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DEVELOPMENT OF THE ARCHITECTURAL SOLUTION OF AN INTELLIGENT DECISION SUPPORT SYSTEM AND SELECTION OF THE OPTIMAL SOLUTION

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received:2025-12-23 Received in revised form:2026-01-12 Accepted Available online</p> <hr/> <p><i>Keywords:</i> Intelligent decision support system; Decision support system; Soft computing; System architecture; Business models</p> <p>2010 Mathematics Subject Classification: 68T01; 68T37; 90B50</p>	<p><i>This study comprehensively investigates theoretical and practical issues related to the development and implementation of intelligent decision support systems used in the management processes of commercial enterprises. Functional and technical requirements for the architectural structure of these systems are identified, and an optimal architectural solution is scientifically selected through comparative analysis of various alternatives. The effectiveness of decision support systems in managerial decision-making is analyzed in terms of efficiency, responsiveness, and accuracy. The impact of implementing intelligent decision support systems on business process effectiveness and rational use of resources in the modern business environment is evaluated. It is substantiated that soft computing methods – such as artificial neural networks, fuzzy logic, and genetic algorithms – significantly expand decision-making capabilities under conditions of uncertainty. It is demonstrated that the proposed modular architectural approach for commercial enterprises enhances management quality and competitiveness</i></p>

1. Introduction

In the modern era, both public and private sector organizations operating in complex and rapidly changing economic environments require timely, well-grounded, and optimal decision-making. Globalization, intensified competition, market volatility, differentiation of customer demands, and the rapid growth of information flows have significantly increased the complexity of management processes. Under these conditions, the development and implementation of decision support systems (DSS) based on modern information technologies become particularly relevant for improving managerial efficiency, ensuring rational resource utilization, and achieving strategic objectives [1].

Decision support systems are interactive information systems that assist decision-makers by processing, analyzing, and interpreting data collected from various sources. Traditional DSS are primarily aimed at solving structured and semi-structured problems and are based on deterministic and statistical models. Such systems have been successfully applied in various fields. For example, in the aviation sector, analytical decision support systems are used to analyze flight and cargo flows, plan resources, and optimize operational decisions. DSS built on

geographic information systems support spatial decision-making and are widely applied in urban planning, transportation, forestry, and security. In the telecommunications industry, DSS are used for pricing strategy formulation, marketing campaign planning, and analysis of customer behavior [2,3].

In the banking and insurance sectors, decision support systems are applied to solve critical tasks such as credit risk assessment, fraud detection, customer segmentation, and financial risk management [4,5]. These examples demonstrate the significant role of DSS in managerial decision-making across various domains. However, in recent years, the rapid increase in the volume of processed information, data heterogeneity, and uncertainty have limited the capabilities of traditional decision support systems.

In commercial enterprises in particular, the decision-making process is influenced by numerous internal and external factors. Issues such as inventory management, sales planning, pricing strategy selection, customer behavior forecasting, and evaluation of marketing and advertising campaign effectiveness are multi-criteria, nonlinear, and inherently uncertain. Such problems are often difficult to fully describe using classical mathematical models and rigid formal methods. Uncertainty, incomplete information, subjective assessments, and expert knowledge constitute integral components of the decision-making process.

For this reason, at the current stage, the intellectualization of decision support systems—namely, the integration of artificial intelligence and soft computing methods into these systems—is considered essential. Intelligent decision support systems (IDSS) offer broader capabilities compared to traditional systems in handling uncertain and poorly formalized data, modeling expert knowledge, and substantiating alternative decision options. IDSS function as systems that complement human cognitive capabilities by providing analytical and intelligent support to decision-makers in solving complex problems [6–8].

Soft computing methods play a crucial role in the development of intelligent decision support systems. These methods include fuzzy logic, artificial neural networks, genetic and other evolutionary algorithms, probabilistic approaches, and their hybrid combinations [9,10]. Fuzzy logic enables the modeling of imprecise, linguistic, and expert assessments. Artificial neural networks are considered effective tools for learning complex nonlinear relationships and solving forecasting problems. Genetic algorithms are widely applied to identify optimal or near-optimal solutions among multiple alternatives. The combined use of these methods enhances flexibility and adaptability in the decision-making process.

Studies indicate that intelligent decision support systems based on soft computing methods demonstrate high effectiveness in solving problems such as inventory optimization, sales forecasting, customer behavior analysis, and pricing strategy formulation in commercial enterprises [11–16]. Artificial intelligence-based decision mechanisms are widely used in modern e-commerce platforms, CRM systems, and analytical marketing tools, further confirming the practical significance of IDSS in the business environment.

It should be noted that the development of intelligent decision support systems depends not only on the methods employed but also directly on the system architecture. Architectural solutions determine system flexibility, scalability, modularity, integration capabilities with various tools, and security levels. In particular, IDSS used in commercial enterprises must have an open architecture that enables the integration of modules developed in different program-

ming environments within a unified system. This makes the selection of an optimal architectural approach a key scientific and practical problem.

In the author's previous studies, issues related to the application of fuzzy logic and artificial intelligence methods in the analysis of commercial and business processes were investigated, and effective results were obtained in modeling customer behavior and analyzing shopping baskets [17,18]. These studies demonstrated that fuzzy and intelligent approaches more adequately reflect the uncertainty and subjectivity inherent in real business environments. The present article continues this line of research by focusing on the architectural aspects of intelligent decision support systems and aims to develop an optimal architectural solution for commercial enterprises.

Thus, this article formulates requirements for intelligent decision support systems by considering the characteristics of business models used in commercial enterprises, analyzes existing approaches, and proposes a modular architectural solution that ensures the integration of soft computing methods. This approach contributes to improving managerial efficiency, scientifically substantiating decision-making processes, and enhancing the competitiveness of commercial enterprises.

2. Systematization of Business Models in Commercial Enterprises and Requirements for Intelligent Decision-Making Systems

The activities of modern commercial enterprises are carried out in a dynamic market environment characterized by a high level of competition and rapidly changing consumer demands. For this reason, managing business processes based on the capabilities of information technologies has become one of the key factors in ensuring sustainable development and competitive advantage for enterprises. As a result of the integration of computer science, data analysis methods, and artificial intelligence technologies into the business environment, business models applied in commercial enterprises have acquired a more flexible, adaptive, and analytically oriented nature.

The formation of business models in commercial enterprises is directly related to the current level of development and application of information technologies. These models aim to structure the core business processes performed within the enterprise and to ensure their interrelationships. According to modern approaches, the main business processes carried out in commercial enterprises include procurement of goods and materials, inventory management, organization of sales and customer service, marketing and advertising activities, financial management, human resource management, as well as analytical analysis and managerial decision-making [19]. The effective management of these processes has a direct impact on the overall performance indicators of the enterprise.

Figure 1 presents a generalized classification of business models typical for commercial enterprises. As shown in the figure, business models are grouped according to functional directions and encompass operational, tactical, and strategic management levels. This approach enables the hierarchical classification of business processes and facilitates a more systematic construction of decision-making mechanisms.

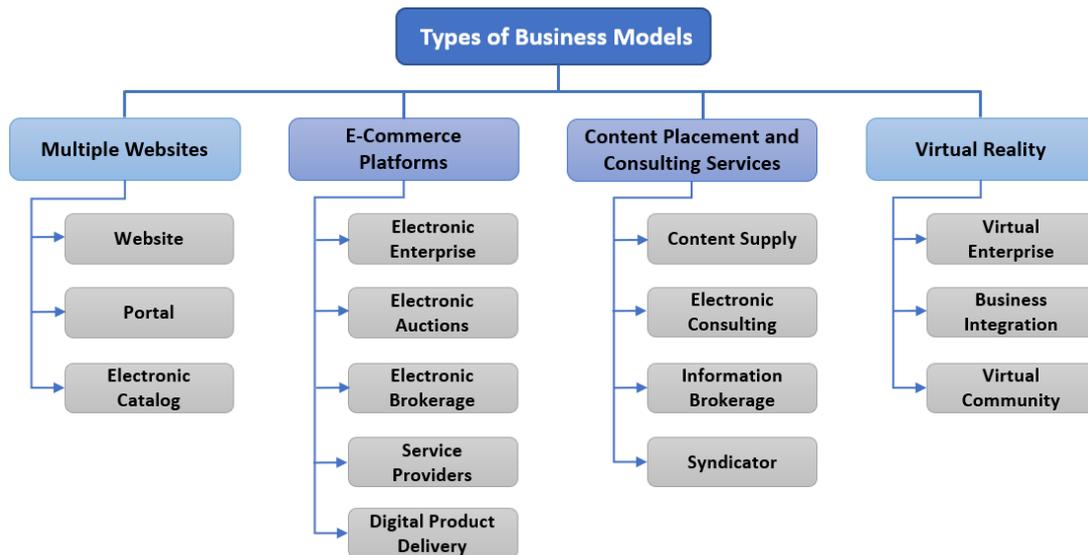


Fig. 1 Classification of business models of commercial enterprises (by operational processes – tactical management – strategic decision-making levels)

The classification shown in Figure 1 clearly demonstrates the integration of business processes with information technologies and the role of analytical tools in decision-making at different management levels. At the operational level, the primary focus is on the execution of day-to-day activities; at the tactical level, on the optimal allocation of resources; and at the strategic level, on making long-term development decisions.

The conducted studies indicate that the effectiveness of methods and tools applied in business process management depends on the extent to which quantitative and qualitative factors influencing these processes are taken into account. The activities of commercial enterprises are shaped by both internal and external factors. Internal factors are related to the organizational structure, resource potential, and management strategy of the enterprise, while external factors are associated with market conditions, the competitive environment, and consumer behavior. A significant portion of these factors is characterized by uncertainty and difficulty in formalization.

Uncertainty, incomplete information, subjective assessments, and ambiguity of objectives complicate the decision-making process and increase the risk of incorrect decisions. Therefore, classical deterministic models have limited capabilities in managing business processes in commercial enterprises. Under such conditions, the application of modern soft computing methods is considered necessary to ensure more substantiated and flexible decision-making.

Soft computing methods represent a set of approaches that include fuzzy logic, artificial neural networks, genetic and other evolutionary algorithms, machine learning, and natural language processing techniques [20]. These methods enable working with imprecise data, modeling expert knowledge, and adapting to changing environments. The use of fuzzy logic in modeling business processes allows decision formation based on linguistic variables, while the application of artificial neural networks facilitates learning complex nonlinear relationships.

The conducted analyses show that intelligent decision-making systems developed for commercial enterprises should be tailored to the enterprise’s operational profile and support the daily decision-making processes of management personnel. The methods used in these systems and the results obtained should be understandable and interpretable for users. Solving the same

decision problem using different methods is of significant importance for comparing alternatives and substantiating decisions, which necessitates the modular design of such systems.

Taking the above characteristics into account, the following key requirements are proposed for intelligent decision-making systems in commercial enterprises: an open and scalable architecture, modularity, the ability to integrate modules developed in different instrumental environments, result visualization, data processing and storage, report generation, as well as the presence of security, authentication, and authorization mechanisms. These requirements ensure that intelligent decision-making systems are designed in accordance with the real needs of commercial enterprises.

3. General Architectural Structure of the Intelligent Decision-Making System for Commercial Enterprises

Based on the functional and technical requirements formulated in the second section, a modular and scalable general architectural approach is proposed for the development of intelligent decision-making systems (IDMS) in commercial enterprises. This architectural approach enables the integration of methods and models developed in various instrumental environments within a unified software system, thereby allowing decision-making processes to be carried out in a flexible and adaptive manner.

The general architecture of the proposed intelligent decision-making system is presented in Figure 2. The figure illustrates the main functional modules of the system and their interactions. The architectural structure covers all stages of the decision-making process, starting from data collection and processing, through intelligent analysis and decision generation, and ending with the presentation of results to users.

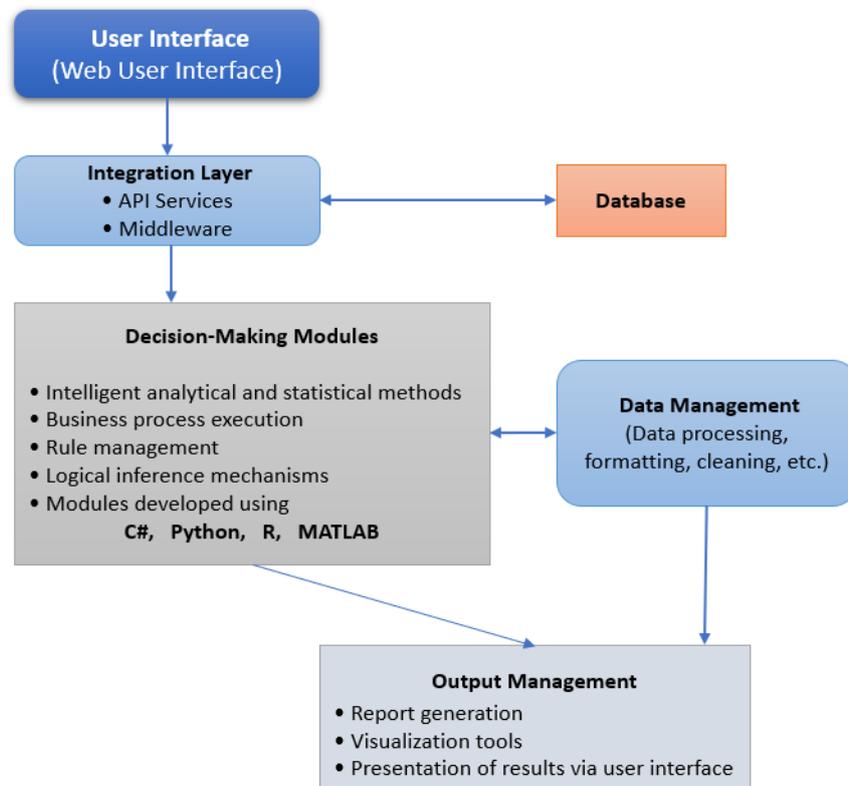


Fig. 2 General architecture of the intelligent decision-making system for commercial enterprises

As shown in Figure 2, the system consists of several main layers. The first layer is the user interface. Since the system is designed based on the web application principle, the user interface should provide remote access capabilities, a user-friendly graphical environment, and functionality tailored to different categories of users. This layer enables interactive communication between managers, decision-makers, and the system.

The second layer is the integration layer, which includes the database, application programming interfaces (APIs), and middleware components. The primary function of this layer is to collect data from various sources, structure the data, and transfer it to the decision-making subsystem. API services ensure flexible and secure data exchange between the database and application modules.

The third and core layer is the decision-making subsystem. This subsystem consists of analytical and intelligent modules developed in different instrumental environments. The main components of the decision-making system are implemented using programming and computational environments such as C#, Java, Python, R, and MATLAB. It should be noted that the core control modules of the system were developed in the Microsoft Visual Studio environment using the C# programming language.

The intelligent analysis and logical inference modules are primarily implemented using fuzzy logic-based Fuzzy Inference System (FIS) tools developed in the MATLAB environment. Integration of these modules into the main software system is achieved through the MATLAB API, which allows dynamic invocation and utilization of various intelligent models. This approach expands the functional capabilities of the system and ensures compliance with the modularity principle.

Example based on MATLAB API:

```
import matlab.engine
eng = matlab.engine.start_matlab()
result = eng.fuzzyInferenceFunction(input_data)
eng.quit()
```

Instead of `fuzzyInferenceFunction`, any developed FIS module or MATLAB function can be invoked.

One of the key components of the architectural structure is the security module. This module provides authentication and authorization mechanisms, as well as secure communication protocols, to ensure the confidentiality, integrity, and availability of data.

The final layer is the output management module. This module is responsible for the visual presentation of generated decisions and analysis results to users in the form of graphs, charts, and reports. Presenting results in a clear and comprehensible manner facilitates faster and more well-grounded decision-making.

Thus, the proposed architecture of the intelligent decision-making system is characterized by an open, modular, and scalable structure and provides a flexible and functional platform for the effective management of various business processes in commercial enterprises

4. Conclusion

Within the framework of the conducted research, issues related to the development and implementation of intelligent decision support systems (IDSS) aimed at improving the efficiency of managerial decision-making in commercial enterprises were comprehensively investigated. For this purpose, the functional capabilities of existing traditional decision support systems were analyzed, and the methods and approaches used in developing intelligent decision support systems based on artificial intelligence and soft computing techniques were evaluated using various practical examples. As a result of the analysis, functional and technical requirements that take into account the operational characteristics of commercial enterprises were identified.

One of the main outcomes of the study is the proposal of an open, modular, and scalable architectural structure for intelligent decision support systems. This architectural approach enables the integration of analytical and intelligent modules developed in different instrumental environments within a unified software system, thereby expanding the possibilities for efficient utilization of existing internal resources of commercial enterprises. The flexibility of the proposed architecture allows the system to be adapted to the changing needs of enterprises and facilitates the gradual incorporation of new methods and technologies.

For future research, it is considered appropriate to develop a prototype of a real intelligent decision support software system based on the proposed architecture, improve integration mechanisms, and conduct experimental testing across commercial enterprises with different operational profiles. The results obtained can serve as a scientific and methodological foundation for the development and practical implementation of intelligent decision support systems in commercial enterprises of various types.

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