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COGNITIVE APPROACH TO MODELING POPULATION'S QUALITY OF LIFE

Abstract. Assessing the position of economic and human capital development level, building a strategy to improve the quality of life is extremely important for the state, so the study of indicators that form the quality of life and have the greatest impact on it remains relevant. Since the very concept of quality of life is a multicomponent category, characterized by both objective and subjective indicators, we consider it appropriate to structure knowledge about the factor environment that shapes the quality of life, their reflection by forming a cognitive model, its static analysis to identify the factors that have the greatest impact on quality of life to improve its level, which reflects the purpose of the study. A cognitive model of quality of life in the form of a balanced digraph was built based on 22 indicators of socio-economic conditions of Ukrainian households, grouped into four groups:

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population, education and health, socio-economic indicators. Structural analysis of the cognitive model made it possible to assess the classes of factors, establish the system characteristics of the model, identify the factors that have the greatest impact on the system, and assess their importance in modeling the self-development of the situation. Considering the weights of factors and external influences, it is determined that the assessment of the quality of life is most influenced by a group of health factors, while the growth of the quality of life indicator contributes most to the growth of the population and reduces its migration.

Keywords: *Quality of life, Cognitive Modeling, Static analysis, digraph, Socio-economic indicators*

Introduction. Advancing the quality of the life of the population is a priority task of the state of any country, and also demonstrates the effectiveness of the social and economic policy. The very understanding of life is a rich-component category, how to characterize both the active and sub-active indicators. That is why it's victorious to be flexible to gain awareness in the capacity of life of the population of the other countries. For example, the approach to measuring the quality of life used by Eurostat is to measure various aspects of quality of life that take into account indicators of economic and social development. According to the study "Quality of Life – 2020". Ukraine ranks 65th among countries. Assessing the position on the level of development of economic and human capital, building a strategy to improve the quality of life is extremely important for the state, so the study of indicators that shape the quality of life and have the greatest impact on it still remains relevant. Assessing its position on the level of development of economic and human capital, building a strategy to improve the quality of life is extremely important for the state, so the study of indicators that shape the quality of life and have the greatest impact on it remains relevant.

Analysis of recent research and publications. The works of many scientists are devoted to the formulation of the definition of "quality of life" and the study of its factors. Rahman (2011) notes that, in essence, quality of life is a multidimensional category in which each of its components can in itself serve as a measure of quality of life. As well ae there are many approaches to determining the quality of life, there are large number of methods for assessing it. Zagorski, for example, (2014) explores three components of the quality of life of Europeans:

– well-being, ie quality components such as happiness, life satisfaction;

– financial quality of life, which includes indicators of satisfaction with living standards, availability of goods and services, subjective poverty;

– health, namely self-assessment of health, satisfaction with health.

Maggino (2012) notes that the quality of life depends on the objective conditions and capabilities of people. Therefore, to improve it, measures should be taken to improve People'shealth, education, personal activities and the environment. State policy in this direction is recommended to focus on the implementation of measures to develop social ties, the importance of political voice and reduce insecurity. Zagorski (2014) in his study proves the positive impact of GDP per capita on subjective well-being, financial quality of life and health, while income inequality does not reduce the importance of these indicators. That is, for European countries there is an irrationality of investing additional financial resources to reduce inequality for the majority of the population.

Novakova (2016) consider the quality of life through material living conditions based on the calculation of the integrated index and made a comparison among European countries.

Royuela (2011) in its study identifies current trends in population distribution within the capital and identifies the impact of quality of life on population growth, as well as the positive impact of population growth on improving quality of life. There are also studies linking quality of life with a certain economic sphere, in

particular, Croes (2018), Andereck (2011) assess the relationship between quality of life and the development of tourism.

In the monograph (L. Cherenko, 2021) the standard of living of the population is considered as a category that combines both its quantitative dimension and qualitative characteristics and is an indicator of the effectiveness of the economic model of the country. This approach is used to build a model of living standards, which also takes into account the factors of direct and indirect action that occur in an unstable socio-economic environment, formed a forecast of living standards and poverty based on the epidemic situation in the country.

The article (V. Brych et al., 2021) used a dynamic approach to the study of living standards, which allowed the authors to conclude that the growth of average wages does not sufficiently affect the living standards of workers because the level of the real wage index does not sufficiently meet their needs. The assessment of the life quality of the population is proposed to be carried out using the DSGE class (dynamic stochastic general equilibrium) models. Each of the selected entities has its own target function.

The authors of the article (A. Stavytsky, & K. Molokanova, 2020) also note that the assessment of the quality of life associated with the socio-economic development of the country can not be carried out only in areas that shape the material sphere of life, it is necessary to take into account intangible indicators such as social equality, health care and the like.

Bucur (2017) notes that various approaches are used to study the quality of life, including methods of mathematical statistics, probability theory, fuzzy systems, time series and other methods. Her research is based on the concept of definite integral, compound function and mathematical optimization. The following indicators are used as objective characteristics of quality of life : health; family life; community life; financial position (GDP per capita, in US dollars); political stability and security; climate and geography; job security (unemployment rate); political freedom; gender equality; life expectancy at birth; life expectancy index; degree of access to education; period of study; income indicator; gross national income at purchasing power parity per capita.

Cognitive approach to modeling poorly structured tasks is used in the research of many scientists, in particular, in the article (O. Kravets, & G. Kucherova, 2019) it is used to study the level of socio-economic development, in the article (O. Yeliseyeva, & V. Sarychev, 2017) – to study the state of health care, etc, Kucherova H. (2020) uses fuzzy cognitive modeling to study the poorly structured category of information transparency. Napoles (2018) notes that the methodology for constructing fuzzy cognitive maps (FCM) is effective for modeling systems characterized by ambiguity, the presence of causal relationships between variables.

Therefore, we consider it appropriate to structure knowledges about the factor environment that formes the quality of life, their reflection by forming a cognitive model, conducting static analysis to identify factors that have the greatest impact on quality of life to improve its level.

Methods. Since we believe that the concept of quality of life is a poorly structured and complex category, which is a qualitative feature characterized by a significant number of factors and causal relationships that have both quantitative and qualitative expression, this category will be explored using soft modeling with the construction of a cognitive model. This approach allows you to explore the system for stability, complexity, balance, to obtain strategies for the development of the built system and more. Quality of life is chosen as the object, which is defined as the target peak. The study aims to structure knowledge about the factor environment that shapes the quality of life, to identify the factors that have the greatest impact on the development of the system in general, and the target peak, in particular, to improve its level.

Next, we present a method for constructing a cognitive model. The algorithm

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of analysis and research of the cognitive model consists of a sequence of stages defined in (H. Kucherova et al., 2020). First, it is necessary to determine the purpose of modeling and to identify targets. At the next stage, a set of factors is formed, that meet the purpose of the study. All factors are classified into target factors (corresponding to the main purpose of modeling), controlled (those that can be directly influenced), intermediate (used to describe the subject area of research), external factors. The next step is to form a causal graph, justifying the direction and strength of the relationship between the factors. That is to form an digraph G=<V, E>, where V is the set of vertices of the digraph corresponding to the set of certain factors, E is the set of arcs of the digraph, which reflects the causal relationship between the factors.

The direction and weight of the arc, ie the relationship between factors, are determined by the direction and degree of intensity of influence between factors and takes values on the segment [- 1, 1]. During this period, the relationship between the factors may have the following meanings:

a) 0, if the effect is absent;

b) from 0 to 1 with a positive effect, ie if a change in the value of the vertex-cause on ei leads to a change in the value of the vertex-consequence on ei;

c) from -1 to 0 with a negative impact, ie if the change of the value of the vertex-cause on ei leads to a change in the value of the vertex-consequence on – ei;

Given that certain factors are characterized by different initial levels, we investigate the constructed cognitive model, considering the fuzzy logical conclusions about their impact on quality of life. The vertices of the sign digraph are denoted as Bi – linguistic variables, the values of input and output variables are transmitted through a linguistic description of the values of the factors T = {"Very low", "low", "medium", "high", "very high"}, given by fuzzy sets $T=\{(\alpha, \mu(\alpha)): \alpha \in X, \mu(\alpha)\in[0; 1]\}$, where α – elements of the set X, $\mu(\alpha)$ – the membership function of the corresponding fuzzy set:

$$\mu(\alpha) = \begin{cases} low \in [0, 0{,}2) \\ belowmedium \in [0{,}2; 0{,}37) \\ medium \in [0{,}37; 0{,}63) \\ abovemedium \in [0{,}63; 0{,}8) \\ high \in [0{,}8; 1] \end{cases} \qquad (1)$$

Measured values of linguistic descriptions are represented by the generalized Harrington desirability function, the range of this scale varies from 0 to 1, where the lowest measured value of the state of the factor corresponds to zero, and the largest – to "1".

At the next stage, a static analysis of the constructed model is performed by determining the balance of the constructed system, consonance and dissonance of influence (V. Silov, 1995, 228 p). This analysis allows to identify indirect interactions of factors on each other. Consonance determines how consistent the presence of concepts in the modeled system is, how adequate the chosen direction and influence is (a measure of the difference between positive and negative influence). Dissonance – how well-argued is the impact of the system on each of the concepts.

At the last stage, dynamic modeling of the constructed system is carried out to form a basic set of alternative strategies for system development and justification of priority strategies for achieving targets.

Results. For the research, we select 22 indicators of socio-economic situation of households in Ukraine, grouped into four groups, namely: Population, Education and Health, indicators of Economic condition (Table 1).

Table 1

Socio-economic indicators of the population of Ukraine

Code	Indicators	Code	Indicators
Population		Economic condition	
X1	Population	Q1	Unemployed population of working age
X2	Population migration	Q2	The average monthly salary
X3	Households without children	Q3	Self-assessment of households by income level
Education		Q4	Signs of poverty
Y1	Preschool and secondary education institutions	Q5	Populations with incomes below the subsistence level
Y2	Institutions of higher and professional higher education	Q6	Satisfaction with their living conditions
Y3	Art schools, libraries, theaters, museums, publishing books and brochures, concert activities	Q7	Funds for any professional education
Y4	Internet access	Q8	Funds for recreation and leisure
Y5	Level of education of the population	Q9	Consumption of a sufficient amount of quality food
Health		Q10	Privileges and subsidies for housing and communal services, electricity and fuel
Z1	Pollution, environmental problems (smog, odors, contaminated water, etc.)	Q11	Debts for housing and communal services
Z2	Satisfaction with the state of the health		Quality of life
Z3	Households in which any of the members were unable to receive medical care during the year		

Source: data generated from the source (State Statistics Service of Ukraine)

Examining the country's population statistics according to official data (State Statistics Service of Ukraine), a sharp decline in population was found due to low birth rates, high mortality rates and migration. Analyzing the indicators of the economic condition it was found an increase in unemployment and, despite the growth of the average monthly wage, a great need for funds for basic things. The study of health indicators revealed a decrease in consumption of almost all products, which, in our opinion, has a negative impact on the quality of life, but during the study period there was a reduction in pollutant emissions in Ukraine. Regarding the education indicator, there is a decrease in the number of students in both schools and institutions of higher education.

Based on their own theoretical conclusions (O. Kravets, & A. Didenko, 2021), using 22 indicators, built a cognitive model of population's quality of life of Ukraine (Fig. 1). Factors that form the system of indicators of population's quality

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of life are presented in the form of vertices of a digraph, where each vertex ui at discrete moments of time takes value $v_i(t)$ t = 0, 1, 2, …. The interaction between the vertices is presented in the form of arcs of the digraph, where the dotted line indicates the negative impact of one factor on another, and the solid line – a positive impact. The next step is to conduct a static analysis of the cognitive model, which will identify the factors that have the greatest impact on the population's quality of life.

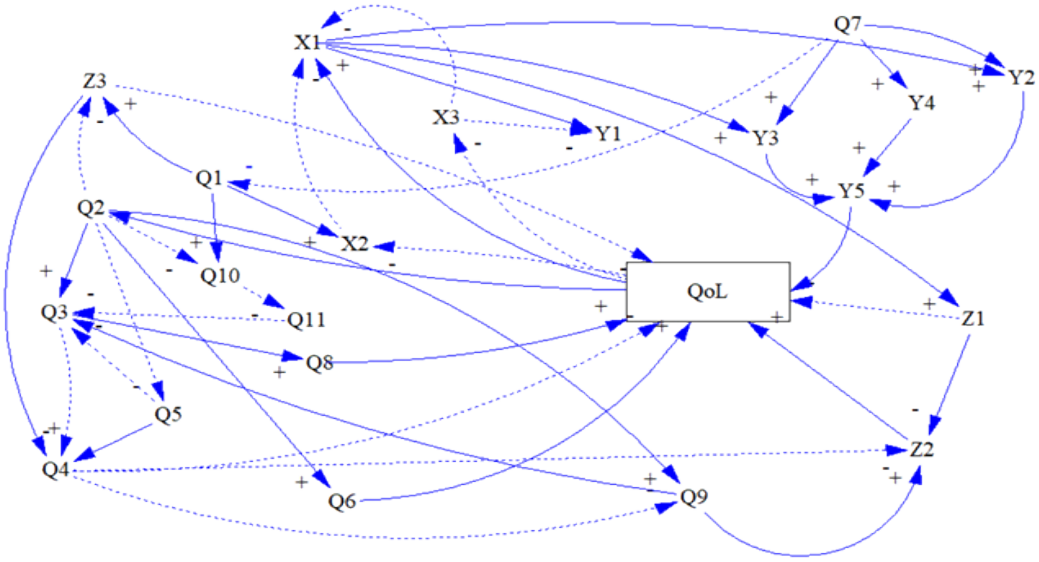

Figure 1 – The digraph of the cognitive model
Source: author's reseach

We turn to the static analysis of the cognitive model of Fig. 1. The fuzzy built model is manifested in the level variation of factors and relationships between them in the constructed system. For static analysis of the situation, the system characteristics of the cognitive model were calculated (see Table 2) according to the approach proposed in the research (V. Silov, 1995, 228 p).

Based on Table 2, the largest values of the consonance of the factor's impact on the system are the indicators of average monthly wages (0.798) and Privileges and subsidies for housing and communal services, electricity, and fuel (0.751). Analysis of the dissonance of the system's impact on the factor revealed the need to increase the level of education of the population as a whole (0.678) and contribute to increased satisfaction with health (0.578). Factors Signs of Poverty (Negative Impact) and Average Monthly Wages (Boosting Impact) are the biggest ones that strengthen the system. At the same time, the system itself has little impact on the Signs of Poverty, and the system has the greatest impact on the level of education. As a result of the analysis using the software product FCMapper, which allows to set the initial weights of the vertices and study their impact on other indicators of the system, cognitive model (Fig. 1), the following results were obtained: the density of the digraph is determined at the level of 0.09, this indicator measures the share of existing connections from potential ones, its value is within the interval [0; 1], the greater its value, the more active is the interaction between factors. The constructed model in the conditions of self-development of the system came to a stable state, which was provided by the availability of feedback, with the largest number of 47 iterations for factors "Population", "Pollution, environmental problems", "Consumption of sufficient quality food" and "Satisfaction with the state of the health", the lowest number of 42 iterations was set for the factor "Internet access".

Table 2

System characteristics of the cognitive model

Factors	Consonance of the factor's influence on the system	Consonance of the system's influence on the factor	Dissonance the factor's influence on the system	Dissonance of the system's influence on the factor	Influence of the concept on the system	Influence of the systems on the concept
X1	0,449	0,756	0,551	0,244	0,072	0,008
X2	0,469	0,731	0,531	0,269	-0,073	-0,054
X3	0,494	0,703	0,506	0,297	-0,002	-0,062
Y1	0,692	0,122	0,309	0,878	0,045	0,027
Y2	0,692	0,791	0,309	0,209	0,045	0,055
Y3	0,692	0,791	0,309	0,209	0,045	0,055
Y4	0,692	0,731	0,309	0,269	0,045	0,046
Y5	0,653	0,322	0,347	0,678	0,046	0,115
Z1	0,687	0,776	0,313	0,224	-0,068	0,029
Z2	0,653	0,422	0,347	0,578	0,046	-0,027
Z3	0,699	0,745	0,302	0,255	-0,044	-0,040
Q1	0,609	0,731	0,391	0,269	0,007	-0,046
Q2	0,798	0,703	0,202	0,297	0,084	0,062
Q3	0,734	0,623	0,266	0,377	0,045	0,041
Q4	0,717	0,671	0,283	0,329	-0,090	-0,003
Q5	0,740	0,712	0,261	0,289	-0,050	-0,050
Q6	0,653	0,712	0,347	0,289	0,046	0,050
Q7	0,684	0,712	0,316	0,289	0,043	0,050
Q8	0,653	0,632	0,347	0,368	0,046	0,040
Q9	0,740	0,757	0,260	0,243	0,067	0,027
Q10	0,751	0,745	0,250	0,255	-0,001	-0,040
Q11	0,742	0,754	0,258	0,246	-0,041	-0,002
QoL	0,619	0,669	0,381	0,331	0,049	0,080

Source: calculated by the authors in decision support system "NEEDLE"

Next, we have analyzed three scenarios of system development when changing the values of the factors that have the greatest impact on the system: "Average monthly wages" and "Benefits and subsidies for housing and communal services, electricity and fuel". To quantify the dynamics of the system, the degree of influence of one factor on another is divided into values on a scale (1). For the first scenario, the initial value of the level of the vertex "Average monthly wages" and "Benefits and subsidies for housing and communal services, electricity and fuel" was chosen as low (0.1); for the second scenario – at the level of medium value (0.5), for the third at the level of high value (0.9).

Low and medium values of the factor "Average monthly wages" have the greatest impact on "Households in which one of the members during the year could not receive medical care", "Signs of poverty", "Populations with incomes below the subsistence level", "Benefits and subsidies for payment for housing and communal services, electricity and fuel".

With the increase in the factor "Average monthly wages" the greatest positive shift

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is in the vertex "Consumption of sufficient quality food", while decreasing the number of households in which any member during the year could not receive health care, decreases the number of households in need benefits and subsidies for housing and communal services, electricity and fuel, and the sign of poverty in general is declining. Low average monthly wages negatively affect a person's satisfaction with their health, reduce household self-esteem in terms of income, satisfaction with their living conditions, reduce funding for vocational education and consumption of a sufficient amount of quality food.

Changing the factor "Privileges and subsidies for housing and communal services, electricity and fuel" to a low and medium value increases arrears of housing and communal services and reduces the self-esteem of households by income level. With a high value of the factor "Benefits and subsidies for housing and communal services, electricity and fuel" decreases "Signs of poverty" and "Debts for housing and communal services", while increasing "Leisure and leisure" and "Self-assessment of households by income level".

The assessment of quality of life is most influenced by a group of health factors, and this group also has a significant impact on population decline. Lack of work is a determining factor for migration, rising arrears of housing and communal services and deteriorating access to health care. The growth of the quality of life indicator contributes the most to the growth of the population and reduces its migration.

Conclusions. Structural analysis of the cognitive model made it possible to assess the classes of factors, establish the system characteristics of the model, identify the factors that have the greatest impact on the system, and assess their importance in modeling the self-development of the situation. Considering the weights of factors and external influences, it is determined that the assessment of the quality of life is most influenced by a group of health factors, while the growth of quality of life contributes most to population growth and migration. Further research is aimed at a dynamic analysis of the cognitive model and the construction of scenarios for improving the population's quality of life.

Conflict of Interest and other Ethics Statements

The authors declare no conflict of interest.

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КОГНІТИВНИЙ ПІДХІД ДО МОДЕЛЮВАННЯ ЯКОСТІ ЖИТТЯ НАСЕЛЕННЯ

Анотація. Оцінка свого положення щодо рівня розвитку економічного та людського капіталу, побудова стратегії для підвищення якості життя є вкрай важливим для держави, тому дослідження показників, що формують якість життя та виявляють найбільший на неї вплив досі залишається актуальним питанням. Оскільки саме поняття якість життя є багатокомпонентною категорією, яку характеризують як об'єктивні, так і суб'єктивні показники, тому вважаємо доцільним структуризацію знань про факторне середовище, що формує якість життя населення, їх відображення шляхом формування когнітивної моделі, проведення її статичного аналізу для виявлення факторів, що мають найбільший вплив на якість життя для підвищення її рівня, що й відображає мету дослідження. Побудовано когнітивну модель якості життя у вигляді зваженого орграфу, який створено на основі 22 показників соціально-економічного становища домогосподарств України, що об'єднані у чотири групи, а саме: населення, освіта та здоров'я, показники економічного стану. Структурний аналіз когнітивної моделі дав змогу оцінити класи факторів, встановити системні характеристики моделі, виявити фактори, що мають найбільший вплив на систему та оцінити їх вагомість при моделюванні саморозвитку ситуації. З урахуванням ваг факторів та зовнішнього впливу визначено, що на оцінку якості життя населення найбільший вплив здійснює група факторів здоров'я, при цьому зростання показника якості життя найбільше сприяє зростанню чисельності населення та зменшує його міграцію.

Ключові слова: *якість життя, когнітивне моделювання, статичний аналіз, орграф, соцально-економічні індикатори*

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