***The IT industry occupies a significant place in the economy of the world. Trends in its development directly affect changes in various sectors of the economy.***

***This paper considers the dynamics of IT industry under conditions of increased entropy of the functioning environment caused by crises, military conflicts, non-standard events. The mathematical basis of the study is an apparatus of fuzzy logic.***

***The proposed technique for analyzing and forecasting the state and dynamics of the IT sector makes it possible to take into account the influences of a set of factors of different nature and direction of action, which contributes to obtaining a reasonable assessment under conditions of inaccurate information. The software platform for implementing the methodology is the authentically designed fuzzy expert system (ES) FuzzyKIDE.***

***The conceptual foundations of the platform structure have been defined. A modification of the fuzzy inference mechanism has been proposed, which, unlike existing samples, makes it possible to eliminate saving intermediate results and reduces the load on the database. The composition and structure of the knowledge base (KB) for ES have been proposed. Fuzzy rules are based on predetermined relationships between key factors of influence. The technology of ES operation is represented using simulated scenarios with obtaining predictive results. The analysis of the final data of expert consultations proves the ES operability, providing for the possibility of KB significant expansion in the process of industrial operation. The use of ES is aimed at forming a holistic view of possible directions of IT sector development. Maintaining the actual state of ES KB is a condition for early warning of the emergent negative/crisis phenomena.***

***The FuzzyKIDE expert consulting system is proposed as a tool to support management decision-making based on the analysis and forecasting of the state and dynamics of IT sector under conditions of high uncertainty***

***Keywords: IT industry, development trends, fuzzy logic, expert system, FuzzyKIDE software platform***

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# FORECASTING DEVELOPMENT TRENDS IN THE INFORMATION TECHNOLOGY INDUSTRY USING FUZZY LOGIC

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## 1. Introduction

The development of society in recent decades has been marked by rapid changes in technology, the growing spread of digital devices and services, which was accompanied by the expansion of big data analytics, artificial intelligence, cloud computing, and digital platforms.

Due to the accelerated pace of technological innovation, the global IT industry has demonstrated almost constant growth dynamics. The annual growth rate of the industry before the pandemic, in the period of 2016–2019, was within a stable range from 2 % to 5 % [1].

During the pandemic, the IT sector, like all other sectors of the economy, suffered a crisis [1]. The recovery of the pace of the industry from 2021 was accompanied by structural changes – in particular, an increase in the activity of some IT market players. Thus, the first lines of exporters of IT services included countries such as India, China, Ireland, and Finland. The share of IT services in the export structure of individual countries has changed. For example, the export of IT services reached more than 8 % of all Ukrainian exports, showing an increase of almost 36 % in 2021 [2, 3].

Analysis of the regional distribution of IT costs proves that at the current stage the main markets are North America, Asia, and Europe, which concentrate 78 % of the total global IT expenditures [4].

The consequences of the COVID-19 pandemic, military conflicts, and environmental shifts continue to put pressure on the global economy, as well as many other factors of diverse nature and direction of action, which exacerbates the uncertainty of global and regional IT markets. This proves the variability of trends in the high-tech IT industry, complicated by the predicted global recession and crisis.

Given the importance of the IT sector for the economies of the world, it becomes relevant to carry out a predictive analysis of the state and dynamics of the IT industry under conditions of increased environmental entropy – crises, military conflicts, non-standard events.

The main challenge is to determine the mathematical apparatus of research, adequate to the tasks set. We are talking about the need to take into account the influences of numerous «qualitative» factors, the effect of which cannot be formalized or amenable only to partial formalization. Quantitative methods in the above conditions are inappropriate. The nature of the studied relationships and the presence of indirect influences complicate the implementation of the stochastic approach. The inaccuracy of incoming information leads to the need to use in the

process of forecasting the knowledge bases of many expert specialists. All this forms the basis for attracting intelligent information technologies – expert systems.

The development of the field of artificial intelligence is inextricably linked with the development of its symbolic direction, within which the development of expert systems (ES) – knowledge-based systems – is underway. But, despite the significant development of the apparatus and the presence of a certain number of actual applications, the processes of improving its mathematical foundations and architectural principles of construction continue. The range of subject areas of use and technology of applied operation is also expanding.

The problem posed conceptually corresponds to the use of expert systems with fuzzy logic:

– availability of fuzzy incoming information;

– information processing using fuzzy logic and fuzzy mathematics;

– transformation of fuzzy result information into a clear result-conclusion on the analytical assessment of the state and determination of forecast trends in the IT industry.

The procedure of application of the apparatus will make it possible to timely assess the directions of development of the IT sector for the future, which will create conditions for the timely identification of problem areas and decision-making in the hierarchy of IT industry management. In fact, expert systems, as a forecasting apparatus in fuzzy conditions, can be used in the decision-making process at all levels of management. At the macro level – in the activities of institutions whose competence includes the development of the IT industry (for example, Ministry of Digital Transformation). At the meso and micro levels – in the course of strategic planning for the development of specific IT clusters, individual product/outsourcing IT companies, or their professional associations (for example, the IT Ukraine Association is a specialized association of IT companies that has a strategic partnership with various IT clusters).

Directions of managerial influences may relate to various aspects of the functioning of the IT sector of the country, namely:

– formation of regulatory policy for the development of the industry. In particular, the creation of a favorable legislative framework for the functioning of IT business, including effective tax legislation;

– providing a business environment favorable for the development of specific clusters. Namely, increasing demand from domestic customers and attracting external customers (for example, attracting international industrial companies to the domestic market) – all this against the background of positive dynamics of digitalization of the economy;

– ensuring balanced development of the product and IT outsourcing sectors, namely supporting the current reorientation to an integrated product approach;

– support of effective investment policy towards industry entities. That is, attracting foreign and domestic investors; reinvestment of funds by local companies in growth, as opposed to withdrawing profits to low-tax jurisdictions; investing in IT education;

– formation of an appropriate level of human capital. We are talking about decisions related to ensuring a sufficient number of specialists of appropriate qualifications, curbing the outflow of personnel and improving the system of training specialists in educational institutions. We are also talking about improving the efficiency of personnel assessment in employment, the introduction of permanent professional development systems for IT specialists and creation of an effective personnel management system for IT companies, in particular, a motivation system.

Thus, regular monitoring and forecasting of global and regional trends in the development of the IT industry will contribute to the development of effective solutions aimed at the balanced development of the domestic IT market; increasing the additional value of software products and services; directing financial flows into the economy and increasing the share of the IT sector in the country's GDP.

## 2. Literature review and problem statement

Solving the problem of uncertainty in the context of economic analysis and modeling through the use of expert systems (ES) attracts the attention of many researchers, which is reflected in a certain range of software developments. The INVEX expert system [5] helps project analysts determine whether a project is acceptable and, if so, whether it is the best alternative, as well as calculate the degree of sensitivity of the project to certain critical assumptions.

The methodology for obtaining knowledge and their representation in the field of financial analysis is implemented in a system called FINEVA [6]. It is a multi-criteria knowledge-based decision support system for assessing corporate performance and viability. The result of FINEVA's work is the ranking of the companies in question according to the risk class.

FAME is a consulting expert system that helps in the preparation of comprehensive recommendations for financial marketing [7].

One can also mention the expert system TAXMAN [8]. It is one of the oldest expert systems and is capable of representing a very structured form of legal justification for corporate reorganization.

A clone of the well-known CLIPS system (in fact, a language platform for creating shells of expert systems) – fuzzy ES FuzzyClips [9] – has become common for solving many problems in various areas, in particular, in the field of economics [10, 11].

There are examples of using fuzzy logic to predict and prevent problems in various sectors of the economy.

Thus, in [12], a fuzzy system is reported, which is used to predict and timely prevent crisis phenomena in the banking sector. The results of the system development on the example of the countries of the Asiatic-Pacific region are given. The rationale for using the apparatus of fuzzy logic is the impossibility of a logical explanation of the behavior of variables affecting the emergence of crises, based on the use of statistical models. It is proved that models of this class lose their efficiency with an increase in the number of variables. Another limitation of the use of econometric apparatus is the problem of stationarity. At the same time, a fuzzy approach eliminates the shortcomings of referring to limited data and statistical models, which opens up the possibility of using a set of the most important variables for the formation of the crisis index, namely, it creates a basis for predictive calculations.

Paper [13] describes an expert system used to predict losses in the credit card industry using macroeconomic in-

dicators. Typical architectural features of the apparatus of expert systems (availability of databases and knowledge bases) make it possible to form and keep up to date a significant set of indicators that cover various aspects of the economy, consumer, business and public sectors. The positive point is use in the process of developing the structure of the proposed expert system of modern machine learning methods. According to the above, the results of the operation of the system have proven ample opportunities to determine the impact of macroeconomic conditions on future losses in the credit card industry. The custom service of the system makes it possible to get a holistic view of the development trends of the studied industry.

One example of the use of an improved fuzzy system based on rules is the original development used to predict investments in the field of ecology [14]. The cited paper proposes a new model for forecasting investments using a fuzzy rules-based system (FRBS), an "evidence-based reasoning" (ER) approach, and a subtractive clustering algorithm (SC), called FRBS-ERSC.

This contributes to the solution of a number of problems of forecasting calculations in the above investment industry based on the use of traditional econometric models:

– considerable dimensionality of the problem;

– the need to attract a large amount of retrospective data;

– the need to take into account the degree of complexity of econometric forecasting models in compliance with a transparent interpretation of the final results.

Experimental data proved that the proposed approach (FRBS-ERSC) provided sufficient interpretation and scalable investment forecasting through effective selection of indicators and keeping the data up to date. The operation of the expert system also ensured higher forecast accuracy compared to existing models.

The use of fuzzy neural network in the forecasting of foreign trade exports is reported in [15]. The forecasting model is based on the unification of the neural network and the theory of fuzziness; types and algorithms for training fuzzy neural network have been introduced. The apparatus used implements the possibilities of predictive calculations taking into account the influences of numerous factors of various nature.

Summarizing the results of specific developments on the creation and implementation of the apparatus of expert systems, we shall focus on the value of their contribution to solving various problems of the economy [16, 17]:

– expert systems should be used to reduce the risk of doing business;

– learning processes in the management of economic systems suggest that the creation of one expert system makes the creation of other expert systems easier and cheaper, thus adding value;

– these systems are very intuitive for decision-makers, especially when the concept of "if-then" rules is used;

– expert systems can combine different sources of knowledge (expert opinion, literary sources, clear data);

– the knowledge base of some expert systems can be quickly updated and improved.

Despite the number of advantages provided by expert systems, it makes sense to focus again on the issue of uncertainty. Determining clear requirements in the field of application of expert systems can cause great difficulties because it is not always possible to clarify them at the beginning of the development of the system itself or the knowledge base for it.

One of the most common techniques to overcome this problem is expert assessment. Although such an assessment can be effective, it suffers from problems of subjectivity and vulnerability to the loss of knowledge. In these circumstances, there is a need not for more formalized metrics – rather, it is necessary to find a way to balance the combination of expert and formal modeling.

The above applications prove the positive results of the use of the apparatus of expert systems, in particular, in the processes of analysis and forecasting. However, the spread of the apparatus in real practice still cannot be considered sufficient. This is especially true of crisis events with the complete absence or presence of a small circle of such precedents.

Working under conditions of inaccurate information creates the need to use a fuzzy logic apparatus – powerful software platforms of fuzzy expert systems.

## 3. The aim and objectives of the study

The aim of our study is to develop a methodology for analyzing and forecasting the state and dynamics of the development of the IT sector of the economy based on the use of a mathematical apparatus of fuzzy logic. This will make it possible to create a system of preliminary response to crisis phenomena and non-standard situations in the processes of functioning of the industry and provide a base for supporting relevant management decisions.

To achieve the set aim, the following tasks have been solved:

– to identify key factors influencing the state and dynamics of the industry's development in an uncertain environment of functioning based on the analysis of current trends in the IT industry;

– to offer the composition and structure of the knowledge base for consultations with the expert system under fuzzy conditions;

– to test the technology of using a fuzzy expert system to predict the state and trends of the regional IT industry.

## 4. The study materials and methods

The object of research is the processes of development of the IT industry under conditions of increased entropy of the functioning environment.

Research hypothesis assumes that assessment of trends in the development of the IT sector for the future under conditions of uncertainty requires a comprehensive system for taking into account the influences of factors of various nature (both quantitative and qualitative) and the direction of action, which is possible on the basis of involving the mathematical apparatus of fuzzy logic.

The following arguments can be given in favor of the use of expert systems based on fuzzy logic [18].

*The ability to cope with uncertainty.* A very important part of the forecasting process is to provide estimates as close as possible to the actual results achieved. The probability of divergence between the actual and the projected estimates increases when only minimal input information is

available. In the case of using fuzzy logic, the assessment can be made more accurate if it is possible to constantly update the information in the database/knowledge base.

*Variability of detail and ability to cope with minimal data*. When analyzing requirements, the input and output data of the model can be represented in linguistic form. This data becomes fuzzy numbers during design and is converted to exact values when more data is known.

*Resistance to abnormal observations*. It often happens that datasets contain unusual observations, thus reducing the overall accuracy of any empirical model. Problems of non-representative data can be reduced or avoided by developing models involving experts where the model can be interpreted, tested, and refined as needed.

*Use of expert knowledge*. Since fuzzy logic allows us to present concepts as functions of membership and association between these concepts (usually in linguistic form), it is possible to make very easy use of expert knowledge about such concepts and relationships in a fuzzy system.

*Accessibility and transparency during learning*. Although there are several important mathematical principles regarding fuzzy logic, the technique is comprehensible for both beginners and experts. The output result of the fuzzy model is also completely clear since the transition from input data to output can be analyzed and modified.

As an applied software implementation of the mathematical apparatus, our original development is proposed – a fuzzy expert system FuzzyKIDE.

The system has been tested in the process of solving the problems of managing a portfolio of outsourcing IT projects [11, 19]. The architectural and technological typicality of the developed software platform proves the possibilities of its use for solving a wide range of problems arising under the conditions of the need to work with inaccurate data using effective mechanisms of logical conclusions.

The general architecture of the shell is shown in Fig. 1. The main components of the FuzzyKIDE ES shell are:

1. Database (input) stores the initial data as comma-separated values (CSV). Each input value consists of its own name, through which it is fed in the knowledge base, a clear value, and a trust factor from 0 to 1, which reflects the user's confidence in a clear meaning.

2. Knowledge base consists of inference rules and linguistic variables that are used to analyze by the core of logical inference.

3. Core of inference handles knowledge base-based input data and is implemented using the SNePS semantic network.

4. Graphical interface (GUI) allows the user to interact with the knowledge base, execute fuzzy core of inference, view fuzzy and clear inference results.

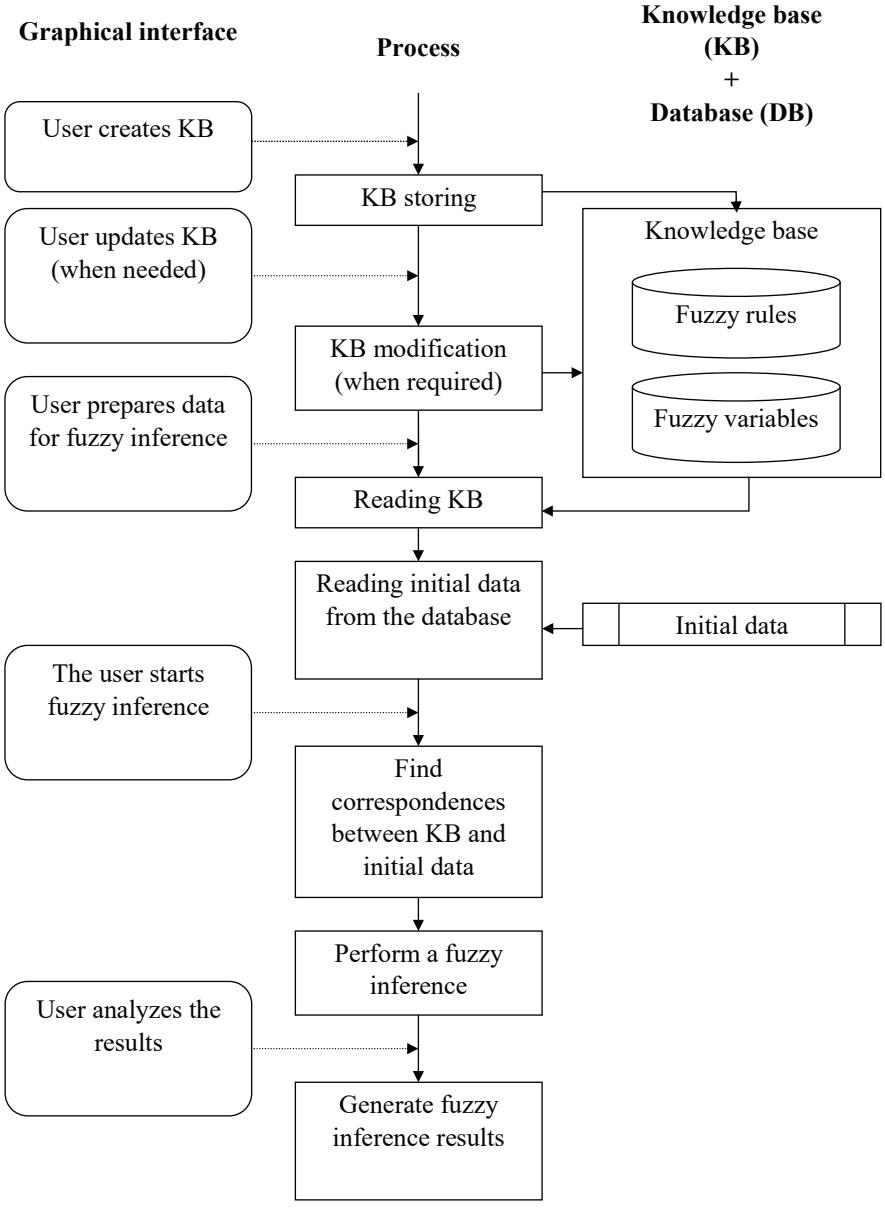


Fig. 1. Interaction process with FuzzyKIDE

The functioning of the system does not depend on the specificity of the subject area; it can work with a knowledge base of various subject areas, which potentially expands the range of its use.

The system works on the basis of a simplified knowledge base structure, which consists of fairly simple-to-understand fuzzy rules and linguistic variables of the following type:

IF (*X*=A) THEN (*Y*=C),

*X*:Initial:[A:Trapezoidal:(A1,A2,A3,A4)|B:Trapezoidal:(B1,B2,B3,B4)],

*Y*:Derivative:[C:Trapezoidal:(C1,C2,C3,C4)|D:Trapezoidal:(D1,D2,D3,D4)],

where *X*, *Y* are the linguistic variables that are specified in the database of linguistic variables;

A, C – fuzzy linguistic equivalents of some clear meanings associated with the corresponding linguistic variable;

A, B – sets of values for the linguistic variable *X*;

C, D – sets of values for the linguistic variable *Y*;

(A1–A4), (B1–B4), (C1–C4), (D1–D4) – limits of clear values for fuzzy values of A, B, C, and D, respectively.

Trapezoidal indicates a trapezoidal type of membership function used to describe the values of a linguistic variable.

FuzzyKIDE's fuzzy inference kernel is implemented based on the SNePS semantic network [20]. The combination of using a simplified knowledge base structure and a semantic SNePS network made it possible to get rid of the intermediate facts base during fuzzy inference. At the same time, that made it possible to obtain all the information necessary for fuzzy inference, without repeated queries to the database or knowledge base, which potentially speeds up the process of fuzzy inference.

A more detailed description of the fuzzy expert system FuzzyKIDE can be found in [19, 21], which prove the advantages of using the system in comparison with the classic fuzzy expert systems. Works [19, 21] carefully described the structure of the knowledge base, on the basis of which the system is implemented, as well as the technology for using SNePS semantic network. Examples of the use of FuzzyKIDE to support decision-making in the IT portfolio management process are demonstrated within a typical IT company.

## 5. Results of the study of forecasting trends in the development of the IT industry using the apparatus of fuzzy logic

### 5. 1. Analysis of the current state of the IT industry using Ukraine as an example

The IT industry is a relatively young industry for Ukraine, but it quickly became an important element in creating the country's image. At the end of 2021, the industry provided 37 % of Ukrainian export for services and USD 6.8 billion in revenues to the Ukrainian economy. At the beginning of 2022, the IT industry involved 285 thousand of IT specialists and paid taxes worth USD 800 million. The share of exports of IT services in Ukraine at the end of 2021 amounted to about 2.7 % of the country's GDP [22].

According to the NBU, the growth of the influence of the IT industry continued until the war and, in February 2022, reached a record monthly export figure of USD 839 million. This is 43 % more than in the same period in 2021 – USD 480 million. Also, according to the bottom of the NBU, it is known that in March 2022, the Ukrainian IT industry lost 35 % of the volume of exports of computer services, namely USD 317 million, compared to exports in February 2022 [23].

The level of emigration of IT specialists since the beginning of hostilities was considered. The war led to a humanitarian crisis, which provoked high levels of forced displacement of the Ukrainian population. Since February 24, 2022, more than 6 million Ukrainian citizens have been forced to seek asylum in countries neighboring Ukraine. More than 2.5 million of them continued their journey to other countries. At the same time, about 6.5 million people are internally displaced persons [24–26]. Thus, about a third of the Ukrainian population was displaced internally and externally.

The ILO estimates that among the total number of refugees, approximately 3 million are of working age. Of these, 43.5 % worked before the war and left or lost their jobs during the war. The vast majority, namely 88 %, were employees of enterprises, and the remaining 12 % were self-employed. Two-thirds have higher education and half were employed in highly skilled professions [26]. Quite a representative indicator is 12 % of self-employed citizens of Ukraine. Most Ukrainian IT companies hire IT specialists as contractors in order to reduce the actual number of their employees, which, in turn, allows companies to reduce the amount of taxes that need to be paid to the Ukrainian treasury. Most of the previously mentioned 12 % can be IT specialists, which is approximately 100–150 thousand IT specialists who have been able to leave the country since the beginning of the war.

In general, estimates show that up to 70 percent of Ukraine's population has already suffered from hostilities [26]. But very interesting is the question of the possible future impact. Since the situation is multifactorial both politically and globally-economically, it is rather difficult to make reliable assumptions. Given the prevailing variability, further forecasts focus on the impact of the war on the incomes of ordinary citizens of Ukraine, namely on the impact of the country's GDP reduction on these incomes. UNDP considered 4 main scenarios [27]:

1. Reduction by 7 %. It is based on armed conflicts in 45 countries in sub-Saharan Africa during 1989–2017.

2. Reduction by 15 %. It is based on the reduction in GDP observed in Ukraine during the ATO in the south-east of the country in 2014–2015.

3. Reduction by 20 %. It is based on the reduction in GDP observed in the wars in Yugoslavia or Georgia, and on economic evidence of large-scale wars.

4. Reduction by 60 %. This is an extreme assumption based on previous experience of Oxford Economics. For example, Lebanon's economy contracted by about 40 % in 1982 (the war in Lebanon) and 1989 (the war for liberation). Also, the economy of South Sudan declined by more than 50 % in 2012 (Heglig crisis). Libya's economy contracted by 53 % in 2014 (second civil war), by 60 % in 2020 (the second civil war), and by 67 % in 2011 (military intervention) [27].

Early UNDP forecasts suggest that regressions in Ukraine's development will be significant in the medium term. If the war drags on, up to 90 % of Ukraine's population may be below the poverty line. The simulation predicts the consequences of a decrease in household incomes of at least 15 % (scenario 2). In this scenario, more than 6 % of the population is expected to live below the USD 5.50 per day poverty line in 12 months. It is estimated that 54 % of the population will live at high risk of returning to poverty, i.e., under the vulnerability limit of USD 13 per day [27]. If the crisis continues and deepens, forecasts indicate that 90 % of the population will face poverty or vulnerability to poverty (scenario 4). This forecast means the loss of 18 years of socio-economic achievements in Ukraine and a return to poverty, which was last observed in 2004.

Taking into account the previously demonstrated static data, it is inevitable to reduce the standard of living, reduced availability of basic things and services, increase prices and general regression of Ukraine's development. The longer the war, the greater the regression level will be. Thus, IT specialists who are already abroad and still work for Ukrainian IT companies may decide to emigrate on an ongoing basis, which harms the IT sector. The potential reduction of the Ukrainian IT sector will negatively affect the economy of Ukraine and reduce the capacity for economic recovery of the country, but this is not the only factor that will have a similar effect. It should not be forgotten that almost 2 million able-bodied refugees have higher education and can come to similar conclusions about emigration on a permanent basis [26]. In combination with the fact that 2 million refugees are children and adolescents, this creates conditions for the outflow of both the present and future intellectual potential of the country, including future IT specialists.

The impact of the Russian-Ukrainian war on the world economy was considered and the existing statistics on this issue were analyzed. As noted above, millions of refugees have moved to Ukraine's neighboring countries. There is a high probability that the crisis will become protracted and the continuation of hostilities will force refugees to stay in the host countries longer and start looking for work in the labor market. Another group of concern is those who are unable to find work on site, i.e. children, the disabled, and the elderly.

Given the number, Poland currently faces the biggest problem of integrating Ukrainian refugees with the Polish labor market: approximately 410,000 previously employed refugees live in Poland, including 200,000 highly skilled ones. Romania is home to about 140 thousand Ukrainians who lost their jobs during the fighting. The current situation will increase the unemployment rate in Poland from 3 % to 5.3 % and from 2.5 % to 6.9 % in Moldova. Slovakia and Romania will see an increase of more than 1 % [26, 28].

One should also consider the impact of the war on the labor market of Central Asia because it is closely related to the Russian population. There are already significant economic disruptions and employment problems in countries such as Kazakhstan, Uzbekistan, Kyrgyzstan, and Tajikistan, whose economies are heavily dependent on remittances of migrant workers from the Russian Federation. For example, in Kyrgyzstan, remittances in 2020 amounted to 31.3 percent of GDP, and in Tajikistan – 26.7 percent [28, 29]. In addition to the fact that these remittances may be significantly reduced in 2023, it is predicted that migrant workers from the Russian Federation will return to their countries of origin. This will create additional pressure on labor markets in these countries, many of which are already suffering from high unemployment and low wages.

Having considered the impact of the war on the immediate neighbors of the participants in the war, the impact on the global economy was further considered. Against the backdrop of the COVID-19 crisis, which has severely affected labor markets around the world, the russian-Ukrainian war has become a source of a new global financial shock. Commodity prices have skyrocketed, especially for food and fuel. Supply chains continue to fail. The FAO food price index in March 2022 amounted to 159.3 points, which is 12.6 % more than in February 2022. This is the highest level since the beginning of index determination in 1990 [30]. The World Food Program estimates that an additional 47 million people were at risk of starvation in 2022 in addition to the baseline of 267 million of people [31]. The negative impact of the food crisis on the labor market and the level of wages in low- and middle-income countries is expected [28].

Taking into account the information above, we can conclude that conditions are being created for finding new regions for IT investments. Possible markets for investment may be North America, Latin America, the Middle East, and Africa, as these regions are less affected by the impact of the war [28]. If we take into account the specificity of the IT industry, then Central Asia and India can also act as additional alternative markets. Negative economic impact on Central Asia and the expected increase in unemployment [28, 29] due to the return of migrant workers from Russia makes this region attractive for accelerating the development of its own IT sector. The development of the IT industry in order to level the expected negative economic impacts may encourage the unemployed to retrain the unemployed and create favorable conditions for investments from abroad. India is already one of the most popular markets for IT outsourcing but the current situation may encourage investors to further strengthen the influence of this region on the global IT industry. Despite the tendency to simplify work in the post-Covid space [32], the negative consequences of the Russian-Ukrainian war may be the reason for finding other IT markets in order to reduce the risk of investment in Ukrainian IT sector.

In parallel with the creation of conditions for the search for new IT markets, it is necessary to take into account the formation of a base for luring Ukrainian IT specialists into the European IT space. European companies, including IT, are in a hurry to create job offers. Many of these companies focus exclusively on Ukrainian refugees. This is happening at a rare rate for the European Union. As long as governments abolish visa requirements and provide almost instant access to the labor and education market, millions of Ukrainians are in a fast lane for protection and employment. This speed is due to the growing labor shortage in Europe in the post-COVID space. During 2020–2022, the pandemic increased demand for a number of scarce professions. Not surprisingly, the biggest deficit is observed for healthcare professionals. But interestingly, following them, the demand for IT specialists continues to grow due to the acceleration of the digital transition due to the pandemic [33].

Thus, the high scale of emigration of highly qualified Ukrainian specialists, outlined earlier, has created favorable conditions for eliminating the labor shortage in Europe. In Germany, where more than 300,000 jobs are not filled, a group of entrepreneurs created JobAidUkraine to help refugees find work. Recently, nearly 30,000 online visitors viewed more than 5,000 jobs offered by companies from London to Lisbon for HR professionals, software developers, and nursing assistants. Portuguese companies have already registered 20 thousand job offers for Ukrainians in the fields of information technology and transport. The Czech Republic, where there are almost 364 thousand vacancies, accepted almost 300 thousand Ukrainian refugees who are trying to integrate as soon as possible. The country needs IT specialists and people who specialize in data analytics and finance [34].

According to the already available statistics, there is a creation of unfavorable conditions for the IT industry of Ukraine as a result of the war. One of the factors is the neg-

ative impact of the war on the economy of Ukraine, namely on the expected decrease in the solvency of the average Ukrainian. The rate of reduction will depend on the duration of the war and will be at least 7 % according to optimistic forecasts [27]. This will lead to an increase in poverty levels. In combination with high levels of destruction of Ukrainian infrastructure and physical assets, this can lead to a massive outflow of IT specialists in future.

Another factor is the labor market crisis that already exists in Europe. The available statistics on the levels of emigration of IT specialists demonstrate the creation of favorable conditions for leveling the crisis of the labor market in Europe at the expense of Ukrainian refugees. In the long run, this may adversely affect the country's economy as a whole.

There are already attempts to popularize the IT sector of Ukraine in order to increase investments [35, 36]. As a response to the expected reduction of the IT sector, the IT Generation initiative from the Ministry of Digital Transformation of Ukraine for the training of IT specialists on budgeting by the Ukrainian government was created [37].

It is quite difficult to predict the success of these attempts in the long run but it makes sense to expect investors to want to invest in less risky areas. Taking into account the impact of the Russian-Ukrainian war on the world economy, Central Asia has the opportunity to become a new IT outsourcing hub, and India is more entrenched as an existing IT outsourcing hub.

### 5. 2. Composition and structure of a fuzzy knowledge base in the FuzzyKIDE ES

The conclusions of the analysis of the state of the IT industry in Ukraine, set out earlier, seem objective. However, they cannot be a reliable basis for assessing the dynamics of the industry for the future due to the variability of its internal and external environment.

Initially, based on the already conducted analysis of the current state of the industry, basic patterns and relationships between factors that affect its development were identified. This helps to build a fuzzy knowledge base and form the initial data necessary for the operation of the system.

Preliminary analysis proved that one of the most important factors of influence is the level of external migration of IT specialists. At the same time, there are a number of second-level factors that determine the level of migration, and can be divided into internal and external. One of the most important internal factors is the average income of an ordinary citizen in wartime. The quality of life in the country depends on this indicator and its change directly affects the level of external migration of highly qualified specialists, including IT.

An influential external factor is the policy of other countries towards Ukrainian specialists. Among the components of this impact are the state of the European IT industry in the post-COVID space and the creation of integration programs and proposals for Ukrainian IT specialists in order to reduce staff shortages. The level of migration is one of the most important factors that affects the number of specialists employed in the Ukrainian IT industry and their distribution among the two largest subsectors – outsourcing IT companies and IT product companies.

This distribution is quite important because it determines the size and nature of investments in the IT industry of Ukraine. On the one hand, the decline in social security in the country may encourage IT specialists who remained in Ukraine to move to product companies that have a greater level of involvement in the social security of their employees. Given that Ukraine is one of the leaders in providing IT outsourcing services in the world, this trend may cast doubt on this status. On the other hand, under martial law, the risks inherent in foreign investment in the Ukrainian IT industry are growing, which will directly affect the reduction of the product subsector, including startups. In turn, the reduction of the IT product subsector can dramatically reduce the level of foreign investment, so it is worth paying attention to the distribution of labor between the product and outsourcing sub-sectors.

The level of migration affects the quality of higher and professional IT education. The outflow of intellectual labor can adversely affect the number of specialists who graduate annually. With the long-term continuation of this trend, we can expect an increase in domestic investment to level this negative effect. But we can also expect a decrease in the levels of foreign investment until it becomes profitable to invest again. In more detail, these factors, and the relationships between them can be illustrated by Fig. 2.

In combination, the previously mentioned factors help to assess the trend of changes in the internal share of the IT sector in Ukraine's GDP, as well as to assess trends in changes in Ukraine's position in the world rankings of IT service providers.

Having a conceptual model of the relationship between various factors, we shall form a fuzzy set of rules for the task of analyzing trends in the development of the IT industry in Ukraine. It should be noted that the created set of rules is simulated, not exhaustive, and is simplified for the purpose of demonstration. If it becomes necessary to take into account a greater number of factors, it is possible to expand the set of rules and try to carry out a fuzzy inference again. A fuzzy set of rules was built from the following templates:

1. IF [Ukraine GPD trend is A] THEN [Average person income scenario is *X*].

2. IF [Average person income scenario is A AND War duration is B] THEN [Population external migration trend is *X* AND Social security trend is *Y*].

3. IF [COVID influence is A AND Europe IT market offers amount is B AND Alternative IT labor markets trend is C] THEN [Europe IT market trend is *X*].

4. IF [Population external migration trend is A AND War duration is B AND Europe IT market trend is C] THEN [IT specialists external migration trend is *X*].

5. IF [Population external migration trend is A AND IT specialists external migration trend is B] THEN [IT education quality is *X*].

6. IF [IT education quality is A and IT specialists external migration trend is B AND Social security trend is C] THEN [Ukraine IT outsource market share is *X* AND Ukraine IT product market share is *Y*].

7. IF [Ukraine IT outsource market share is A AND Ukraine digitalization program trend is B AND Central Asia IT market development trend is C] THEN [Foreign outsource offers trend is *X*].

8. IF [Ukraine IT product market share is A AND Ukraine digitalization program trend is B AND Central Asia IT market development trend is C] THEN [Foreign product investments trend is *X*].

9. IF [Ukraine IT product market share is A] THEN [Start-up investments trend is *X*].

10. IF [Foreign outsource offers trend is A AND Foreign product investments trend is B AND Start-up investments trend is C] THEN [Ukraine IT market GDP share trend is *X*].

11. IF [Ukraine IT market GDP share trend is A] THEN [Ukraine IT export global share is *X*].

12. IF [Ukraine IT export global share is A] THEN [Ukraine IT global ratings share is *X*].

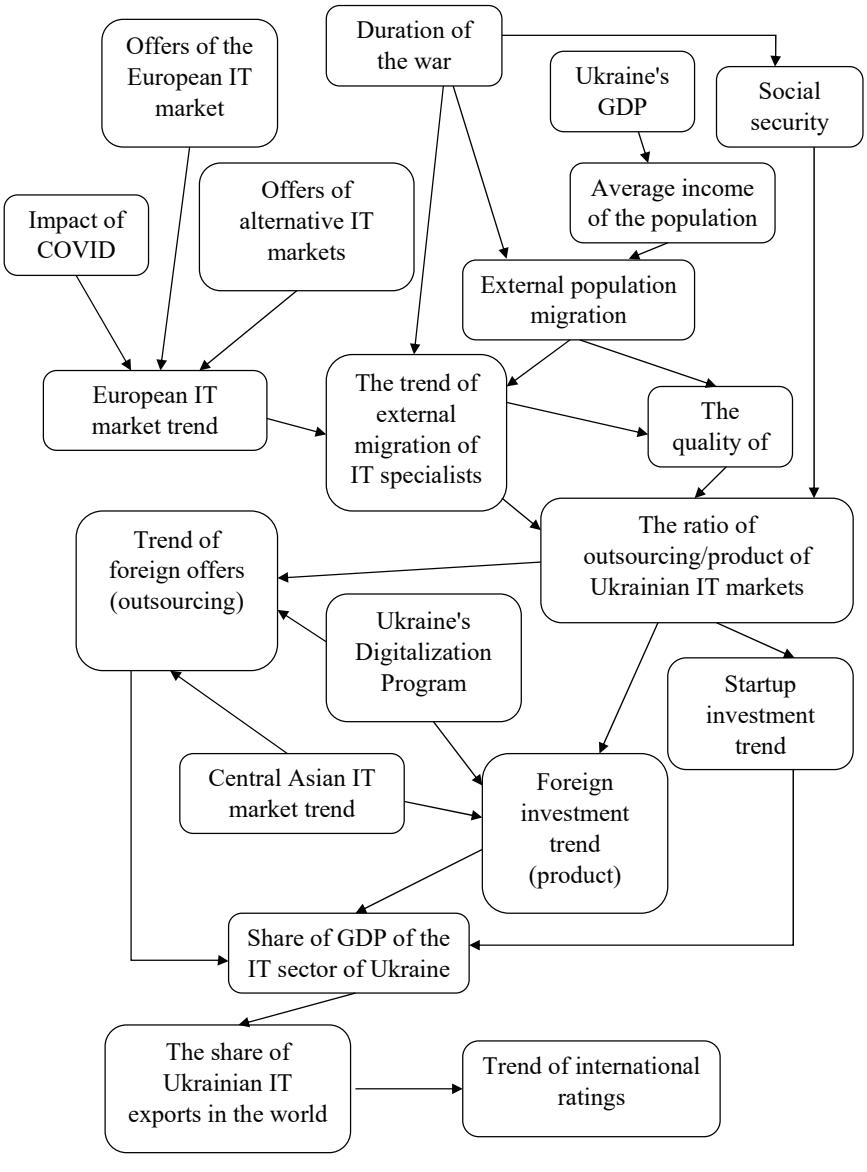


Fig. 2. Graph of the mutual influence of external factors

**5. 3. Technology of using the FuzzyKIDE ES to predict the state and trends of the IT industry**

The fuzzy knowledge base, built using the above templates, has been used for fuzzy derivation regarding the following:

– assessment of trends in external emigration of IT specialists;

– changes in the ratio between product and IT outsourcing subsectors;

– determination of trends in GDP changes in the share of the IT sector of Ukraine;

– trends of changes in the country's position in world rankings as an IT service provider. The preliminary analysis contributed to the formation of initial data for several simulated scenarios for the development of the situation. Tables 1–4 give more detailed information on the content of the initial data that were directly used in the process of fuzzy inference.

The first scenario is based on the following assumptions:

– forecast data on scenario No. 1 UNDP [27, 34]: reduction of income of ordinary citizens of Ukraine by 7 %;

– short-term duration of hostilities;

– high level of impact of the COVID pandemic on European markets (according to available statistical information);

– high level of offers and lack of IT resources in alternative labor markets (Central Asia, India, etc.);

– slow level of growth in popularity of IT sectors of countries that can replace the IT sector of Ukraine in the world market;

– moderate success of Ukraine's digitalization program.

Table 1

Initial data for scenario 1

| | |
|---|---|
| The level of GDP reduction | Small |
| Duration of hostilities | Short |
| Impact of COVID | Significant |
| The number of offers of the European IT market | Big |
| Growth rate of alternative IT markets | Slow |
| The success of the digitization program of Ukraine | Average |

The second scenario is based on the following assumptions:

– forecast data on scenario No. 2 UNDP [27]: reduction of income of ordinary citizens of Ukraine by 15 %;

– short-term duration of hostilities;

– high level of impact of the COVID pandemic on European markets (according to available statistical information);

– high level of offers and moderate level of IT labor growth in alternative labor markets (Central Asia, India, etc.);

– slow growth of alternative IT markets;

– moderate success of Ukraine's digitalization program.

Table 2

Initial data for scenario 2

| | |
|---|---|
| The level of GDP reduction | Below average |
| Duration of hostilities | Short |
| Impact of COVID | Significant |
| The number of offers of the European IT market | Big |
| Growth rate of alternative IT markets | Below average |
| The success of the digitization program of Ukraine | Average |

The third scenario is based on the following:

– forecast data on scenario No. 3 UNDP [27]: reduction of income of ordinary citizens of Ukraine by 20 %;

– moderate delay in hostilities;

– high level of impact of the COVID pandemic on European markets (according to available statistical information);
– high level of offers and moderate level of IT labor growth in alternative labor markets;
– slow growth of alternative IT markets;
– moderate success of Ukraine's digitalization program.

Table 3

Initial data for scenario 3

| | |
|---|---|
| The level of GDP reduction | Average |
| Duration of hostilities | Prolonged |
| Impact of COVID | Significant |
| The number of offers of the European IT market | Big |
| Growth rate of alternative IT markets | Below average |
| The success of the digitization program of Ukraine | Average |

The fourth scenario is the most pessimistic and takes into account the following:
– forecast data on scenario No. 4 UNDP [27]: reduction of income of ordinary citizens of Ukraine by 60 %;
– long-term military operations;
– high level of impact of the COVID pandemic on European markets (according to available statistical information);
– high level of offers and high level of IT labor growth in alternative labor markets;
– moderate level of growth of alternative IT markets;
– moderate success of Ukraine's digitalization program.

Thus, each subsequent scenario works with more pessimistic predictions and taking into account the increasing delay in the duration of hostilities.

Based on the initial data described in the tables and the knowledge base based on the previously mentioned templates, fuzzy consultations were conducted using the Fuzzy-KIDE software shell.

For the first scenario, a fuzzy inference gave the results, which can be viewed in Table 5.

Table 4

Initial data for scenario 4

| | |
|---|---|
| The level of GDP reduction | Big |
| Duration of hostilities | Prolonged |
| Impact of COVID | Significant |
| The number of offers of the European IT market | Big |
| Growth rate of alternative IT markets | Average |
| The success of the digitization program of Ukraine | Average |

Table 5

Fuzzy inference result for scenario 1

| The name of the indicator | Value |
|---|---|
| Migration trend of IT specialists | Slow |
| Share of the outsourced IT market | Average |
| Share of the product IT market | Average |
| Share of the GDP of the IT market of Ukraine | Stable |
| The share of the world export of the IT market of Ukraine | Stable |
| The trend of the global rating of the IT market of Ukraine | Stable |

The results can be considered quite logical because minor changes in the incomes of ordinary citizens and short hostilities will not contribute to a serious deterioration in social security conditions in the long term. This should have a positive impact on slowing down the external migration of IT specialists. Maintaining stable social conditions also helps to maintain a balance of product and outsourcing subsectors of the Ukrainian IT sector, which in turn does not create conditions for foreign investors to find alternative labor markets. Thus, we can expect continued growth of the share of GDP of the IT sector with a slight slowdown, as well as the absence of influence on the export of IT services in Ukraine and on its global ratings as a supplier.

For the second scenario, a fuzzy inference gave the results, which can be viewed in Table 6.

The results of fuzzy inference for the second scenario are not much different from the first scenario, which is logical. The deterioration of social security conditions due to lower incomes of ordinary citizens can lead to a slight acceleration of the external migration of IT specialists and a shift in the balance of the IT sector of Ukraine towards the product subsector. But these indicators are leveled by the still low levels of investor interest in changing the labor market. Thus, as in the previous scenario, we can expect continued growth in the share of the IT sector's GDP with a slight slowdown, as well as the absence of impact on Ukraine's IT exports and its global rankings as an IT service provider.

For the third scenario, a fuzzy inference gave the results, which can be viewed in Table 7.

Table 6

Fuzzy inference result for scenario 2

| The name of the indicator | Value |
|---|---|
| Migration trend of IT specialists | Below average |
| Share of the outsourced IT market | Average |
| Share of the product IT market | Above average |
| Share of the GDP of the IT market of Ukraine | Stable |
| The share of the world export of the IT market of Ukraine | Stable |
| The trend of the global rating of the IT market of Ukraine | Stable |

Table 7

Fuzzy inference result for scenario 3

| The name of the indicator | Value |
|---|---|
| Migration trend of IT specialists | Average |
| Share of the outsourced IT market | Below average |
| Share of the product IT market | Above average |
| Share of the GDP of the IT market of Ukraine | Moderate desrese |
| The share of the world export of the IT market of Ukraine | Moderate desrese |
| The trend of the global rating of the IT market of Ukraine | Stable |

The results of fuzzy inference for the third scenario differ from the previous ones. The main difference of this scenario from the previous ones is to delay hostilities, which gives time and opportunities for creating competitive alternative markets for IT specialists, for example in Central Asian countries. Also, the protracted hostilities have a negative impact on the level of migration of domestic IT specialists. Thus, we can expect the interest of foreign investors in finding alternative markets, which, in turn, will lead to a gradual decrease in the share of GDP of the IT sector of Ukraine and the global share of exports of domestic IT services.

For the fourth scenario, a fuzzy inference gave results, which can be viewed in Table 8.

Table 8

Fuzzy inference result for scenario 4

| The name of the indicator | Value |
|---|---|
| Migration trend of IT specialists | Above average |
| Share of the outsourced IT market | Below average |
| Share of the product IT market | Big |
| Share of the GDP of the IT market of Ukraine | Desrese |
| The share of the world export of the IT market of Ukraine | Desrese |
| The trend of the global rating of the IT market of Ukraine | Moderate desrese |

The results are the most pessimistic, which follows from the worst expected trends in changes in world exports and the global rating of the Ukrainian IT market. The rapid decline in the incomes of ordinary citizens and the protracted hostilities will have a strong negative impact on social security, which will greatly accelerate the pace of external migration of IT specialists. On the other hand, we can expect a shift in the balance towards the IT product subsector but this indicator will be offset by high levels of investors' interest in alternative emerging IT services markets. As a result, we can expect a reduction in both product and outsourcing IT subsectors, which directly causes a fairly rapid decrease in the global share of Ukrainian IT exports and a decrease in the country's global ratings as an IT service provider.

## 6. Discussion of results of the study of forecasts of trends in the development of the IT industry

The proposal to use the apparatus of expert systems based on fuzzy logic is based on the statement about a high level of economic uncertainty under conditions of martial law. It is worth noting that most of the available research, for example [12–14], focuses on solving individual problems in accordance with the considered sector of the economy. At the same time, the use of a typical fuzzy FuzzyKIDE ES is aimed at forming a holistic view of the possible directions of development of the sector under consideration. It is also worth noting that there are already fuzzy expert systems with a high level of typicality, for example, FuzzyClips. But the rapid growth in the popularity of the IT industry in the last decade and the low popularity of fuzzy expert systems results in the lack of research into the use of this apparatus for forecasting trends in the IT sector.

As an example, the analysis of the functioning of the Ukrainian IT industry at the beginning of the war and currently confirms the negative impact of hostilities on the IT sector and determines further negative consequences in the existence of the industry. The most influential factors in the functioning of the IT industry and their interrelationships were identified. The main limitation of the study is the simplification of the model of the IT sector. Thus, in the course of constructing the conceptual basis of a fuzzy expert system, based on the identified factors, a number of simplifications were accepted regarding the detail of the model being considered. For example, the influence of other economic sectors is considered indirectly because of their impact on GDP and on changes in the incomes of ordinary citizens.

The technological platform for research is the fuzzy expert system FuzzyKIDE. To solve the tasks, the components of the knowledge base of the system are formed and constantly updated by determining the current factors influencing the state of the IT sector. Initial data are formed according to a variety of expert scenarios for the development of the situation. The basis of the proposal to use FuzzyKIDE is the belief that it is possible to level the uncertainty of the economic situation with the help of a fuzzy logic apparatus:

– it helps to reduce dependence on clear data;

– it simplifies the procedure of repeated expert consultations;

– it describes knowledge in an easily understandable lexical format;

– it provides a balanced way to combine expert and formal modeling of knowledge.

The fuzzy inference of the system according to the four selected scenarios is represented in a simplified form for a general illustration of the operation of the apparatus. However, in industrial operation, it is possible to expand the knowledge base and data almost unlimited by updating them, and therefore, anticipating various scenarios for the development of the studied trends.

The operation of the FuzzyKIDE system proves the following advantages of using the fuzzy expert systems in the course of economic analysis under martial law:

1. The variability of economic situations is taken into account, especially under conditions of martial law.

2. It is possible to describe knowledge and anomalous data in a lexical format, which reduces dependence on clear data.

3. The formation and updating of the knowledge base is ensured by the adaptability and simplicity of its structure. It also enables the exchange of a knowledge base between experts.

4. It is possible to conduct repeated expert consultations without clear recalculations.

5. In contrast to the existing research in the field of fuzzy expert systems, it is possible to form a holistic view about the possible directions of development of the sector under consideration.

These results are explained by the nature of the changes in the results of fuzzy inference in accordance with the changes in the initial data. More pessimistic initial data entail more pessimistic forecasts, which is confirmed by the results of fuzzy inference in Tables 5–8 and their correlation to changes in the initial data in Tables 1–4. Given the imposed limitation on the detail of building a model of the IT sector, this result is quite expected.

The disadvantages of using fuzzy expert systems for economic analysis under martial law are as follows:

1. The quality of expert advice directly depends on the information relevance of the knowledge base, which makes this approach somewhat subjective. At the same time, during industrial operation, the institutional memory of the expert system can be significantly expanded due to the accumulation of experience/knowledge of a wide range of different experts, which will positively affect the final results of expert consultations.

2. There is a need for a specialist to form and maintain a knowledge base.

Further research will be aimed at finding ways to level these shortcomings. One such way could be to directly use templates to generate a knowledge base. This will simplify the process of forming and maintaining a knowledge base, as well as reduce dependence on expert errors in this process.

## 7. Conclusions

1. On the example of the IT-industry of Ukraine, a statistical analysis of the current state of the IT industry under the conditions of military conflict was carried out. Four main scenarios for the development of events depending on the duration of the conflict were considered. Unfavorable conditions for development and investment in the Ukrainian IT industry were demonstrated. There is a potential deterioration of these conditions in the event of a delay in the war. The possibility is noted for Central Asia to become a new IT outsourcing hub, and for India to gain a stronger foothold as an existing IT outsourcing hub.

A set of interrelated factors that have the greatest impact on the results of the IT industry was defined. Among them is the level of external migration of IT specialists. The nature of the impact on it of other factors is proved – such as the level of social security, GDP, the content and pace of shifts in the world IT markets.

2. The use of the apparatus of fuzzy expert systems for the analysis and forecasting of the state and trends in the development of the studied objects/processes in economic situations with a high level of uncertainty is proposed. As an example, the use of the fuzzy ES FuzzyKIDE is suggested.

Based on the formed set of factors and the interrelationships between them in the notations of fuzzy logic, the composition and structure of the FuzzyKIDE ES knowledge base have been developed. The peculiarity of the developed system is the use of modification of the direct inference algorithm based on the semantic network SNePS, as the core of fuzzy inference, as well as the application of a simplified lexical structure of the knowledge base.

3. The technology of working with the FuzzyKIDE ES in the process of expert consultations is demonstrated on the example of forecasting trends in the development of the IT industry of Ukraine under martial law. Different sets of initial data are used depending on the scenarios of the situation.

The results of the study demonstrate a subjective dependence on the quality of the knowledge base, namely on the expert level of the specialists who create it. On the other hand, the results obtained demonstrate the convenience of forming and maintaining a knowledge base up to date, unlimited possibility of repeated expert consultations, and minimal dependence on clear data. Given the above, it is advisable to use the apparatus of fuzzy expert systems in the context of forecasting economic situations under conditions of uncertainty and risk.

## Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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## Data availability

All data are available in the main text of the manuscript.

References

1. Gartner. Available at: https://www.gartner.com/en
2. IT-eksport u 2020. Za danymy NBU shchodo platizhnoho balansu i zovnishnoi torhivli. Available at: https://brdo.com.ua/wp-content/uploads/2021/02/IT-eksport-u-2020-2.pdf
3. Vasyuk, K. (2022). IT is Ukraine's fastest-growing sector. When the war is over, it will be the driver of our economy once again. DigitalEurope. Available at: https://www.digitaleurope.org/news/it-is-ukraines-fastest-growing-sector-when-the-war-is-over-it-will-be-the-driver-of-our-economy-once-again/
4. IT Industry Outlook 2021. CompTIA. Available at: https://comptiacdn.azureedge.net/webcontent/docs/default-source/research-reports/report---2021-comptia-it-industry-outlook.pdf?sfvrsn=18f99ffd_0
5. Vraneš, S., Stanojević, M., Stevanović, V., Lučin, M. (1996). INVEX: Investment Advisory Expert System. Expert Systems, 13 (2), 105–119. doi: https://doi.org/10.1111/j.1468-0394.1996.tb00183.x
6. Matsatsinis, N. F., Doumpos, M., Zopounidis, C. (1997). Knowledge acquisition and representation for expert systems in the field of financial analysis. Expert Systems with Applications, 12 (2), 247–262. doi: https://doi.org/10.1016/s0957-4174(96)00098-x
7. Apté, C., Kastner, J. (1991). An object-centered representation for financial analysis. Expert Systems with Applications, 3 (1), 19–25. doi: https://doi.org/10.1016/0957-4174(91)90085-s
8. McCarty, L. T. (1977). Reflections on "Taxman": An Experiment in Artificial Intelligence and Legal Reasoning. Harvard Law Review, 90 (5), 837. doi: https://doi.org/10.2307/1340132
9. Orchard, R. (2004). FuzzyCLIPS Version 6.10 d User's Guide. National Research Council of Canada. Available at: https://raw.githubusercontent.com/rorchard/FuzzyCLIPS/master/Docs/FuzzyCLIPS610d.pdf
10. Sokolovska, Z. M. (2005). Ekspertni systemy v ekonomichnykh doslidzhenniakh. Odessa: Astroprynt, 204.
11. Sokolovska, Z. M., Dudnyk, O. O. (2022). Ekspertni systemy: teoriya ta prykladne zastosuvannia. Odessa: Ekolohiya, 408.
12. Farajnejad, E., Lau, W.-Y. (2017). A Fuzzy Based Early Warning System to Predict Banking Distress on Selected Asia-Pacific Countries. The Journal of Asian Finance, Economics and Business, 4 (1), 39–49. doi: https://doi.org/10.13106/jafeb.2017.vol4.no1.39
13. Taghiyeh, S., Lengacher, D. C., Handfield, R. B. (2021). Loss rate forecasting framework based on macroeconomic changes: Application to US credit card industry. Expert Systems with Applications, 165, 113954. doi: https://doi.org/10.1016/j.eswa.2020.113954
14. Yang, L.-H., Ye, F.-F., Liu, J., Wang, Y.-M., Hu, H. (2021). An improved fuzzy rule-based system using evidential reasoning and subtractive clustering for environmental investment prediction. Fuzzy Sets and Systems, 421, 44–61. doi: https://doi.org/10.1016/j.fss.2021.02.018

15. Liu, Y. (2021). Foreign Trade Export Forecast Based on Fuzzy Neural Network. Complexity, 2021, 1–10. doi: https://doi.org/10.1155/2021/5523222
16. O'Leary, D. (2000). Value Creation from Expert Systems: An Economic Approach with Applications to Accounting, Auditing and Finance. Artificial Intelligence in Accounting and Auditing, 2–18. Available at: https://www.researchgate.net/publication/312165636_VALUE_CREATION_FROM_EXPERT_SYSTEMS_AN_ECONOMIC_APPROACH_WITH_APPLICATIONS_IN_ACCOUNTING_AUDITING_AND_FINANCE
17. Sonnet, D. (2017). An evaluation of the use of expert systems in economics. Zeszyty Studenckie Wydziału Ekonomicznego „Nasze Studia", 8, 190–199. Available at: http://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.desklight-098c6ae9-7256-41d2-a2b7-f1150909d8d3?q=bwmeta1.element.cejsh-1b83898e-6682-466f-ab52-35ac17dd262a;17&qt=CHILDREN-STATELESS
18. Zadeh, L. A. (1983). The role of fuzzy logic in the management of uncertainty in expert systems. Fuzzy Sets and Systems, 11 (1-3), 199–227. doi: https://doi.org/10.1016/s0165-0114(83)80081-5
19. Sokolovska, Z., Dudnyk, O. (2021). Devising a technology for managing outsourcing IT-projects with the application of fuzzy logic. Eastern-European Journal of Enterprise Technologies, 2 (3 (110)), 52–65. doi: https://doi.org/10.15587/1729-4061.2021.224529
20. Shapiro, S. C., Rapaport, W. J. (1992). The SNePS family. Computers & Mathematics with Applications, 23 (2-5), 243–275. doi: https://doi.org/10.1016/0898-1221(92)90143-6
21. Dudnyk, O., Sokolovska, Z. (2022). Application of Fuzzy Expert Systems in IT Project Management. Project Management - New Trends and Applications [Working Title]. doi: https://doi.org/10.5772/intechopen.102439
22. Ukraine IT Report 2021. IT Ukraine Association. Available at: https://drive.google.com/file/d/1rDOzj3_hKgXfIj8czwIVzP8Ct4lBY5eW/view
23. Statystyka finansovoho sektoru. Natsionalnyi Bank Ukrainy. Available at: https://bank.gov.ua/files/ES/BOP_m.xlsx
24. Ukraine Refugee Situation. Available at: https://data.unhcr.org/en/situations/ukraine
25. Ukraine Internal Displacement Report: General Population Survey, Round 6 (2022). International Organization for Migration. Available at: https://migration.iom.int/sites/g/files/tmzbdl1461/files/reports/IOM_Gen%20Pop%20Report_R6_final%20ENG.pdf
26. ILO Brief: The impact of the Ukraine crisis on the world of work: Initial assessments (2022). International Labor Organisation. Available at: https://www.ilo.org/wcmsp5/groups/public/---europe/---ro-geneva/documents/briefingnote/wcms_844295.pdf
27. The Development Impact of the War in Ukraine - Initial Projections. (2022). United Nations Development Programme. Available at: https://www.undp.org/sites/g/files/zskgke326/files/2022-03/Ukraine-Development-Impact-UNDP.pdf
28. Yousaf, I., Patel, R., Yarovaya, L. (2022). The reaction of G20+ stock markets to the Russia–Ukraine conflict "black-swan" event: Evidence from event study approach. Journal of Behavioral and Experimental Finance, 35, 100723. doi: https://doi.org/10.1016/j.jbef.2022.100723
29. International Migrant Stock (2020). United Nations. Available at: https://www.un.org/development/desa/pd/content/international-migrant-stock
30. FAO Food Price Index. Food and Agriculture Organization of the United Nations. Available at: https://www.fao.org/worldfoodsituation/foodpricesindex/en/
31. Projected increase in acute food insecurity due to war in Ukraine (2022). World Food Programme. Available at: https://www.wfp.org/publications/projected-increase-acute-food-insecurity-due-war-ukraine
32. Microsoft New Future of Work Report 2022. Microsoft. Available at: https://www.microsoft.com/en-us/research/uploads/prod/2022/04/Microsoft-New-Future-of-Work-Report-2022.pdf?fbclid=IwAR03lUijsKZDMse1-ben8icYIWOQpgcFBCfrKtXWlhAscFVQZNnCxaMMlKk
33. McGrath, J. (2021). Report on Labour Shortages and Surpluses. European Labour Authority. Available at: https://www.ela.europa.eu/sites/default/files/2021-12/2021%20Labour%20shortages%20%20surpluses%20report.pdf
34. Alderman, L., Cohen, P. (2022). Fleeing War in Ukraine, They're Met With Employers Offering Paychecks. The New York Times. Available at: https://www.nytimes.com/2022/03/21/business/refugees-ukraine-jobs.html
35. Gengler, E. (2022). 3 things you can do right now to support Ukraine's IT sector. TechCrunch. Available at: https://techcrunch.com/2022/04/01/3-things-you-can-do-right-now-to-support-ukraines-it-sector/
36. Turak, N. (2022). 'Ukrainians are built different': The software developers still working under Russian bombing. CNBC. Available at: https://www.cnbc.com/2022/03/04/ukrainians-are-built-different-the-coders-still-working-under-russian-bombing.html
37. IT Generation. Ministerstvo Tsyfrovoi Transformatsiyi Ukrainy. Available at: https://it-generation.gov.ua/