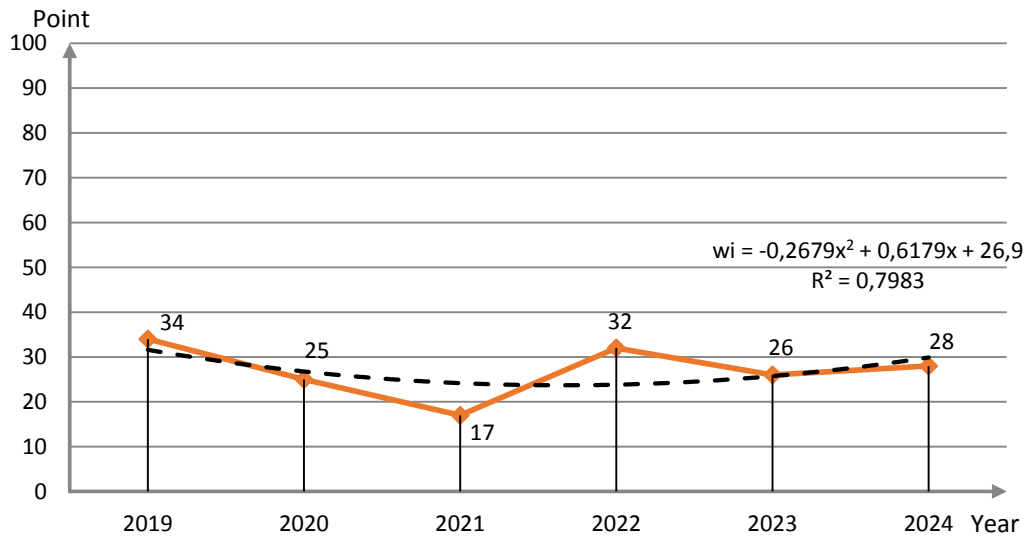

Fig. 11: The results of estimation and prediction of level of public welfare of Ukraine

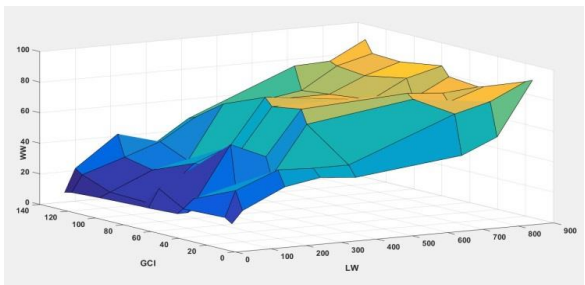

Fig. 12: Graphic representation of two-dimensional dependencies WI (GCI, LW)

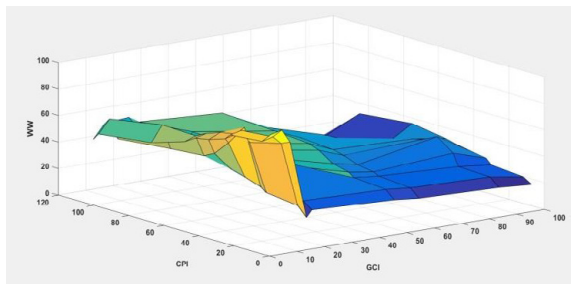

Fig. 13: Graphic representation of two-dimensional dependencies WI (GPI, CPI)

of interference with the situation. Subjective factors play a significant role in the perception of public welfare and policy formulation. Modern ideas about public welfare vary. Some scholars tend to link it to the material conditions needed to reproduce human powers, and accordingly measure this welfare by such macroeconomic indicators as GDP per capita, purchasing power index, Gini coefficient, poverty rate and others. Other scholars believe that public welfare involves not only income and social guarantees, but also public benefits, and can be measured by a number of objective and subjective indicators, including human development index, public health and infant mortality rates in different socio-economic groups, self-esteem, the level of accessibility of social infrastructure for representatives of all social groups, etc. In Ukraine, the standard of living wage and average wages (pensions) are generally used to assess the population welfare. However, these indicators do not quite meet market conditions for economic development and household income structure, do not take into account indirect and subjective estimates, which give more comprehensive characterization of public welfare.

CONCLUSION

This study offers a completely different approach to estimation of country's welfare based on international indicators that characterize the country's economic and social development, such as Economic Freedom Rating (IEF), Global Peace

Index (GPI), Democracy Index (DI), the Corruption Perceptions Index (CPI), the Human Development Index (HDI), the Prosperity Index (PI), the Global Competitiveness Index (GCI), and the indicator that characterizes the country's level of economic development, namely the Living wage (LW). The mathematical model of assessment of public welfare in Ukraine was built due to using methods of intellectual analysis, namely the theory of fuzzy sets. The model made it possible to measure the level of public welfare in Ukraine. In general, the result is disappointing, as the level of public welfare of Ukraine is low and is not tending to improve in the long term (until 2024 and further), unless some state and administrative measures are taken. The results of assessment of impact of indicators on assessment of public welfare in Ukraine revealed that the key welfare indicator of Ukraine is the living wage. In Ukraine, it does not exceed 70 USD, which is extremely low. It was found that it will be possible to significantly increase the general public welfare in the country, provided the living wage is raised. No matter which theoretical approach is used to assess the level of public welfare, this indicator remains low for Ukraine, since the country ranks low in the world lists and takes next to the last places among other European countries. Based on the modeling and experiments, it can be seen that for Ukraine, the key indicator of social welfare is the cost of living indicator. The paradox in the Ukrainian economy is that social guarantees of the state (pensions and benefits) are below the specified subsistence level, what, basically, is not possible in a market and modern economy. This situation does not make it possible to conduct a true analysis of the level of social welfare using classical methods, and to construct pessimistic and optimistic development scenarios. The solution to this problem is possible only with synergetic approaches, namely the use of modern modeling methods, methods of intellectual analysis, namely, methods of the theory of fuzzy sets. The use of these methods determined that the key factor in the development of the Ukrainian economy, improving the welfare of its population, in terms of public administration methods, is the problem of the paradoxically low level of the living wage, the state establishes. In Ukraine, the net wage in the public sector and the private sector is formed from the subsistence level. It can be concluded that inefficient state administration of Ukraine in this sector is, now, the main factor in the low level of public welfare of the country. Even other, economic, political, environmental factors are not a key in this problem. The practical significance of the study results lies in their potential use by legislative and executive authorities, as well as by investors at both the state and individual project level. New scientific results gained by the authors, grounded theoretical conclusions and suggestions can serve a basis for further theoretical and practical research in the field of welfare economics.

AUTHOR CONTRIBUTIONS

S. Kozlovskyi developed the structure and architecture of a model based on the theory of fuzzy sets. L. Nikolenko collected statistical information and made the defuzzification of the model. O. Peresada worked on a literary review of this problem and evaluated the indicators of the model of the level of economic public welfare. O. Pokhyliuk conducted an analysis of international reporting and made a forecast of the economic welfare level. O. Yatchuk worked on a literature review and a review of international studies on this topic, and also proposed international indices as factors of influence. N. Bolgarova took part in the development of a mathematical model, proposed and justified the choice of membership functions. O. Kulhanik worked on the construction of graphical dependencies of indicators, and also conducted an analysis of international data.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

A	Average
b	Maximum function coordinate of membership function
c	Stretching concentration factor of membership function
CPI	Corruption Perceptions Index
DI	Democracy Index
FS	Fuzzy sets
EUR	Official currency of the European Union
H	High
HDI	Human Development Index
GDP	Gross domestic product
GCI	Global Competitiveness Index
GPI	Global Peace Index
IEF	Index of Economic Freedom
L	Low
LW	Living wage
mWi	Membership function of the output parameter Welfare Index
μ	Membership function
PI	Prosperity Index
ProZorro	System public procurement of Ukraine
SAP	Specialized anti-corruption prosecutor's
NABU	National anti-corruption bureau
UN	United Nations
UNDP	United Nations Development Program
USD	United State dollar
WE	Welfare economics
WEF	World Economic Forum
WI	Welfare Index
WT	Welfare theory
WI_E	Lower limit of the variable range «WI»
WI_A	Upper limit of the variable range «WI»

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