CHAPTER «STRATEGIC BUSINESS MANAGEMENT PLANNING AND FORECASTING»

Valeriy Balan
Candidate of Physical and Mathematical Sciences, Associate Professor,
Associate Professor at the Department of Management of Innovation and Investment Activities
Taras Shevchenko National University of Kyiv

Inna Tymchenko
Candidate of Economic Sciences, Associate Professor,
Associate Professor at the Department of Management of Innovation and Investment Activities
Taras Shevchenko National University of Kyiv

DOI: https://doi.org/10.30525/978-9934-26-565-5-13

EXPERT SYSTEMS BASED ON FUZZY MODELING TECHNOLOGIES IN STRATEGIC MANAGEMENT OF ENTERPRISES

Summary

Changing conditions of functioning of enterprises, new transformations, and challenges generated by their external and internal environment determine the need to use new tools of analysis, strategic choice and "navigation" in the strategic management of enterprises. Intelligent expert systems have a powerful potential for application at all stages of the strategic process, and the most effective in this case may be the tools of fuzzy multi-criteria analysis (Fuzzy MCA), fuzzy inference systems (FIS) and artificial intelligence and neural network (ANN) technologies. The study conducted a bibliometric analysis of sources related to the problems of development and application of expert systems and, in particular, intelligent expert systems in the strategic management of enterprises. The most promising areas, limitations and risks of applying expert systems in strategic management were identified. An approach was developed to build an intelligent expert system for forming enterprise strategies using the General Electric-McKinsey matrix, fuzzy multi-criteria analysis, and mechanisms based on precedents. It is concluded that the latest expert systems built using fuzzy methodology tools can provide excellent opportunities for interaction and integration and complement the basic tools

used in strategic enterprise management and, in many cases – the main ones for supporting strategic decision-making.

Introduction

Important distinguishing features of the modern business environment of enterprises are their extremely dynamic, difficult to predict and turbulent nature, the presence of market uncertainty and instability, unprecedented changes, shocks and challenges. Effective management in these difficult conditions requires not only extensive experience of top managers, managers, their knowledge and qualifications, but also the use of modern information technologies and appropriate intelligent decision support systems that can search for the necessary data, process and analyze diverse relevant information about the state of the enterprise and the external environment, and offer management several alternative solutions (actions).

One of the most important and powerful modern tools in strategic management of enterprises are intelligent expert systems built using fuzzy set theory and fuzzy logic [2], which have a high adaptability to expert data, to a high-quality, verbal description of the parameters being analyzed, are sufficiently flexible and adequate to the input information. With a tolerant attitude towards inaccuracy, uncertainty and partial truth, they provide ease of manipulation, robustness, better agreement with reality, allow operating with fuzzy input data, perform fuzzy formalization of evaluation and comparison criteria, conduct qualitative assessments by specialists and experts of both input data and output results, provide the possibility of rapid modeling of complex multi-parameter systems and their comparative analysis with a given degree of accuracy, etc. [3].

New expert systems built using fuzzy methodology (fuzzy set theory, fuzzy logic, "soft" computing, neuro-fuzzy networks, fuzzy cognitive modeling, fuzzy multi-criteria analysis, expert technologies using artificial intelligence (AI) and big data (Big Data)) provide great opportunities for interaction and integration, and can be both complementary to the basic tools used in strategic management of an enterprise, and in many cases – the main ones for supporting strategic decision-making. At the same time, at all stages of the strategic process, both software applications already developed by specialized companies and frameworks and software tools created "for a specific enterprise" can be used. The use of modern intelligent expert systems in the strategic management of enterprises can become one of the strategic resources and means of strengthening their competitiveness.

Chapter 1. Analysis of the state of research in the field of application of expert technologies in strategic enterprise management

A relatively large number of publications are devoted to the problem of introducing expert technologies into the strategic management of enterprises [1; 3; 5; 8; 10; 11; 12; 15].

In order to study the trends in the development and application of expert technologies in the strategic management of enterprises, a bibliometric analysis of the most relevant publications on the topic of the study was carried out in the scientometric database SCOPUS. In order to ensure careful selection, the terms: "expert systems", "strategic management", "strategic analysis" or "strategic control", or "strategic planning", which were to appear exclusively in the titles of documents, were included in the search query. Additional restrictions were also added to the search query regarding

– document type – article (in English);

– period – from 2000 (inclusive) to 2025;

– research areas: Business, Management and Accounting; Computer Science; Economics, Econometrics and Finance.

Therefore, the search query for forming the sample took the following form: (TITLE-ABS-KEY (strategic AND (management OR analysis OR control OR planning) AND TITLE-ABS-KEY (expert AND systems)) AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "COMP")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")).

According to the general query (strategic management + expert systems), 1069 publications were found, and the refined query (strategic management + intelligent expert system) – 62 publications. Figure 1 and Figure 2 present the dynamics of the number of publications on a specific topic (expert systems and intelligent expert systems, respectively, in strategic management of enterprises) in the SCOPUS bibliometric database for the period from 2000 to 2025 2018–2019, which indicates a rapid growth in interest in this issue in the last 5 years, with an increase of more than 2 times in expert systems in general, and 4 times in intellectual expert systems.

Figure 3 and Figure 4 provide information on the number of scientific publications on a specific topic by country. Among the TOP-10 countries presented by authorship of articles for the period from 2000 to 2025, the leading three countries by general query include the United States of America (128), the United Kingdom (92) and China (87), followed by India (85) with a slight lag. According to the specified query (strategic management + intelligent expert system), China (9), the United Kingdom (7), and Spain (6) are in the lead. The leadership of these countries is explained by the presence of centres, scientific schools and centres that are engaged in research on this issue.

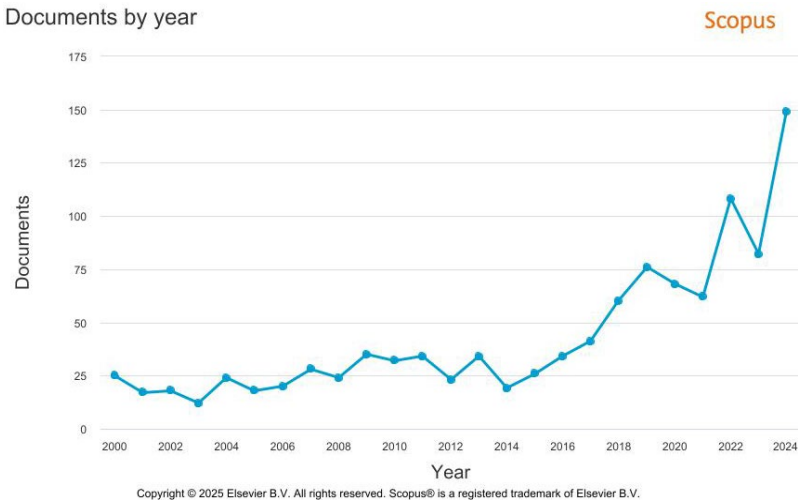

Figure 1. Dynamics of the number of publications on a specific topic (strategic management + expert systems) in SCOPUS for the period from 2000 to 2025

Source: constructed by the authors based on SCOPUS data

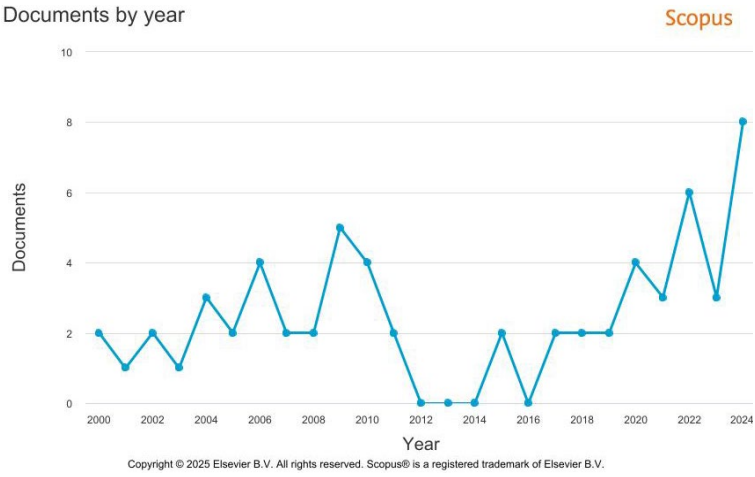

Figure 2. Dynamics of the number of publications on a specific topic (strategic management + intelligent expert system) in SCOPUS for the period from 2000 to 2025

Source: constructed by the authors based on SCOPUS data

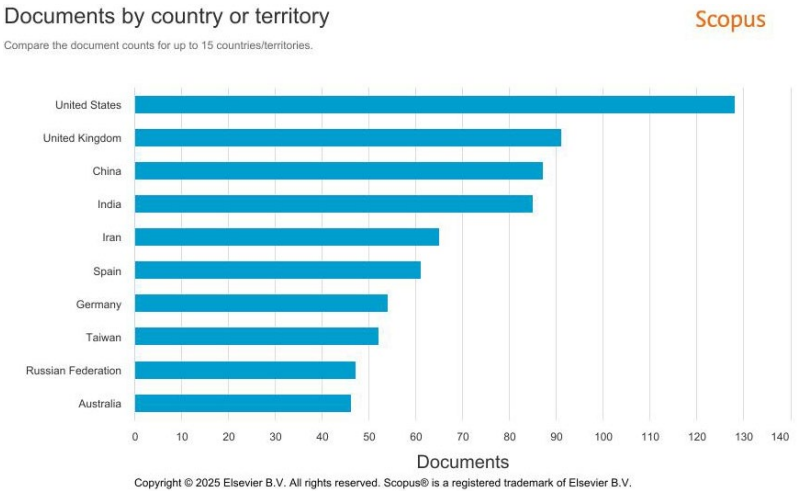

Figure 3. TOP-10 countries by authorship of articles (strategic management + expert systems) for the period from 2000 to 2025

Source: constructed by the authors based on SCOPUS data

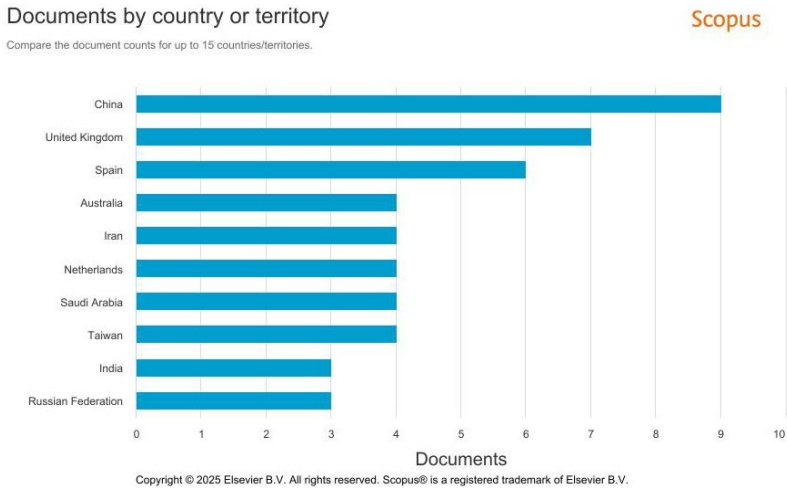

Figure 4. TOP-10 countries by authorship of articles (strategic management + intelligent expert systems) for the period from 2000 to 2025

Source: compiled by the authors based on SCOPUS data

Among the most promising areas of application of expert systems in strategic management, the following should be highlighted:

– audit of the enterprise's macroenvironment;

– analysis of the microenvironment of the enterprise (here separate frameworks are possible: for competitive analysis (assessment of the level of competition in the industry based on the five forces model of M. Porter), for comparative assessment of the competitiveness of enterprises, for determining the attractiveness of market segments, etc.;

– analysis of the internal environment of the enterprise (frameworks are possible for individual components of the internal environment here, as well as assessment of strategic potential, flexibility, and readiness for strategic changes).

– formation of the strategic vision, mission and strategic goals of the enterprise;

– development of strategic alternatives (formation of strategic recommendations based on the correlation matrix of SWOT analysis, IE analysis; development of strategic alternatives based on the portfolio analysis tools (GE-McKinsey, BCG, Arthur D. Little (ADL LC) matrices, dynamic SPACE analysis, etc.); formation of strategic sets to achieve corporate strategic goals of the enterprise);

– evaluation of strategic alternatives and strategic choice (stratification of strategies (or selection of a group of the most priority strategic alternatives); application of a quantitative matrix of strategic planning or other tools for ranking alternatives by priority; evaluation and ranking of strategic sets);

– strategy implementation and strategic control (identification of key performance indicators (Key Performance Indicators); collection of information on the implementation of the strategy by individual components; ensuring the functioning of the strategic controlling system and implementation of effective feedback).

In general, expert systems make it possible to study complex formalized tasks, from predicting the impact of political and social factors to ranking alternatives for the strategic development of an enterprise. Analysis of the development of industrial expert systems (Table 1) indicates the growing role of artificial intelligence and the expansion of the functionality of expert systems to solve interdisciplinary problems.

It is also necessary to note certain limitations regarding the application of expert systems in strategic management [5]:

– narrow subject area;

– expert systems are limited by specific knowledge since a large amount of information is required to make informed decisions, which limits the types of problems they can solve and leads to a lack of flexibility;

– inability to imitate general intelligence: expert systems cannot consistently reproduce the general intellectual behaviours demonstrated by human experts, especially in cases where there is no orderly logic to follow in decision-making;

– complexity of systems: The development of expert systems is often associated with customization, which makes them complex and challenging to maintain and improve;

– time and financial costs: The process of designing, testing and implementing expert systems can be time-consuming and expensive;

– problems with user interaction: Most expert systems do not have a natural language interface, making them less user-friendly and complicating effective communication.

Table 1

Evolution of the development of industrial expert systems

Generation	Characteristics	Characteristics
First generation	Highly specialized rule-based systems with strong problem-solving capabilities based on expert knowledge. Capable of logical reasoning and decision-making, offering valuable solutions to specific industry problems.	Industry-specific tasks
Second generation	Single-industry professional and application systems with advanced capabilities for logical inference and decision-making. They use more complex technologies for representing knowledge and reasoning.	Engineering design, data analytics
Third generation	Multidisciplinary integrated systems that use multiple AI languages and technologies. They are not limited to a single field, offering flexible and powerful reasoning and decision-making capabilities. They use technologies such as fuzzy logic, genetic algorithms, and neural networks.	Multidisciplinary tasks
Fourth generation	They use the latest AI technologies, including large-scale multi-expert collaborative systems and various knowledge representation methods. They are focused on collaboration and knowledge exchange between experts to solve complex, multidisciplinary problems. They apply ontologies, semantic networks, and integrated knowledge bases.	Complex multidisciplinary tasks, collaborative knowledge sharing

Source: [15]

The main risks that arise when using expert systems are associated with:

– obtaining and presenting information (bringing the collected, heterogeneous information to a form adequate for perception by the information system);

– verification and evaluation (the expert system must ensure that the results of the list of criteria comply with it – completeness, accuracy, efficiency);

– ethical and legal aspects, data security: expert opinions can radically change the state of the enterprise, so developers of such systems need to

consider the consequences that the use of subjective expert opinions can cause. Another important aspect is data protection and ensuring the anonymity of the evaluation process);

– user perception and trust – the effectiveness of the developed expert system is identified by the end-user usage factor – how convenient the interface is, the reliability and accuracy of calculations, the convenience of data entry – that is, expectations must be met).

Chapter 2. General approaches to the development of intelligent expert systems

Let us present the most typical types of decision-making mechanisms in the strategic management of enterprises that use information and knowledge from databases (DBs), knowledge bases (KBs) and model bases (MBs) in intelligent expert systems.

The first type of selection mechanism is a mechanism based on production rules, for the construction of which the most common methods are the method based on expert reasoning and judgments (the most powerful here are algorithms based on fuzzy inference according to Mamdani, Sugeno, etc.) and the method of constructing rules based on optimization models. Figure 5 shows an example of developing an expert system for evaluating and selecting strategic alternatives for implementation in an enterprise [4].

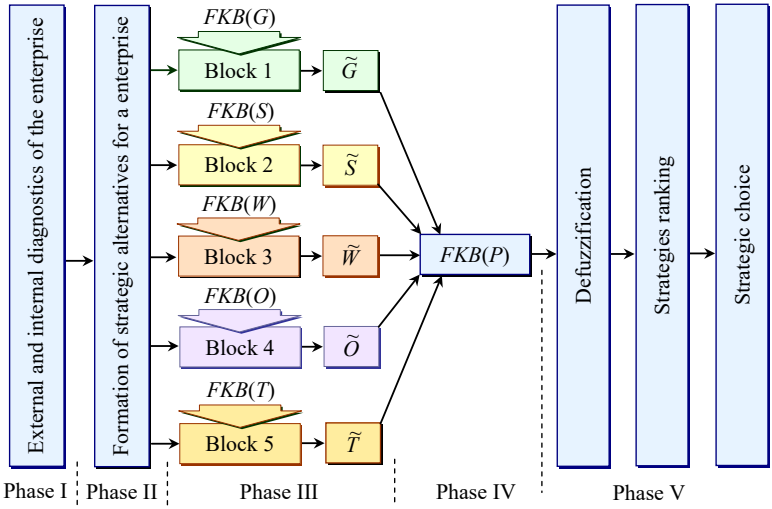

Figure 5. Phases of application of the framework for assessing and choosing enterprise strategies

Source: [4]

Table 2

Framework blocks for evaluating and selecting enterprise strategies

Block 1. Evaluation of strategic alternatives based on the criterion of achieving the strategic goals of the enterprise
1.1. Identification of strategic goals. 1.2. Fuzzy assessment of the priority of strategic goals. 1.3. Linguistic assessment of the "contribution" of strategic alternatives to the achievement of defined strategic goals (construction of a "contribution" matrix). 1.4. Determination based on a fuzzy inference according to Mamdani of the integral "contribution" of each strategic alternative to the achievement of the strategic goals of the enterprise.
Block 2. Evaluation of strategic alternatives based on the criterion of improving and strengthening the strengths of the enterprise.
2.1. Identification of the strengths of the enterprise. 2.2. Fuzzy assessment of the priority of the strengths of the enterprise. 2.3. Linguistic assessment of the provision of strategic alternatives with the ability to improve the strengths of the enterprise. 2.4. Determination based on the fuzzy conclusion according to Mamdani for each strategic alternative of the integral value of the ability to strengthen and improve the strengths of the enterprise.
Block 3. Evaluation of strategic alternatives based on the criterion of improving and strengthening the weaknesses of the enterprise.
3.1. Identification of the weaknesses of the enterprise. 3.2. Fuzzy assessment of the priority of the weaknesses of the enterprise. 3.3. Linguistic assessment of the ability of strategic alternatives to improve the weaknesses of the enterprise. 3.4. Determination of the integral value of the ability to strengthen and improve the weaknesses of the enterprise based on the fuzzy inference according to Mamdani for each strategic alternative.
Block 4. Evaluation of strategic alternatives based on the criterion of using the enterprise's capabilities.
4.1. Identification of existing and forecasted opportunities. 4.2. Fuzzy assessment of the importance of identified opportunities. 4.3. Linguistic assessment of the ability of strategic alternatives to use identified opportunities. 4.4. Determination based on fuzzy inference according to Mamdani for each strategic alternative of the integral value of using identified opportunities of the enterprise.
Block 5. Evaluation of strategic alternatives based on the criterion of responding to threats to the enterprise.
5.1. Identification of existing and predicted threats to the enterprise. 5.2. Fuzzy assessment of the importance of identified threats. 5.3. Linguistic assessment of the provision of strategic alternatives with the ability to respond to identified threats. 5.4. Determination based on fuzzy inference according to Mamdani for each strategic alternative of the integral value of the ability to respond to identified threats.

Source: [4]

The second type of selection mechanisms are mechanisms built on the basis of the application of multi-criteria selection algorithms (Figure 6), using the capabilities of fuzzy set theory and fuzzy logic (Figure 7).

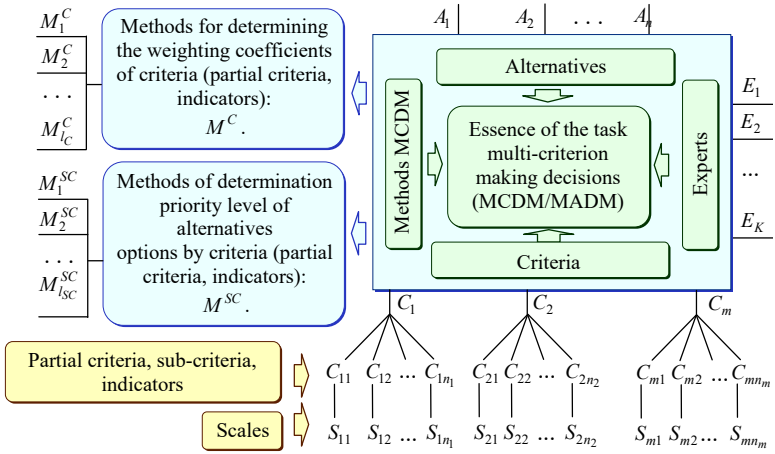

Figure 6. Structure of the problem of group fuzzy multi-criteria evaluation

Source: [2]

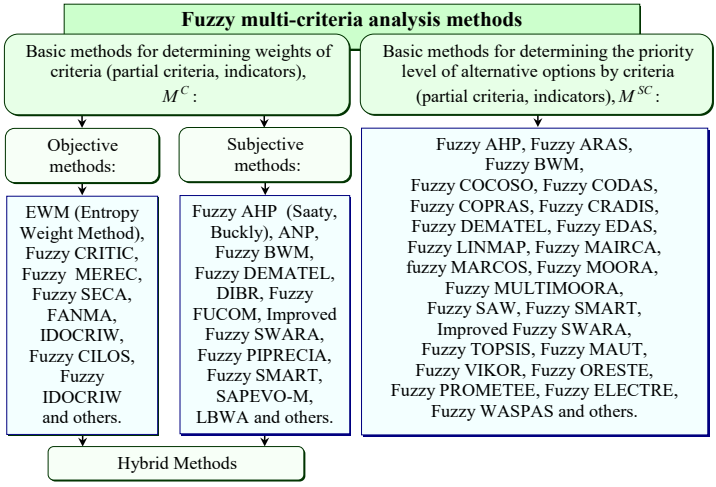

Figure 7. Methods of fuzzy multi-criteria analysis

Source: [2]

The third type of choice mechanism is based on precedents (which use classification models of decision-making). Such choice mechanisms are used in problem situations, the complexity of which does not allow for their constructive formalization but for which there is accumulated positive experience (precedents) of their successful solution. The logical conclusion (choice) in the system of fuzzy situations is based on a single-step or multi-step procedure for determining the degree of similarity of the current fuzzy situation to the situations taken as reference, to which the decisions taken are put in accordance.

Chapter 3. Development of an intelligent expert system for the formation of enterprise strategies

Let us give an example of building an intelligent expert system for portfolio analysis and selecting appropriate strategic recommendations for business units of an enterprise using the General Electric-McKinsey matrix based on the "precedent" approach. For this purpose, a trapezoidal representation of a fuzzy number will be used $\widetilde{X} = (x_1; x_2; x_3; x_4)$ (Figure 8) with the corresponding membership functions – formula (1).

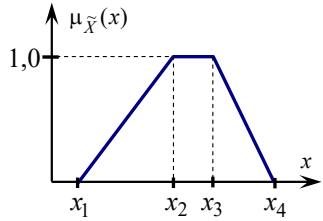

Figure 8. Graphical representation of a fuzzy number in trapezoidal form

$$\mu_{\tilde{X}}(x) = \begin{cases} 0, & x < x_1; \\ \dfrac{x - x_1}{x_2 - x_1}, & x \in [x_1; x_2]; \\ 1, & x \in [x_2; x_3]; \\ \dfrac{x - x_4}{x_3 - x_4}, & x \in [x_3; x_4]; \\ 0, & x > x_4. \end{cases} \quad (1)$$

According to [14] for defuzzification of a fuzzy trapezoidal number $\tilde{X} = (x_1; x_2; x_3; x_4)$ the ratio is used (2):

$$def(\tilde{X}) = \frac{1}{3}\left(x_1 + x_2 + x_3 + x_4 - \frac{x_3 x_4 - x_1 x_2}{(x_3 + x_4) - (x_1 + x_2)} \right). \quad (2)$$

To find the distance between two fuzzy numbers $\tilde{X} = (x_1; x_2; x_3; x_4)$ та $\tilde{Y} = (y_1; y_2; y_3; y_4)$ you can use the relation for Euclidean distance (3):

$$d(\tilde{X}, \tilde{Y}) = d_E(\tilde{X}, \tilde{Y}) = \sqrt{\frac{(x_1 - y_1)^2 + 2(x_2 - y_2)^2 + 2(x_3 - y_3)^2 + (x_4 - y_4)^2}{6}}, \quad (3)$$

or for the Hamming distance (4):

$$d(\tilde{X}, \tilde{Y}) = d_H(\tilde{X}, \tilde{Y}) = \frac{|x_1 - y_1| + 2|x_2 - y_2| + 2|x_3 - y_3| + |x_4 - y_4|}{6}. \quad (4)$$

3.1. Identification of partial evaluation criteria and determination of their weight coefficients

To determine partial criteria for evaluating business competitiveness and business (market) attractiveness, you can use the list of GE/McKinsey matrix factors proposed by J. Day (Table 3) or generate sets of these criteria based on expert considerations.

Table 3

List of GE/McKinsey matrix factors according to J. Day

Business attractiveness	Business competitiveness
Market factors: – size (in value and volume terms); – product market size; – market growth rate; – life cycle stage; – market diversity; – price elasticity; – purchasing power; – cyclicality (seasonality) of demand.	Market position: – relative market share; – rate of change in share; – share variation by segment; – perceived differentiation in quality, price, and service; – product range; – image of the organization.
Economic and technological factors: – investment intensity; – nature of investment (terms, working capital, leases); – ability to withstand inflation; – industry capacity; – level and duration of technology use; – barriers to entry and exit in the industry; – access to sources of raw materials.	Economic and technological position: – relative cost position; – capacity utilization rate; – technological position; – patented technology, products, processes.

Competitive factors: – type of competitors; – structure of competition; – threat of substitute products; – tangible changes among competitors.	Capabilities: – strengths of the management system; – strengths of the marketing system; – distribution system; – labor relations.

Source: [6]

Therefore, we obtain the following sets of partial criteria:

– for the criterion BS: $C^{BS} = \{C_1^{BS}, C_2^{BS}, ..., C_{m^{BS}}^{BS}\}$ та

– for the criterion MA: $C^{MA} = \{C_1^{MA}, C_2^{MA}, ..., C_{m^{MA}}^{MA}\}$.

The experts' assessment of the importance of partial criteria is carried out using linguistic assessments based on the term set in Table 4.

Table 4

Linguistic variables and corresponding trapezoidal fuzzy numbers (TrFN) for determining the importance of partial criteria and evaluating business units according to them

Linguistic variable	Designation	TrFN
Very low	VL	(0; 0; 0; 1)
Low	L	(0; 1; 2; 3)
Medium Low	ML	(2; 3; 3; 4)
Medium	M	(3; 4; 5; 6)
Medium High	MH	(5; 6; 6; 7)
High	H	(6; 7; 8; 9)
Very high	VH	(8; 9; 9; 9)

Source: improved by the authors based on [7]

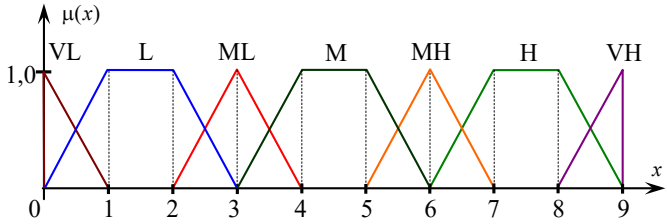

Figure 9. Membership functions of terms for assessing the importance of partial criteria (level of competitiveness of business units and attractiveness of the market (industry) according to partial assessment criteria)

Source: improved by the authors based on [7]

One set method can be used to calculate the weight coefficients M^C (Figure 7). Using Fuzzy SMART, we will transform the linguistic assessments of the importance of partial criteria obtained from experts into trapezoidal fuzzy numbers based on Table 4:

$l_j^{BS} \rightarrow \tilde{W}_j^{BS} = (A_{1j}; A_{2j}; A_{3j}; A_{4j})$, $j = 1, m^{BS}$ and

$l_j^{MA} \rightarrow \tilde{W}_j^{MA} = (B_{1j}; B_{2j}; B_{3j}; B_{4j})$, $j = 1, m^{MA}$.

The weighting coefficients of partial criteria are calculated using formulas (5) and (6):

$$w_j^{BS} = \frac{def(\tilde{W}_j^{BS})}{\bigoplus_{k=1}^{m^{BS}} def(\tilde{W}_k^{BS})}, \ (j = 1, m^{BS}); \tag{5}$$

$$w_j^{MA} = \frac{def(\tilde{W}_j^{MA})}{\bigoplus_{k=1}^{m^{MA}} def(\tilde{W}_k^{MA})}, \ j = 1, m^{MA}. \tag{6}$$

Therefore, w_j^{BS} – calculated weighting coefficients of partial criteria for assessing business competitiveness ($j = 1, m^{BS}$, де m^{BS} – the number of those criteria, $\sum_{j=1}^{m^{BS}} w_j^{BS} = 1$), і w_j^{MA} – weighting coefficients of partial criteria for evaluating the attractiveness of the market ($j = 1, m^{MA}$, де m^{MA} – the number of those criteria, $\sum_{j=1}^{m^{MA}} w_j^{MA} = 1$). These weights will then be used to calculate the "weighted" distances between the enterprise (strategic business unit) and the corresponding precedent according to the BS and MA criteria.

3.2. Forming a set of precedents

A set of precedents $\tilde{P} = \{\tilde{P}^1, \tilde{P}^2, ..., \tilde{P}^9, \}$ (fig. 10), where $\tilde{P}^i = (B\tilde{S}^i, M\tilde{A}^i)$, ($BS$ – Business Strength, MA – Market Attractiveness), at the first stage can be formed on the basis of classical strategic recommendations [13] and recommendations of Monieson D.D. [9] and Day G.S. [6] (Table 5).

Average values characterize each of the precedents according to the specified partial criteria of competitiveness of business units and attractiveness of the market MA (industry), i.e

$B\tilde{S}_j^1 = (0;1;2;3)$, $B\tilde{S}_j^2 = (0;1;2;3)$, $B\tilde{S}_j^3 = (0;1;2;3)$, $B\tilde{S}_j^4 = (3;4;5;6)$, $B\tilde{S}_j^5 = (3;4;5;6)$, $B\tilde{S}_j^6 = (3;4;5;6)$, $B\tilde{S}_j^7 = (6;7;8;9)$, $B\tilde{S}_j^8 = (6;7;8;9)$, $B\tilde{S}_j^9 = (6;7;8;9)$, ($j = 1, m^{BS}$).

$M\tilde{A}_j^1 = (0;1;2;3)$, $M\tilde{A}_j^2 = (3;4;5;6)$, $M\tilde{A}_j^3 = (6;7;8;9)$, $M\tilde{A}_j^4 = (0;1;2;3)$, $M\tilde{A}_j^5 = (3;4;5;6)$, $M\tilde{A}_j^6 = (6;7;8;9)$, $M\tilde{A}_j^7 = (0;1;2;3)$, $M\tilde{A}_j^8 = (3;4;5;6)$, $M\tilde{A}_j^9 = (6;7;8;9)$, ($j = 1, m^{MA}$).

Let us denote these values in general form as follows: $B\tilde{S}_j^i = (\alpha_{1j}^i; \alpha_{2j}^i; \alpha_{3j}^i; \alpha_{4j}^i)$, $j = 1, m^{BS}$ and $M\tilde{A}_j^i = (\beta_{1j}^i; \beta_{2j}^i; \beta_{3j}^i; \beta_{4j}^i)$, $j = 1, m^{MA}$, $i = 1,2,...,9$.

Table 5

Set of precedents
for the General Electric-McKinsey (GE/McKinsey) matrix

"Coordinates" and names of precedents	**Strategic recommendations (precedents)**		
	Classic [13]	**Monieson D.D. [9]**	**Day G.S. [6]**
$\tilde{P}^1 = ((0;1;2;3);(0;1;2;3))$ – «Defeated 3»	– strive to get the maximum profit that can be obtained; – refuse any investment at all, and exit this business.	**Make a profit or go out of business:** – exit the market or reduce the range; **–** develop work plans to maximize value.	**Exit the business:** – sell the business when you can get the highest price; – cut fixed costs and avoid investments for a while.
$\tilde{P}^2 = ((0;1;2;3);(3;4;5;6))$ – «Defeated 1»	– look for ways to develop without high risk; – otherwise, minimize investments and improve the organization at the operations level.	**Get income or go out of business:** – do not engage in material support of non-essential operations; – prepare an option in case of exit from business or – move into a more attractive segment.	**Minor expansion:** – look for ways to develop without high risk; – otherwise, minimize investment and improve the organization at the operations level.
$\tilde{P}^3 = ((0;1;2;3);(6;7;8;9))$ – «Doubtful business»	– development of the enterprise in the direction of strengthening those of its advantages that	**Invest for income:** **–** protect your strengths; – refocus on an attractive segment;	**Develop selectively:** – focus on a small number of strengths; – look for ways to strengthen

	promise to turn into strengths; – allocation by the enterprise of its market niche and investment in its development; – if the first and second options are impossible, then leave this sector of business.	– assess industry recovery; – monitor income generation or suspend investments.	weaknesses; – exit the business if there are no signs of sustainable growth.
$\widetilde{P}^4 = ((3;4;5;6);(0;1;2;3))$ – «Defeated 2»	– protect your positions in the most profitable segments; – update the assortment; – minimize investments.	Protect your revenue system: – act to preserve and grow cash; – consider options to sell your business; or – consider opportunities to streamline your business to build on your strengths.	**Get income:** – protect your positions in the most profitable segments; – update the assortment; – minimize investments.
$\widetilde{P}^5 = ((3;4;5;6);(3;4;5;6))$ – «Medium business»	– pursue a cautious strategic line of conduct: invest selectively and only in highly profitable and least risky projects.	**Invest selectively for income:** – segment the market; – have contingency plans.	**Get income:** – protect existing positions; – develop selectively in those areas where you are strong, in those segments where there is a sufficiently high rate of return and relatively low risk; – strengthen your vulnerable areas.
$\widetilde{P}^6 = ((3;4;5;6);(6;7;8;9))$ – «Winner 2»	– – pursue a cautious strategic line of conduct: invest selectively and only in highly profitable and least risky projects.	**Selectively invest in growth:** – invest seriously only in selective segments; – maximize your market share;	**Invest in development:** – try to seize leadership; – develop selectively

	– identify your strengths and weaknesses, and then make the necessary investments to maximize your strengths and improve your weaknesses.	– find new attractive segments to apply your skills.	in those areas where you are strong; – strengthen your vulnerable areas.
$\widetilde{P}^7 = ((6;7;8;9);(0;1;2;3))$ – «Cash generator»	– investment management in terms of achieving short-term results; – investments should be directed to the most attractive business sectors.	**Selectively invest in obtaining "live" money:** – manage the market; – find your niches (specialization); – try to develop your strengths.	**Protect yourself and change your focus:** – try to make money today; – concentrate on attractive segments; – protect your strengths.
$\widetilde{P}^8 = ((6;7;8;9);(3;4;5;6))$ – «Winner 3»	– identifying the most attractive business sectors (markets) and investing in them; – developing the ability to counteract the influence of competitors and thereby achieve increased profitability.	**Invest in growth.** – grow selectively based on your strengths; – develop the ability to withstand competition.	**Develop selectively.** – invest as much as possible in attractive industries; – develop the ability to withstand competition; – focus on increasing profitability by increasing productivity.
$\widetilde{P}^9 = ((6;7;8;9);(6;7;8;9))$ – «Winner 1»	– protecting one's position mainly through additional investments.	**Invest in growth:** – ensure maximum investment; – global diversification; – consolidate positions; – accept even a modest rate of return.	**Defend your position:** – invest in development to the maximum; – focus your efforts on preserving your strengths.

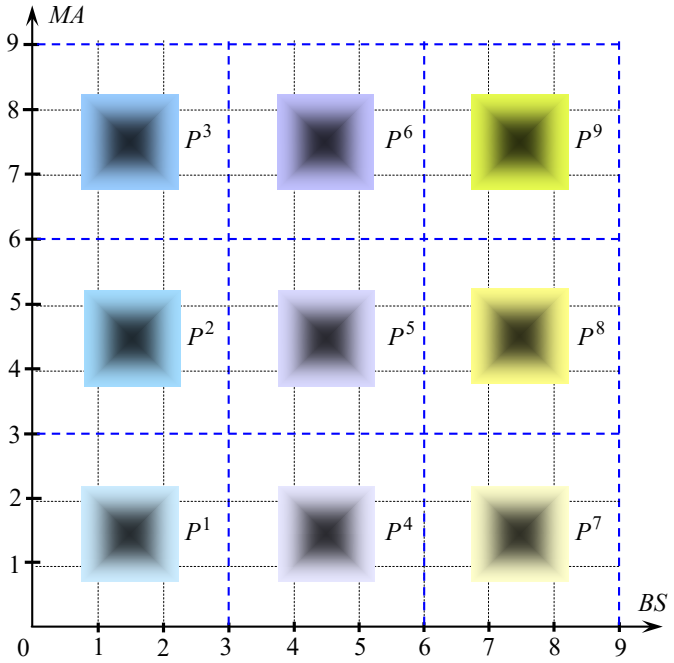

Figure 10. General Electric-McKinsey matrix with defined precedents

Source: constructed by the authors

3.3. Defining enterprise strategies

To identify the position of an enterprise (strategic business unit) on the GE/McKinsey matrix, it is necessary to conduct an expert assessment of the level of its competitiveness and market attractiveness and transform these values into fuzzy trapezoidal numbers using the equivalent of Table 4:

$$L_j^{BS} \to B\tilde{S}_j = (\alpha_{1j};\alpha_{2j};\alpha_{3j};\alpha_{4j}),\ j = 1, m^{BS}.$$

$$L_j^{MA} \to M\tilde{A}_j = (\beta_{1j};\beta_{2j};\beta_{3j};\beta_{4j}),\ j = 1, m^{MA}.$$

Note that if the estimates of several experts are used, then the Fuzzy Delphi procedure can be applied in case of disagreement between these estimates. Then, the average values of these estimates can be found. A similar approach can be used when calculating the weight coefficients of partial criteria *BS* and *MA*.

The next step is to define for each $i = 1, 2, ..., 9$ distances from $B\tilde{S}_j$ and $B\tilde{S}_j^i$ ($j = 1, m^{BS}$), and also from $M\tilde{A}_j$ to $M\tilde{A}_j^i$ ($j = 1, m^{MA}$):

$$d(B\tilde{S}_j, B\tilde{S}_j^i) = \sqrt{\frac{(\alpha_{1j} - \alpha_{1j}^i)^2 + 2(\alpha_{2j} - \alpha_{2j}^i)^2 + 2(\alpha_{3j} - \alpha_{3j}^i)^2 + (\alpha_{4j} - \alpha_{4j}^i)^2}{6}};$$

$$d(M\tilde{A}_j, M\tilde{A}_j^i) = \sqrt{\frac{(\beta_{1j} - \beta_{1j}^i)^2 + 2(\beta_{2j} - \beta_{2j}^i)^2 + 2(\beta_{3j} - \beta_{3j}^i)^2 + (\beta_{4j} - \beta_{4j}^i)^2}{6}}.$$

Next, you need to calculate $d(B\tilde{S}, B\tilde{S}^i) = \sum_{j=1}^{m^{BS}} w_j^{BS} \times d(B\tilde{S}_j, B\tilde{S}_j^i)$ – "weighted" distance according to the criterion "business competitiveness" between the enterprise (strategic business unit) and the *i-th* precedent and $d(M\tilde{A}, M\tilde{A}^i) = \sum_{j=1}^{m^{MA}} w_j^{MA} \times d(M\tilde{A}_j, M\tilde{A}_j^i)$ – "weighted" distance according to the criterion "market attractiveness" between the enterprise (strategic business unit) and the *i-th* precedent.

Let BS^* i MA^* – sets of precedents for which $d(B\tilde{S}, B\tilde{S}^i) \le 1{,}5$ and $d(M\tilde{A}, M\tilde{A}^i) \le 1{,}5$ respectively. Then the set of strategic alternatives sought will be the result of the intersection of these sets: $S = BS^* \bigcap MA^*$.

It should be noted that the obtained strategic alternatives should be considered only as recommendations, as possible courses of action, and the top management should make the final decision of the enterprise. Successful strategies can be entered into the model database, expanding the precedents for future application.

Conclusions

Implementing effective intelligent expert systems at all stages of the strategic process in enterprise management is one of the strategic resources and means of achieving and maintaining competitive advantages in the modern, rather complex, difficult to predict and turbulent environment. Analysis of sources on the problems of developing and applying expert technologies, expert systems in strategic enterprise management, allows us to conclude that publication activity has significantly increased in the last 5 years in this area. The most promising areas of application of expert systems in strategic management are: assessing the level of competition in the industry based on the five forces model of M. Porter, comparative assessment of the competitiveness of enterprises, determining the attractiveness of market segments, assessing the strategic potential of the enterprise, forming strategic recommendations and their evaluation, ensuring the functioning of the strategic controlling system.

Decision-making mechanisms (mechanisms based on production rules; mechanisms based on the use of multi-criteria selection algorithms; mechanisms based on precedents) based on information and knowledge from

databases, knowledge bases and model bases can be most widely used in the development of intelligent expert systems in strategic management of enterprises.

The framework developed by the authors for formulating enterprise strategies based on the GE/McKinsey matrix, fuzzy tools, and the "precedent" approach allows identifying strategic alternatives from the list of effective strategic decisions from the "past experience" of a given enterprise or other companies.

Therefore, the use of intelligent expert systems in strategic management of enterprises is a powerful tool that significantly facilitates and improves the decision-making process through:

– identification and research of information;

– use of real-time data;

– modelling and analysis based on machine learning and logical models;

– creation of control and evaluation systems based on fuzzy models;

– cooperation and exchange of information between all participants of the decision-making group.

Such a symbiosis – technologicality and critical thinking – allows for organisational efficiency in the professional activities of managers.

Prospects for future research in this area can be aimed at:

– development of appropriate frameworks of intelligent expert systems that provide support for decision-making in the strategic process, using tools of fuzzy multi-criteria analysis, fuzzy inference systems, modelling based on fuzzy cognitive maps, fuzzy clustering;

– integration of expert technologies with advanced technologies of artificial intelligence and neural networks;

– interpretation and ensuring user convenience.

References:

1. Al-Refaie A., Rawabdeh I., Arabiyat H. (2013) Developing a Fuzzy Logic Decision Support System for Strategic Planning in Industrial Organizations. *International Journal of Intelligent Systems and Applications in Engineering*, vol. 1(2), pp. 14–23.

2. Balan V. H. (2025) Methods of fuzzy multicriteria analysis in the formation of a new paradigm of strategic management of enterprises. *International Scientific Journal «Internauka». Series: «Economic Sciences»,* vol. 1 (1/93), pp. 132–146. DOI: https://doi.org/10.25313/2520-2294-2025-1-10665

3. Balan V. H. (2025) Intelligent expert systems in strategic management of enterprises. Economics, finance, and management in the digital age: proceedings of the International scientific and practical conference. Eastern European Center for Scientific Research, Sumy, 2025, April 20. Research Europe, pp. 43–47.

4. Balan V., Tymchenko I. (2021) Fuzzy Logic Framework for Assesing and Choising of Etreprise Strategies / 2021 11th International Conference on Advanced

Computer Information Technologies (ACIT), Deggendorf, GERMANY, 15-17 September 2021, pp. 410–414. DOI: https://doi.org/10.1109/ACIT52158.2021.9548473

5. Dašić M., Trajković S., Tešanović B. (2011) The necessity of using expert systems in strategic decision making. *International journal of economics & law,* vol. 1(1), pp. 27–35.

6. Day G.S. (1986) Analysis for Strategic Marketing Decisions. West Publishing Company, 123 p.

7. Li D.-F. (2007) Compromise ratio method for fuzzy multi-attribute group decision making. *Applied Soft Computing*, vol. 7(3), pp. 807–817. DOI: https://doi.org/10.1016/j.asoc.2006.02.003

8. Mohammed Al-Mafrji A.A., Hamodi Y.I., Hassn S.G., Mohammed A.B. (2023) Analyzing the use of expert systems in improving the quality of decision-making. *Eastern-European Journal of Enterprise Technologies*, vol. 1(3(121)), pp. 73–80. DOI: https://doi.org/10.15587/1729-4061.2023.274584

9. Monieson D.D. (1986) Effective Marketing Planning: An Overview. New York : Basic Books, 83 p.

10. Najdawi M. K., Chung Q. B., Salaheldin S. I. (2008) Expert systems for strategic planningin operations management: A framework for executive decisions. *International Journal of Manage ment and Decision Making*, vol. 9(3), pp. 310–327.

11. Sousa M.J., Rocha Á. (2024) Expert systems supporting strategic decisions. *Expert Systems,* vol. 41. DOI: https://doi.org/10.1111/exsy.13531

12. Tenchurin D.R., Shatilov M.P., Avdoshin S.M. (2009) Information System of Scenario Strategic Planning. Proceedings of Spring / Summer Young Researchers' Colloquium on Software Engineering (SYRCoSE), pp. 1–6.

13. Thompson A.A., Strickland A.J. (2003) Strategic Management: Concepts and Cases.13th edition. Mcgraw-Hill.

14. Wang Y.-M., Yang J.-B., Xu D.-L., Chin K.-S. (2003) On the centroids of fuzzy numbers. *Fuzzy Sets and Systems*, vol. 157(7), pp. 919–926. DOI: https://doi.org/10.1016/j.fss.2005.11.006

15. Yang X., Zhu C. (2024) Industrial Expert Systems Review: A Comprehensive Analysis of Typical Applications. *IEEE Access*, vol. 12, pp. 88558–88584. DOI: https://doi.org/10.1109/ACCESS.2024.3419047