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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

DEVELOPMENT OF INTELLIGENT DECISION-MAKING SYSTEMS FOR COMMERCIAL ENTERPRISES UNDER CONDITIONS OF MULTI-CRITERIA AND UNCERTAINTY

Speciality:	3338.01 - System Analysis, Management, and Information Processing (management and decision-making)
Field of science:	Technical sciences
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DEFINING FEATURES OF THE RESEARCH

Relevance and significance of the topic. In the current global economic landscape, the imperative for commercial enterprises to maintain and expand their market share is critical for sustainable economic growth. This is particularly salient in small and developing nations, where economic resilience is often challenged by fierce competition. For our country, diversifying the economy beyond the oil sector necessitates bolstering the economic strength and competitive capacity of commercial enterprises within the non-oil sector.

In light of this, the development of intelligent decision-making systems is crucial. These systems are instrumental in optimizing business processes, thereby enhancing the operational efficiency and overall competitive standing of commercial enterprises.

The existing scientific literature contains numerous studies on the analysis and solution of individual issues related to the creation of intelligent decision-making systems. This dissertation is distinguished by its development of an intellectual system that provides a comprehensive solution for the business processes of commercial enterprises. This system addresses a wide range of functions, from the physical placement of objects to customer relations and sales, while accounting for the mutual relationships between these processes. This integrated approach enables decision-making under multi-criteria and uncertain conditions.

The theoretical and practical significance of this system lies in its novel application of soft-computing methods and models to these complex business processes, which collectively underscores the relevance and importance of this dissertation topic.

Research object and subject. The object of the research is the comprehensive management of commercial enterprise business processes and the quantitative and qualitative factors that influence them.

The subject of the research is the development of an integrated, single-system software solution. This system is designed to investigate and resolve the complex decision-making issues

associated with implementing business processes, ultimately providing essential support for executives and managers.

Research objectives and goals. The primary objective is to develop a methodology for creating an intelligent decision-making system and the corresponding intelligent software. This system is designed to aid in the management of commercial enterprises by:

- Facilitating decision-making under conditions of multi-criteria analysis, uncertainty, and incomplete information.
- Leveraging the knowledge and experience of specialists.
- Comprehensively applying quantitative and qualitative parameters through an integrated approach that utilizes big data, data mining, fuzzy sets, and neural networks.

To achieve the stated objective, the following models have been developed:

1. Analysis and development of an intellectual decision-making system for the management of commercial enterprises.
2. Comprehensive analysis of the tasks performed in commercial enterprises and the selection of methods to be applied for their solution.
3. Development of a model for selecting new branches and sales points in wholesale and retail enterprises.
4. Evaluation of potential customers for the organization of online commerce and advertising activities.
5. Determination of demand and supply for inventory.
6. Effective management of financial resources.

Evaluation of the marketing activities of commercial enterprises.

Research methods. To solve the issues identified, the following methods were applied: system analysis, expert evaluations, classification methods, mathematical modeling techniques, and methods for developing business process software.

Main Provisions Submitted for Defense

- An intellectual decision-making system for the management of commercial enterprises.
- A hierarchical multi-criteria approach for solving the problem of selecting potential locations for commercial enterprises under

conditions of multi-alternativity and uncertainty.

- A fuzzy logic inference model for evaluating the effectiveness of marketing activities under uncertainty.
- A model for the customer shopping basket and its intelligent analysis, based on the joint use of data mining and fuzzy set theory.
- A method for evaluating the financial efficiency of commercial enterprises under conditions of uncertainty.

Scientific novelty of the research. Developed rules for describing quantitative and qualitative indicators affecting the decision-making process under multi-criteria, multi-alternativity, and uncertainty, and for representing them in the form of fuzzy variables and concepts.

Developed the knowledge used in decision-making into the form of fuzzy production rules.

Developed a method for evaluating potential location options for commercial enterprises under conditions of multi-alternativity and uncertainty.

Developed the structure of a unified software system to support managers and executives of commercial enterprises during decision-making.

Applied a hierarchical multi-criteria approach to evaluate the effectiveness of marketing activities under uncertainty.

Developed a method for evaluating the financial efficiency of a commercial enterprise under conditions of uncertainty.

Theoretical and practical significance of the research. The results of this dissertation can be applied to decision-making processes for solving business problems in commercial enterprises under conditions of multi-criteria analysis and uncertainty. The proposed structure of the intelligent decision-making system features an open-access, modular design, which allows for the integration of methods developed in various software tools to solve business processes. This intelligent decision-making system enables:

- The resolution of issues in commercial enterprises under conditions of multi-criteria analysis and uncertainty.
- The execution of multi-alternative evaluations during the

decision-making process.

- The comparative analysis of financial activities within commercial enterprises.
- The rapid evaluation of marketing activities in commercial enterprises under multi-criteria and uncertain conditions.
- The assessment of potential location options for commercial enterprises under multi-alternative and uncertain conditions.
- The provision of support to managers and executives in commercial enterprises during decision-making through a unified software system.

Approbation. The main findings of this dissertation have been discussed at numerous international, national, and regional conferences and symposiums. These include: the "XIV International Conference on Applications of Fuzzy Systems, Soft-computing and Artificial Intelligence Tools" (ICAFS 2020) held in Budva, Montenegro; the "International Conference on Intelligent and Fuzzy Techniques: Smart and Innovative Solutions" (INFUS 2020) held in Turkey; the "I International Scientific and Practical Conference on Azerbaijan and Turkey Universities: Education, Science, Technology" (2019) held in Azerbaijan; the "International Conference on Digital Economy: Modern Challenges and Real Opportunities" (2020) held in Azerbaijan; and the "International Conference on Eurasian Economies" (2020) held in Azerbaijan. The findings were also discussed at scientific seminars at the university.

Publications. Ten scientific articles, reflecting the final results of the dissertation, have been published in local and international journals.

Institution of performance. This dissertation was completed at “Odlar Yurdu University”.

Volume and structure of the dissertation. The dissertation consists of an introduction, three chapters, a conclusion, and a list of references. The total volume is 175,420 characters. The introduction is 7,135 characters, the first chapter is 54,780 characters, the second chapter is 51,120 characters, the third chapter is 61,230 characters, and the conclusion is 1155 characters. The work also includes 16 tables and 37 figures.

MAIN CONTENT OF THE WORK

The introduction substantiates the relevance of the dissertation topic, outlines the objectives of the work, presents the scientific novelty and the theoretical and practical significance of the results, and specifies the degree of approbation and the overall structure of the dissertation.

Chapter I provides a justification for the importance of creating intelligent decision-making systems for commercial enterprises and formulates the requirements for such systems. An analysis of the approaches used in creating intelligent decision-making systems and the various methods for developing decision-making models shows that the structure of these systems and the methods they employ are highly dependent on the specific characteristics of the subject area.

The development of Intelligent Decision-Making Systems (IDMS) for commercial enterprises has become a highly relevant issue, attracting the interest of many companies in recent years and finding application in various fields[1,2]. In addition to soft computing methods, IDMS also utilizes machine learning and cognitive technologies to analyze, monitor, and process data. IDMS can be used to solve numerous business processes in commercial enterprises, including:

1. Marketing and sales;
2. Customer services;
3. Digital management and logistics;
4. Human resources;
5. Security issues.

The development of an intelligent decision-making system for commercial enterprises is highly dependent on a thorough

[1]https://corporatefinanceinstitute.com/resources/management/decision-support-system dss/#:~:text=Disadvantages%20of%20a%20Decision%20Support%20System,-The%20cost%20to&text=A%20DSS%20may%20lead%20to,backlash%20from%20lower%2Dlevel%20employees

[2] Turban E and Aronson J 1998 Decision Support Systems and Intelligent Systems. A. Simon and Schuster Company, Upper Saddle River, NJ

investigation of the business processes being performed and the selection of appropriate decision-making methods that will enable these processes to operate more effectively and efficiently.

To achieve the stated objective, it is essential to carry out the following tasks:

1. Analysis and Research:

- Analyze the current state of existing technologies, methods, approaches, and the development level of intelligent decision-making systems.
- Analyze the business processes, main objectives, and specific characteristics of the enterprise that differentiate it from other sectors.
- Integrate the intelligent decision-making system with the enterprise's overall strategy and objectives.

2. Data Collection and Preparation:

- Gather data from the enterprise's primary technical infrastructures, customer information, and other diverse sources.
- Clean, structure, and prepare the data for analysis.

3. Model Development:

- Select and develop models that are aligned with the enterprise's requirements and business strategy.

Chapter II focuses on how the management of business processes, based on the application of modern methods and technologies in the field of information technology, helps enterprises increase their operational efficiency and achieve their goals. A classification of modern business models, based on the application of computer science and contemporary information technologies to the management of commercial enterprise business processes, can be presented as follows (Figure 1).

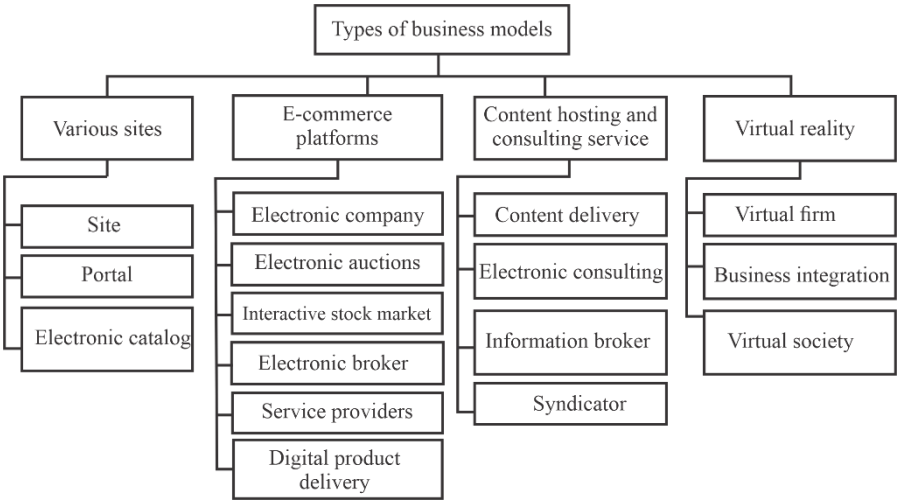


Figure 1. Classification of Business Models.s

As shown in the figure, the formation of business models is based on the modern level of information technology development.

In this dissertation, a classification of business processes [3] performed based on business models is provided:

1. Purchasing of goods and materials
2. Management of goods and materials (inventory)
3. Management of sales and customer services
4. Marketing and advertising
5. Financial management
6. Management of personnel
7. Analytical analysis and management decision-making

Additionally, this dissertation analyzes a three-pronged approach to the use of information systems and technologies in enterprises:

1. The use of an enterprise's internal capabilities.
2. The adaptation of purchased, off-the-shelf products to a

[3] Hiduke G., Ryan J. D.: Small Business: An Entrepreneur's Business Plan 9th Edition. South-Western College Pub. (2013)

company's needs with modifications using its own resources.

3. Outsourcing, meaning the entire system's concept, including its specific design and development, is entrusted to a third-party company.

Soft computing methods, particularly fuzzy logic and genetic algorithms, are widely used in solving business problems. These approaches have been effectively applied on platforms such as Walmart, Best Buy, Amazon, Salesforce, and Trustpilot to manage customer relationships, analyze sentiment, optimize inventory, and determine pricing strategies.

The research conducted has allowed for the following justifications:

1. Intelligent decision-making systems created for commercial enterprises are highly dependent on the enterprise's specific profile and the nature of the tasks performed within it.
2. Intelligent systems developed for commercial enterprises must align with the daily decision-making processes carried out by executives and managers.
3. The methods used to solve business processes in commercial enterprises and their results must be easily interpretable.
4. In some cases, solving the same decision-making process with different methods is crucial for justifying the decisions made.
5. An intelligent decision-making system should be created with a modular structure. This is very important for increasing the number of methods used in the system and for justifying the decisions to be made.

Chapter III examines the design and implementation of an intelligent decision-making system for the management of commercial enterprises, using the solution of various business processes as examples. The methods and techniques for solving these business processes and the requirements for the software system were analyzed and implemented based on the following:

1. A model for selecting the locations of new branches and sales points in commercial enterprises.
2. An intelligent analysis model of the consumer basket in commercial enterprises.

3. A model for evaluating the marketing activities of commercial enterprises.
4. Methods for the comparative analysis of the financial activities of commercial enterprises.

1. A Model for Selecting the Location of New Branches and Sales Points[4]**.** The selection of a location for new branches is evaluated as a multi-criteria decision-making problem and is solved using models based on fuzzy logic. The main factors influencing the selection are high-traffic areas and socio-economic uncertainties.

Let us assume that managers have defined the potential placement options for the objects as illustrated in Table 1, and have evaluated them with varying scores across 8 criteria. As shown in Table 1, the alternative placement options for the object are designated as A-a1, B-a2, and C-a3, respectively. In this context, the "Norms" column in Table 1 represents the intervals for each criterion as determined by the managers.

Suppose that , $A = \{a_1, a_2, \ldots, a_m\}$ (where m is the total number of alternatives) a set of alternatives (location options for retail outlets) and a set of criteria $K = \{K_1, \ldots, K_n\}$ (where n is the total number of criteria) affecting their evaluation and selection are given.

The evaluation of alternatives is described in the form of fuzzy sets $\widetilde{K}_i$ for each criterion[5] as follows:

$$\widetilde{K}_i = \left\{\frac{\mu_{K_i}(a_1)}{a_1}, \ldots, \frac{\mu_{K_i}(a_m)}{a_m}\right\}, i \in n \qquad (1)$$

Here, $\mu_{K_i}(a_j), i \in n, j \in m$ are the membership functions of fuzzy sets. Fuzzy sets a_j allow us to determine the degree of membership

[4] Veliyev, A., Abdullayev, T., Alekperov, R., Salahli, V. (2021). Solution of the Retail Marketing Problem of Rational Choice of the Location of Trade Enterprises Using the Method of Hierarchy Analysis and Fuzzy Set Theory. Advances in Intelligent Systems and Computing, vol 1306. Springer, Cham. https://doi.org/10.1007/978-3-030-64058-3_9

[5] Lotfi A Zadeh, Rafik Aliev, Fuzzy Logic Theory and Applications: Part I and Part II, https://doi.org/10.1142/10936 | December 2018, Pages: 61.

of the best-rational solution in terms of the criterion of alternatives K_i.

Table 1.

Examples for Evaluating Commercial Enterprise Location Options

№	Criterion (K)	Evaluation (Q - satisfactory)				
		Norms (N)	Criterion Priority (cp)	Priority (cp)Alternative Options (A)		
				a 1	a 2	a 3
K 2	Relative purchasing power per resident	200 per resident	2	100	66.67	75
K 3	Number of customers in the impact zone	8000	3	66.67	79.17	95.83
K 1	Pedestrian flow in 1 hour	500	1	62.33	83.33	50
K 4	Sales area size of the object	Min. 800 sq. m.	4	79.17	83.33	91.67
K 5	Area of sales points	Min. 40 sq. m.	5	100	100	83.33
K 6	Number of parking spaces	Min. 10 spaces	5	75	91.67	100
K 7	Delivery possibility	-	6	96	83.33	90
K 8	Public transport	At a distance of 3 minutes	7	100	91.67	93.34
	Total evaluations for comparison			679.17	679.17	679.17

Let us assume that each criterion has a different weight degree, $\alpha_i, (i \in 1, n)$. Each weight degree is calculated with the following formula:

$$\alpha_i = n \cdot \omega_i, i \in n \qquad (2)$$

Here, ω_i the time preference coefficients are determined in the following manner:

1. For each $K_i \in K, i \in n$ criterion, Saaty preference coefficient is evaluated using expert knowledge. Initially, experts perform a pairwise $K = \{K_1, \ldots, K_n\}$ comparison of each element within the

set with respect to the selection of the optimal solution, G. This is based on the logic of determining "the degree to which criterion K_i is superior to criterion K_j" and is facilitated by Table 2. The results of this comparison are recorded in the following comparison matrix:

$$(G)\quad \begin{matrix} K_1 \\ K_1 \\ \\ K_n \end{matrix} \begin{matrix} K_1 & \dots & K_n \\ \begin{pmatrix} g_{11} & \cdots & g_{1n} \\ . & \cdots & . \\ g_{n1} & \cdots & g_{nn} \end{pmatrix} \end{matrix}$$

Table 2.

Saaty empirical scale

	g_{ij} (meaning)		Value g_{ij}
K_i	Equally important	K_j	1
K_i	Slightly superior	K_j	3
K_i	Superior	K_j	5
K_i	Significantly superior	K_j	7
K_i	Absolutely superior	K_j	9
K_i	Intermediate values for compromise decisions	K_j	2, 4, 6, 8

When filling out this matrix, the following ratio is taken into consideration:

$$g_{ii} = 1;\ g_{ij} = 1/g_{ji},\ i \neq j$$

2. To determine the consistency degree of the constructed comparison matrix, the preference coefficient of the criteria is calculated using the following formula:

$$g_i = \sum_{j=1}^{n} g_{i\ \ j}, i \in n \qquad (3)$$

$$\omega_i = \frac{g_i}{\sum_{j=1}^{n} g_j} \qquad (4)$$

ω_i - is also considered as the consistency degree of the criterion K_i for the purpose of G - $\mu_G(K_i)$.

Subsequently, the consistency degree of the constructed matrix is evaluated by calculating the consistency index using the following formula:

$$CI = \frac{\lambda - n}{\sigma \cdot (n-1)} \qquad (5)$$

Here, n is the number of criteria under consideration.

$$\begin{pmatrix} g_{11} & \cdots & g_{1n} \\ \cdots & .. & \cdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \cdot \begin{pmatrix} \omega_1 \\ \cdots \\ \omega_n \end{pmatrix} = \begin{pmatrix} y_1 \\ \cdots \\ y_n \end{pmatrix}; \quad (6)$$

$$\lambda \approx \frac{1}{n} \cdot \left(\frac{y_1}{\omega_1} + \ldots + \frac{y_n}{\omega_n} \right); \quad (7)$$

σ – the random index, RI, is found according to Table 3 and is dependent on the number of criteria, n[6].

Table 3.

Determination of σ - random index (RI) Values

n	3	4	5	6	7	8	9	10	11	12	13	14
σ	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57

During a consistent survey, the condition of $CI \leq 0.20$must be satisfied. This indicates that the survey procedure has been successfully completed. If this condition is not met, the experts are surveyed again, or the validity of the problem statement is re-examined. The rule for selecting the best alternative is determined based on the following intersection formula:

$$P = K_1^{\alpha_1} \cap \ldots \cap K_n^{\alpha_n}. \qquad (8)$$

The alternative that satisfies the following condition is selected as the rational solution:

$$a^* = \arg \max_{i=1,\ldots,m} \mu_P(a_j), j \in m \quad (9)$$

For each $K_i (i \in n)$ criterion, the $\mu_P(a_i)$ following is calculated in the

[6] Саати Т.Л.Принятие решений. Метод анализа иерархий. М.: Radio i svyaz', 1989

specified manner:

$$\mu_P(a_j) = \min\left\{\frac{\mu_{K_1}{}^{\alpha_1(a_j)}}{a_j}, \ldots, \frac{\mu_{K_i}{}^{\alpha_i(a_j)}}{a_j}\right\}, i \in n, j \in m \quad (10)$$

Based on the formulas above, let us solve the problem of selecting the best rational solution from among the alternatives (a_1, a_2, a_3) given in Table 1, taking into account the following criteria: K_1 - pedestrian flow passing in front of the object per hour; K_2 - number of customers in the object's area of influence; K_3-customers' real purchasing power; K_4-the width of the assortment of products sold in the object; K_6-the area of the sales points; K_7-the possibility of sales delivery; K_8-public transport.

The results of the expert surveys, conducted in accordance with Table 3, are recorded in Table 4. This table shows the experts' opinions on the criteria's preference degrees, as well as the calculated ω_i - Saaty preference coefficients for each criterion.

Table 4.

Calculation of Saaty Preference Coefficients – ω_i

	G -matrix								gi	Matricies		
	K_1	K2	K3	K4	K5	K6	K7	K8		W	α_i	Y
K1	1	2	3	3	5	7	9	9	39	0.23	1.86	3.24
K2	0.5	1	3	3	5	7	7	9	35.5	0.21	1.7	2.83
K3	0.33	0.33	1	3	3	4	5	9	30.67	0.18	1.47	1.73
K4	0.33	0.33	0.33	1	3	3	5	9	24	0.14	1.15	1.22
K5	0.2	0.2	0.25	0.33	1	3	3	5	12.98	0.08	0.62	0.74
K6	0.14	0.14	0.25	0.33	0.33	3	3	5	14.2	0.08	0.68	0.66
K7	0.11	0.14	0.11	0.14	0.33	0.2	1	7	9.04	0.05	0.43	0.28
K8	0.11	0.11	0.11	0.11	0.2	0.2	0.14	1	1.99	0.01	0.09	0.14
Total (g)									167.38			

The result of the product of matrices G and W (Formula 6), denoted as Y (Y = G * W), corresponds to the Y matrix shown in Table 4. Using this matrix and Formulas 5, 6, and 7, let us calculate the Consistency Index (CI):

In accordance with Table 4, the consistency index for the 8 criteria is $\sigma = 1.41$

$$CI = \frac{\lambda - n}{\sigma \cdot (n-1)} = \frac{9.90-8}{1.41 \cdot 7} = 0.1928 \leq 0.20. \quad (11)$$

$$\lambda \approx \frac{1}{8} \cdot \left(\frac{3.24}{0.23} + \frac{2.83}{0.21} + \frac{1.73}{0.18} + \frac{1.22}{0.14} + \frac{0.74}{0.08} + \frac{0.66}{0.08} + \frac{0.28}{0.05} + \frac{0.14}{0.01}\right) = 9.90; \quad (12)$$

In accordance with Formula 10, we observe that the condition set for the consistency index has been satisfied. This, in turn, confirms the success of the expert surveys and the consistency of the criteria's preference degrees with their priorities.

Next, the concept of "the expediency of selecting an alternative based on the criterion under consideration" is modeled using the Gaussian membership function (Figure 2).

$\mu(u) = \exp(-(u-10)^2/\sigma_k^2)$ (k=1÷8) (where the values for σ_k are selected based on the significance degree of criteria K1, K2, K3, K4, K5, K6, K7, and K8; for our case, σ=20+cp), fuzzy sets were constructed for each criterion (Table 5).

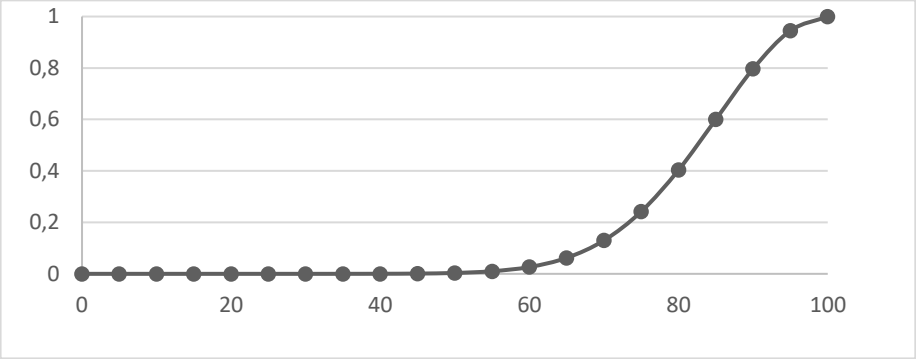


Figure 2. Gaussian Membership Function.

Table 5.

Membership Function Values for Alternatives Across Criteria

	K1	K2	K3	K4	K5	K6	K7	K8
a1	0.0400	1.0000	0.1225	0.4703	1.0000	0.3679	0.9766	1.0000
a2	0.5325	0.1007	0.4403	0.6173	1.0000	0.8949	0.6629	0.9092
a3	0.0035	0.2749	0.9677	0.8865	0.6411	1.0000	0.8625	0.9410

Using the values from Table 5, Formulas 8 and 10, and the α_i coefficients, let us calculate the values of the membership functions of the fuzzy set P:

$$\mu_P(a_1) = \min(0.0400^{1.86}, 1^{1.70}, 0.1225^{1.47}, 0.4703^{1.15}, 1^{0.62}, 0.3679^{0.68}, 0.9766^{0.43}, 1^{0.09}) = 0.00248;$$

$$\mu_P(a_2) = \min(0.5325^{1.86}, 0.1007^{1.70}, 0.4403^{1.47}, 0.6173^{1.15}, 1^{0.62}, 0.8949^{0.68}, 0.6629^{0.43}, 0.9092^{0.09}) = 0.01635;$$

$$\mu_P(a_3) = \min(0.0035^{1.86}, 0.2749^{1.70}, 0.9677^{1.47}, 0.8865^{1.15}, 0.6411^{0.62}, 1^{0.68}, 0.8625^{0.43}, 0.9410^{0.09}) = 0.00002;$$

According to Formula 9, let us select the best alternative.

$$a^* = \arg\max_{i=1,..,3} \mu_P(x_i) = \arg\max(0.00248; 0.01635; 0.00002) = a_2$$

As can be seen, the alternative $a^* = a_2$ is considered the most purposeful.

2. An Intelligent Analysis Model of the Consumer Basket in Commercial Enterprises[7].

The objective of the intelligent analysis of the shopping basket is to answer the following research questions:

1. Do supermarket customers prefer large or small volume purchases?
2. What do customers prefer depending on the type of goods?
3. Is there a relationship between the ratio of product types in a shopping basket and the number of baskets?

The analysis of the shopping basket is performed based on the following influencing parameters: product type, the ratio of product types in the basket, basket length (the number of products in a

[7] Salahli, V. (2020) Analysis of Food Shopping Baskets in a Supermarket in Terms of Different Parameters Using Fuzzy Logic. Open Journal of Business and Management, 8, 2195-2204. doi: 10.4236/ojbm.2020.85134

transaction), and the number of transactions. Food products have been classified as follows: basic foods, semi-finished products, and ready-to-eat semi-finished products. Local consumption habits can also influence the list of basic foods.

As a result of data collection from sources and interviews with potential customers, food products were divided into three groups (Table 6).

Table 6.

Food Categories

BP	Basic foods	bread, pasta, cheese, water, etc.
NB1	Non-basic, but widely used foods	sweets, juices, etc.
NB2	Non-basic, low-consumption foods	alcoholic drinks, cigarettes, etc.

A fuzzy representation of the product categories, obtained using the FisPro[8] application, is shown in Figure 3.

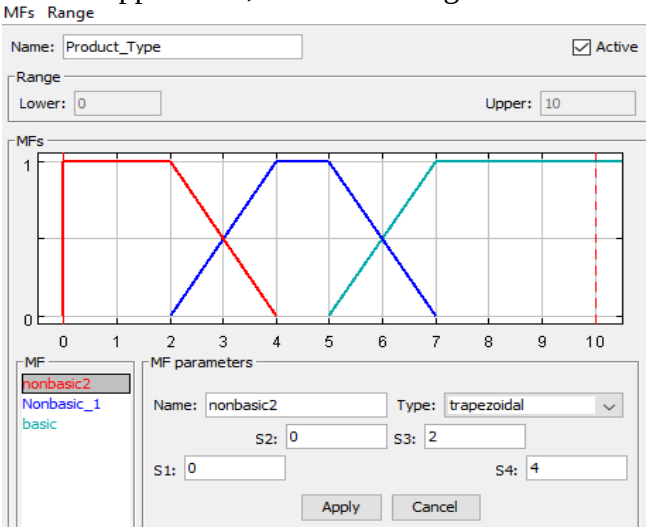


Figure 3. Fuzzy Set Representation of Product Categories.

The first research topic of the intelligent analysis of the shopping basket, as noted above, is to answer the question, "Do

[8] FisPro:An open source portable software for fuzzy inference systems FisPro, https://www.fispro.org/download/documentation/fispro36inline.pdf

supermarket customers prefer large or small purchases?" This research is crucial for identifying methods to improve the quality of customer service. For this purpose, data on shopping in a Baku supermarket in May 2020 was used as the research data. The study was conducted based on an analysis of approximately 600 commercial transactions (shopping baskets).

Depending on the size of the purchases (the number of goods in the consumer basket), all shopping baskets were divided into three categories, as shown in Table 7.

Table 7.

Fuzzy Classification of Baskets

Basket Type	Linguistic Meaning of Basket Size	Numerical Values of Basket Size Range
SB	Small	1-10
MB	Medium	11-20
LB	Large	21 and above

The preliminary processing of the purchase data was performed using the WEKA data mining application. The numerical distribution of baskets by size is shown in Figure 4. As can be seen, the distribution is quite uniform (221 small baskets, 217 medium baskets, and 198 large baskets). The blue bar represents the small baskets, the red bar represents the medium baskets, and the green bar represents the large baskets.

Figure 4. Number of Transactions by Basket Size (Number of Shopping Baskets).

The second research problem in this chapter is to determine customer preferences based on product categories. To answer this question, a new parameter was introduced: the ratio of each product type in the basket. The ratios of each product type in the basket are expressed using the fuzzy values in Table 8.

Table 8.

Fuzzy Ratios of Product Types in Baskets

Fuzzy Set	Description	Precise Value Interval
LR	Low ratio of goods in the basket	0-4
MR	Medium ratio of goods in the basket	2-6
HR	High ratio of goods in the basket	5-10

Figure 5 shows a fuzzy set representation of the prices of the goods.

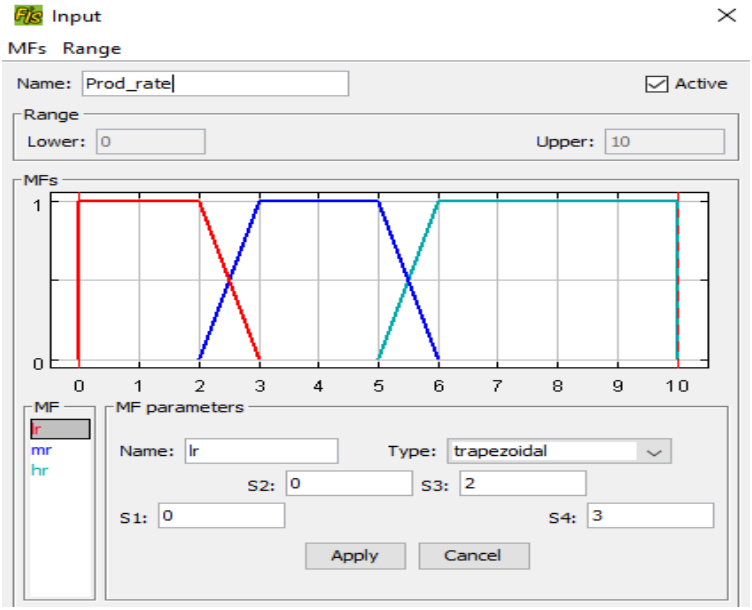
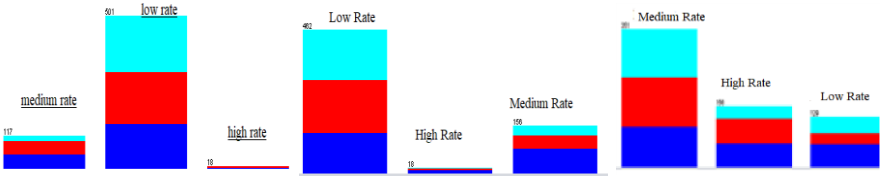


Figure 5. Fuzzy Set Representation of Goods' Prices.

The quantitative ratios of product types NB2, NB1, and BP are presented in Figures 6-a, 6-b, and 6-c.



a. NB2 Type Product. b. NB1 Type Product. c. BP Type Product.

Figure 6. Number of Baskets by Product Type and Product Ratio in the Basket.

As seen in Figure 6a, for the NB2 group, the ratio of products in 117 baskets is medium. In only 18 baskets, the ratio of NB2 group products is large (approximately 3%). The share of NB2 products is small in the vast majority of purchases (approximately 70%). For the NB1 group, the number of baskets with a large product ratio is only 18. Simultaneously, there are 158 baskets with a medium ratio of products in the NB1 group. The number of baskets with a small ratio for the NB1 group is 482. The number of baskets with a medium proportion of BP-type products is 351, while the number of baskets with a large proportion of BP products is only 156. The number of baskets with a small proportion of BP-type products is 129. In all the graphs, the blue, red, and green colors correspond to small, medium, and large baskets, respectively.

To answer the third research question – whether there is a relationship between the share of products in a basket and the number of baskets – a fuzzy logic model was developed.

A set of fuzzy rules was developed based on data processing using the Weka[9] software. A fragment of these rules is provided below:

- If "Product type" is NB2 and the product ratio in the baskets is "Small," then the number of baskets is "Few."
- If "Product type" is NB2 and the product ratio in the baskets is "Medium," then the number of baskets is "Medium."
- If "Product type" is BP and the product ratio in the baskets is "Medium," then the number of baskets is "Few."

[9] Bouckaert RR, Frank E, Hall MA, Holmes G, Pfahringer B, et al. (2010) WEKA–Experiences with a Java Open-Source Project. J Mach Learn Res 11: 2533–2541

- If "Product type" is BP and the product ratio in the baskets is "High," then the number of baskets is "Medium," and so on.

The fuzzy logic inference module was developed using the FisPro software based on the rules above. Figure 7 illustrates the activation of these rules for a scenario where NB2 products have a low sales rate.

For example, if the product type value is 4.1 (corresponding to product type NB1) and the NB1 ratio is 3.8 (a medium degree), this means that approximately 182 baskets would satisfy these conditions. More precisely, the ratio of NB1-type products was at a medium level in approximately 182 shopping transactions.

Based on this approach, a supermarket's shopping baskets were analyzed over a specific period. The purchase transactions were examined in terms of product types, basket size, the number of baskets, and basket content. The analysis was conducted using a combination of data mining and fuzzy logic. Based on a review of sources and interviews with potential customers, food products were divided into three categories according to their demand and utility. Customer preferences for these product categories were also analyzed.

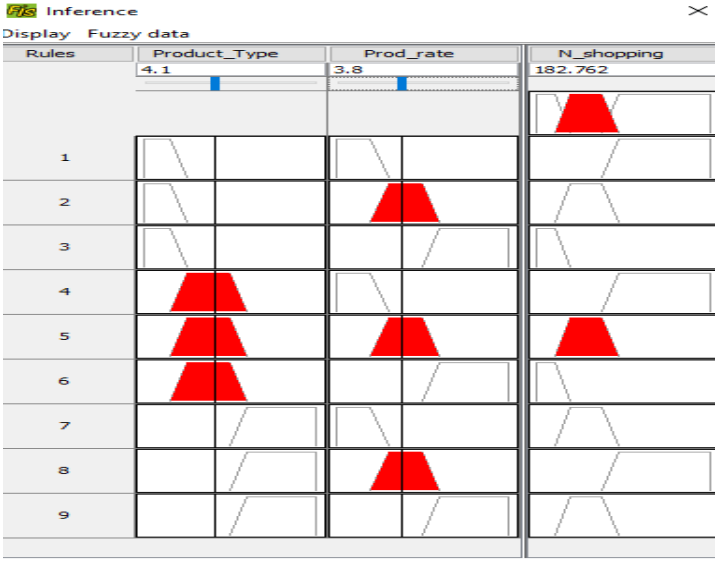


Figure 7. Activation of Fuzzy Rules.

3. A Model for Evaluating the Marketing Activities of Commercial Enterprises [10].

The issues of marketing quality evaluation have been investigated by several international researchers (Wong et al., 1989; Liu et al.; Narver & Slater, 1990; Shaw & Doyle, 1991; Doyle; Avlonitis et al., Wink, 1992; Jaworski & Kohli; Mueller-Heumann, 1993).

In this dissertation, an approach was developed for evaluating the marketing activities of commercial enterprises that allows for the combined use of identified factors (survey questions) and fuzzy set theory. The fuzzy inference model created to evaluate the effectiveness of marketing activities utilized the MATLAB environment and the Mamdani algorithm[11].

The model's input parameters (criteria for evaluating the effectiveness of marketing activities) and their corresponding fuzzy term sets are given as follows:

1. Frequency of research on external factors affecting marketing activities (markets, customers, and competitors) (X_1):
   - LOW (L): 5 years or more ago, or never.
   - MIDDLE (M): In the range of 1 to 5 years.
   - HIGH (H): Recently (up to 12 months) (Figure 8a).
2. Effectiveness of product policy (X_2) (evaluated on a 10-point scale):
   - Low (L)
   - Medium (M)
   - High (H) (Figure 8b).
3. Frequency of updating the marketing information system in terms of obtaining high-quality information (X_3):
   - LOW (L): Information is collected irregularly and loaded into the electronic database with a delay of more than two days. This data is primarily paper-based and collected intuitively.

[10] Ramiz, A., Vuqar, S. (2022). Assessment of the Effectiveness of Marketing Activities of Commercial Enterprises Using the Theory of Fuzzy Sets. Lecture Notes in Networks and Systems, vol 504. Springer, Cham. https://doi.org/10.1007/978-3-031-09173-5_18

[11] Fuzzy Logic Toolbox. https://www.mathworks.com/products/fuzzy-logic.html

- MIDDLE (M): The system is reasonably efficient, with information being collected regularly and entered into the electronic database within two days. The information is mainly stored on paper.
- HIGH (H): Information is collected regularly online from the internet and electronic databases, filtered, processed, and entered into the electronic database within 24 hours (Figure 9c).

4. Effectiveness of pricing policy (X_4) (evaluated on a 10-point rating system):
   - Low (L)
   - Medium (M)
   - High (H) (Figure 8c).
5. Effectiveness of advertising campaign (X_5) (evaluated on a 10-point rating system):
   - Low (L)
   - Medium (M)
   - High (H) (Figure 8c).

As shown in Figure 8d, the term set of the output linguistic variable – {Does not affect (NE), Satisfactory (S), Good (G), High effectiveness (HE)} – is used to evaluate the effectiveness of a commercial enterprise's marketing activities.

More than 200 fuzzy rules were used as the model's knowledge base. The evaluation of marketing activity effectiveness is performed during the fuzzy logic inference process [12] based on the set of production rules shown below:

IF (X_1 is A) AND (X_2 is B) AND (X_3 is C) AND (X_4 is D) AND (X_5 is E) THEN (O is L)

Here, the linguistic values A, B, C, D, E, and L are determined based on the identification of the membership functions of the linguistic variables X_1, X_2, X_3, X_4, X_5, and O.

As a result of this research, more than 200 fuzzy production rules were developed.

[12] Zadeh, L.A., Aliev, R.: Fuzzy Logic Theory and Applications: Part I and Part II (2018). https://doi.org/10.1142/10936

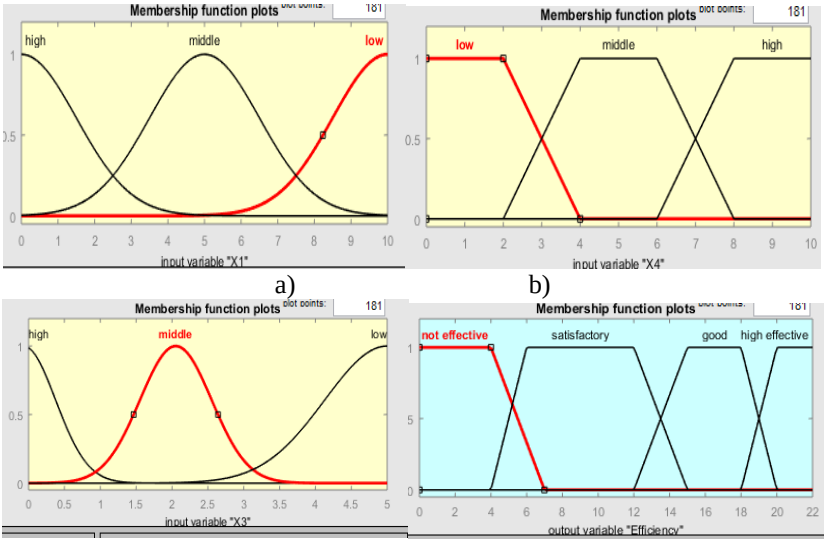


Figure 8. Parameters of Input and Output Linguistic Variables: a) Frequency of research (X_1) b) Term sets of variables X_2, X_4, X_5 c) Frequency of marketing data updates (X_3) d) Quality of the enterprise's marketing activities (O).

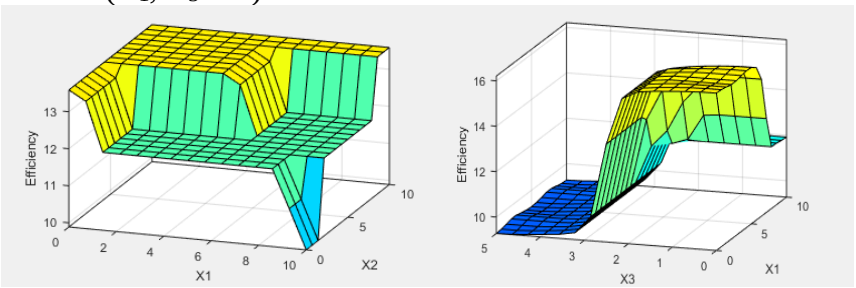
Table 9.

Fragment of the Fuzzy Production Rules Database

X_1 - Research Frequency	X_2 - Product Policy Effectiveness	X_3 - Marketing Data Update Frequency	X_4 - Pricing Policy Effectiveness	X_5 - Advertising Campaign Effectiveness	O - Quality of the Enterprise's Marketing Activities
H	**L**	**L**	**L**	**M**	**G**
H	**H**	**L**	**L**	**L**	**G**
M	**L**	**L**	**L**	**H**	**G**
L	**H**	**L**	**H**	**M**	**G**
M	**M**	**L**	**H**	**H**	**G**
L	**L**	**H**	**M**	**L**	**NE**
L	**M**	**H**	**L**	**L**	**NE**
H	**L**	**H**	**L**	**L**	**S**
M	**L**	**H**	**L**	**H**	**S**
M	**L**	**H**	**H**	**L**	**S**

The fuzzy logic inference model was developed using the Fuzzy Logic Toolbox extension within the MATLAB environment.

The influence of the criteria described in the developed production rules on the quality of the enterprise's marketing activities is shown in Figure 9a for the variables (X_1, X_2->O) and in Figure 9b for the variables (X_1, X_3->O).



a) b)

Figure 10. Influences: a) - X_1, X_2->O; b) - X_1, X_3->O.

Based on the developed model, the marketing effectiveness of several commercial enterprises was evaluated. The results of the research showed that commercial enterprises such as "Coca-Cola Azerbaijan," "Bazar Store," "Bravo Supermarket Azerbaijan," and "AzerSun Holding" LLC have organized their marketing activities at a very high level. This is primarily attributed to their distinguishing features, which include having their own ERP systems, a dedicated pricing policy, an extensive sales network, and the ability to collect market, customer, and consumer data online.

This method can be used by marketing centers, marketing researchers, and the marketing departments of commercial enterprises.

4. A Method for Comparative Financial Analysis of Commercial Enterprises[13].

During the evaluation of financial indicators, an enterprise's financial data (profit and loss statements, balance sheets) are

[13] Salahli, V., Suleymanov, A. (2022). Financial Performance Analysis with Intuitive Fuzzy Logic and Entropy-Based Multi-criteria Decision Making Method. Lecture Notes in Networks and Systems, vol 362. Springer, Cham. https://doi.org/10.1007/978-3-030-92127-9_94

analyzed using various approaches. Profitability, sales volume, the efficient use of funds, the level of debt, debt repayment ability, and the enterprise's market position are analyzed in various contexts. Thirteen criteria were used for the evaluation of financial indicators (Table 10).

The following steps outline the proposed methodology for evaluating the financial indicators of furniture companies using a multi-criteria decision-making process based on entropy and intuitive fuzzy logic.

Table 10.

Criteria for Evaluating Financial Performance

Criterion Group	Criteria Used	Purpose of Use
Growth Rates	Growth of Assets (Y_1) Growth of Sales Turnover (Y_2) Growth of Capital (Y_3)	Criteria showing the growth of business assets.
Activity Ratios	Turnover rate of current assets (Y_4) Turnover rate of receivables (Y_5) Asset RPM (Y_6) Rate of change of debt turnover (Y_7)	Criteria showing how efficiently business assets are used.
Creditworthiness	Total Debt/ Total Assets (Y_8) Fixed Assets/ Basic Capital (Y_9)	Criteria that evaluate the ability of enterprises to meet their long-term obligations.
Profitability	Return on Assets (Y_{10}) Return on Capital (Y_{11})	Criteria for evaluating how efficiently business assets are used.
Liquidity	Current Ratio (Y_{12}) Liquidity Ratio (Y_{13})	Criteria for evaluating the ability of the business to pay its short-term debts.

Using data from the Finnet database [14] information on eight furniture companies from 2016 to 2020 was processed, and their average values were determined in Table 11.

[14] Randall Richard C. The Quality Yearbook. Published by McGraw-Hill, Inc.

Table 11.
Average Values of 5-Year Performance Data for Furniture Companies, by Criterion

Criteria							
	Growth Rates			Activity Ratios			
Alternatives	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7
Embawood (X_1)	50.11	50.14	89.68	3.21	12.14	1.16	1.16
Woodpecker (X_2)	26.04	62.88	83.64	1.36	8.25	0.21	0.17
Damlamebel (X_3)	13.54	16.18	13.57	3.58	5.52	0.68	0.71
Gumushmobilya (X_4)	8.04	298.2	14.26	0.71	23.41	0.06	0.08
Hacıoğullar (X_5)	19.25	27.05	10.34	1.52	10.15	0.23	0.21
SaloğluMebel (X_6)	9.51	30.49	-7.25	1.56	9.25	0.08	0.14
KardaşlarMebel (X_7)	16.75	12.46	7.55	1.96	4.40	0.97	0.39
FurkanMebel (X_8)	19.25	27.05	10.34	1.52	10.17	0.23	0.19
Average for the furniture trade sector	19.49	64.09	32.62	2.11	11.04	0.51	0.46
Criteria							
	Creditworthiness		Profitability		Liquidity		
Alternatives	Y_8	Y_9	Y_{10}	Y_{11}	Y_{12}	Y_{13}	
Embawood (X_1)	0.81	1.08	2.17	11.81	0.89	0.64	
Woodpecker (X_2)	0.91	1.33	-2.84	-26.9	0.43	0.38	
Damlamebel (X_3)	0.70	1.14	2.21	7.02	0.66	0.65	
Gumushmobilya (X_4)	0.57	1.34	-10.7	-24.8	0.34	0.17	
Hacıoğullar (X_5)	0.81	1.16	-0.85	-4.38	0.60	0.49	
SaloğluMebel (X_6)	0.36	0.98	-4.41	-8.12	3.31	3.16	
KardaşlarMebel (X_7)	0.74	1.19	-2.04	-11.8	0.66	0.28	
FurkanMebel (X_8)	0.81	1.14	-0.85	-4.40	0.60	0.47	
Average for the furniture trade sector	0.71	1.16	-1.04	-5.20	1.03	0.85	

The alternatives were evaluated using fuzzy numbers, as shown in Table 12. During the evaluations, deviations from the average values were eliminated.

Table 12.

Representation of Criteria Values as Fuzzy Numbers

Linguistic Terms	Intuitive Fuzzy Numbers
Very Good (VG)	(0,90; 0,10; 0,00)
Good (G)	(0,75; 0,20; 0,15)
Medium (M)	(0,50; 0,45; 0,05)
Bad (B)	(0,35; 0,60; 0,05)
Very Bad (VB)	(0,10; 0,90; 0,00)

After determining the weight coefficients of the criteria, the average weight coefficients for each alternative were identified (Table 13).

Table 13.

Average Values of Alternatives' Final Weighted Coefficients

Alternatives	μ	ϑ
Embawood ($\boldsymbol{X_1}$)	0.657	0.335
Woodpecker ($\boldsymbol{X_2}$)	0.513	0.476
Damlamebel ($\boldsymbol{X_3}$)	0.454	0.510
Gumushmobilya ($\boldsymbol{X_4}$)	0.537	0.47
Hacıoğullar ($\boldsymbol{X_5}$)	0.575	0.403
SaloğluMebel ($\boldsymbol{X_6}$)	0.366	0.594
KardaşlarMebel ($\boldsymbol{X_7}$)	0.564	0.395
FurkanMebel ($\boldsymbol{X_8}$)	0.362	0.612

After calculating the μ and ϑ values of the weights for each alternative, the following formula was used to calculate the ranking values: ranqXi = μXi - ϑXi , iϵ[1,8] The results are presented in Table 14.

As shown in Table 14, the analysis of five-year financial performance indicates that the Embawood company has organized its activities more effectively compared to the other companies. Among the alternatives, the Furkan furniture company had the lowest performance indicators.

Table 14.

Ranking of Alternatives

Alternatives	$ranq_{Xi} = \mu_{Xi} - \vartheta_{Xi}$, $i \epsilon [1,8]$
Embawood ($\boldsymbol{X_1}$)	0.322
Woodpecker ($\boldsymbol{X_2}$)	0.037
Damlamebel ($\boldsymbol{X_3}$)	-0.056
Gumushmobilya ($\boldsymbol{X_4}$)	0.067
Hacıoğullar ($\boldsymbol{X_5}$)	0.172
SaloğluMebel ($\boldsymbol{X_6}$)	-0.228
KardaşlarMebel ($\boldsymbol{X_7}$)	0.169
FurkanMebel ($\boldsymbol{X_8}$)	-0.25

5. Structure and Main Features of an Intelligent Decision-Making Software System for Commercial Enterprises.

The research conducted within the framework of this dissertation has made it possible to substantiate the following points:

- Numerous methods and techniques have been developed for managing the business processes of commercial enterprises.
- The software implementation of modules for managing business processes has been carried out using various instrumental tools.
- While most existing systems today are closed, some have an open-source structure, which allows other developers to make changes.
- Most modern software tools have the ability to integrate with one another within a unified software environment.

Based on these findings, the following requirements are placed on intelligent decision-making systems for commercial enterprises:

- To have an open-source structure.
- Modularity.
- The ability to integrate modules created with various instrumental tools into a unified software environment.
- The ability to provide visualization.
- The ability to transform, clean, and store data.
- The ability to prepare reports and deliver results to users in an

understandable format.

- The ability to support authorization.
- The ability to ensure security.

Based on the points mentioned above, the general structure of the developed intelligent decision-making system for commercial enterprises is presented in Figure 10. The structure of this software system, which reflects its main modules and their interconnections, allows for the integration of modules developed in the MATLAB environment as well as various other modules. The system consists of the following components:

- User Interface: Since the system is to be developed as a web application, the user interface should have the capabilities typical of such systems. This includes remote access and the use of web-based graphical features.
- Integration Layer: This layer consists of a database, API services, and middleware used to facilitate integration between them. The main purpose of the API services is to retrieve the necessary data from the database based on various queries.

Decision-Making Subsystem: This subsystem consists of multiple modules, which were developed using various tools, including C#, Java, Python, R, and MATLAB. It is important to note that the core modules of the proposed system were written in the C# language using the Microsoft Visual Studio development environment.

The logical inference and rule-based inference modules were primarily developed with the help of the Fuzzy Inference System add-on, which was created using the MATLAB environment.

- Security: To protect data and system integrity, the system provides secure connection, authentication, and authorization capabilities.
- Output Management: The main purpose of this module is to visually present decisions and results to users. This is achieved through graphs, diagrams, and other visual aids created using report processing, visualization tools, and result display modules.

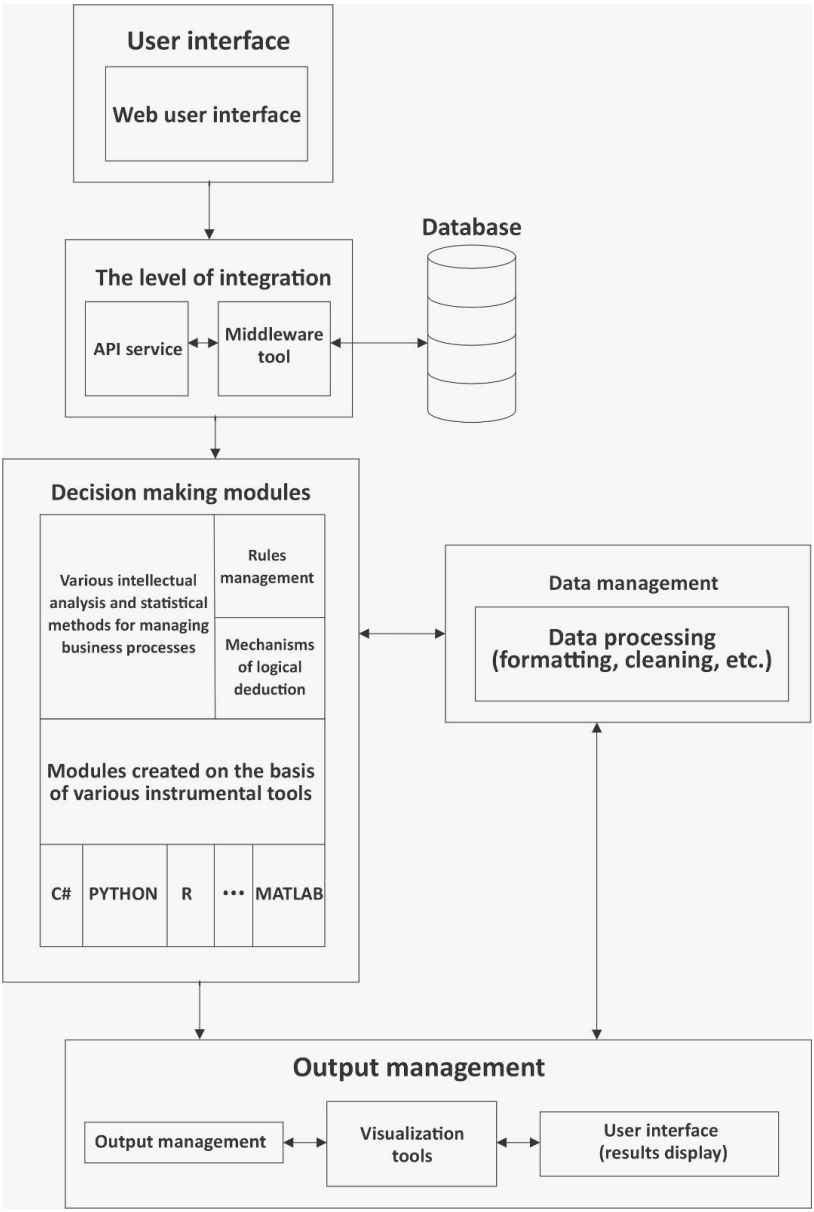


Figure 10. General Structure of the Intelligent Decision-Making System.

The proposed approach for building this intelligent decision-making system for commercial enterprises allows for the creation of a flexible and scalable system. It can manage various business processes by utilizing modules from different software tools (such as MATLAB and others).

The software implementation of the system was developed according to the requirements and overall structure outlined in subsection 3.5.1. Users of the system have specific permissions and can access functions based on those permissions. The list of user groups includes:

- Administrator
- User
- Expert

The software system consists of the following modules:

- Decision-making
- Location selection
- Statistical analysis
- ABC analysis
- Forecasting
- Intelligent analysis
- Product placement
- Shopping basket analysis
- Anomaly and fraud detection
- Product classification
- Customer classification
- Region classification
- Login

In this dissertation, the operation of the software system is explained in detail using the example of selecting sales locations for commercial enterprises.

CONCLUSION

The main scientific results obtained in this dissertation are as follows:

1. A functional architecture for an intelligent decision-making system for managing commercial enterprises was proposed, and its software structure and functional characteristics were determined. The architecture reflects the system's main modules, their interconnections, and the flow of information in decision-making.
2. The problem of selecting locations for new branches and sales outlets was formulated as a multi-criteria decision-making problem. To solve this, a fuzzy logical inference model based on fuzzy set theory was proposed and developed.
3. A multi-criteria evaluation model for assessing the marketing activities of commercial enterprises was proposed and developed. The effectiveness of marketing strategies was analyzed based on this model.
4. A model for the combined application of data mining methods and fuzzy logic was developed for the intelligent analysis of shopping basket contents and purchasing behavior.
5. An approach based on fuzzy set theory was proposed for the comparative analysis of the financial activities of commercial enterprises. This approach allows for the evaluation of profitability by comparing different enterprises.

LIST OF SCIENTIFIC WORKS PUBLISHED ON THE TOPIC OF THE DISSERTATION:

1. Salahli, V. Analysis of Food Shopping Baskets in a Supermarket in Terms of Different Parameters Using Fuzzy Logic. // Open Journal of Business and Management, – 2020. Vol. 8(5), – p.2195–2204. https://doi.org/10.4236/ojbm.2020.85134
2. Salahli, V. Süper Marketlerde Alış-Veriş Bilgilerinin Veri Madenciliği ve Bulanık Mantık Yöntemleriyle Analizi // 6 th

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3. Alekperov, R.B. Estimation of Potential Locations of Trade Objects on the Basis of Fuzzy Set Theory. / R.B.Alekperov, V.M.Salahli // In Advances in Intelligent Systems and Computing. Springer, Cham. – 2021. Vol. 1197, – p.228-237. https://doi.org/10.1007/978-3-030-51156-2_28
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10. Salahli, M.A. Fuzzy Logic Analysis of Parameters Affecting Students' Satisfaction with Their Life at University / M.A.Salahli, T.Gasimzade, V. Salahli, F.Alasgarova, A.Guliyev // In Lecture Notes in Networks and Systems, Springer, Cham. – 2023. Vol. 610, – p.382–390. https://doi.org/10.1007/978-3-031-25252-5_51.

The author's personal contribution to co-authored scientific articles is as follows:

For articles [3, 5, 7, 8, 9, 10], the author was responsible for the problem statement, solution methodology, analysis of the obtained results, and computer-based simulation.

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