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METHODOLOGY FOR DEVELOPING INFORMATION TECHNOLOGY FOR SECURITY-ORIENTED MANAGEMENT OF SOCIO-ECONOMIC SYSTEMS BASED ON FUZZY LOGIC

In today's environment, socio-economic systems face increasingly complex challenges associated with high levels of uncertainty, risks, and rapid changes in the external environment. This necessitates the development of effective management methods that can ensure the reliability and flexibility of decision-making. The research is aimed at creating a methodology for the development and application of information technology for security-oriented management based on the principles of fuzzy logic. Fuzzy logic, based on the theory of fuzzy sets developed by Lotfi Zadeh, is a powerful tool for working with incomplete and fuzzy data, allowing to model complex systems and processes where traditional approaches may be ineffective.

The paper discusses the peculiarities of using fuzzy logic to create models that take into account possible risks and facilitate informed decision-making even with limited information. The proposed methodology allows to integrate various data sources, process them in real time and provide recommendations for risk management and security of socio-economic systems. The study also describes the structure of the technology, which includes the stages of data collection, fuzzification, fuzzy inference, defuzzification, and decision support. Systems based on fuzzy logic demonstrate high adaptability, resilience to change, and the ability to operate in the face of unpredictable changes.

The results of the study confirm that the proposed information technology can be applied in various industries, such as transportation, healthcare, and industry, to improve the safety and efficiency of management decisions. The use of the proposed methodology helps to reduce risks, improve the quality of management and adaptability to changes in external conditions, which are key requirements in modern management.

Keywords: security-oriented management, fuzzy logic, information technology, management systems, uncertainty, adaptability, socio-economic systems.

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МЕТОДОЛОГІЯ РОЗРОБЛЕННЯ ІНФОРМАЦІЙНОЇ ТЕХНОЛОГІЇ БЕЗПЕКООРІЄНТОВАНОГО УПРАВЛІННЯ СОЦІО-ЕКОНОМІЧНИМИ СИСТЕМАМИ НА ОСНОВІ НЕЧІТКОЇ ЛОГІКИ

У сучасних умовах соціо-економічні системи стикаються з дедалі складнішими викликами, що пов'язані з високим рівнем невизначеності, ризиками та швидкими змінами зовнішнього середовища. Це обумовлює необхідність розроблення ефективних методів управління, які здатні забезпечити надійність і гнучкість прийняття рішень. Дослідження спрямоване на створення методології розроблення та застосування інформаційної технології безпекоорієнтованого управління, що базується на принципах нечіткої логіки. Нечітка логіка, заснована на теорії нечітких множин, розробленій Лотфі Заде, є потужним інструментом для роботи з неповними та нечіткими даними, що дозволяє моделювати складні системи та процеси, де традиційні підходи можуть бути неефективними.

У роботі розглядаються особливості використання нечіткої логіки для створення моделей, які враховують можливі ризики та сприяють прийняттю обґрунтованих рішень навіть за умов обмеженої інформації. Запропонована методологія дозволяє інтегрувати різноманітні джерела даних, обробляти їх у реальному часі та надавати рекомендації щодо управління ризиками та забезпечення безпеки соціо-економічних систем. У дослідженні також описується структура технології, яка включає етапи збору даних, фазифікації, нечіткого висновку, дефазифікації та підтримки прийняття рішень. Системи, що базуються на нечіткій логіці, демонструють високу адаптивність, стійкість до змін і здатність працювати в умовах непередбачуваних змін.

Результати дослідження підтверджують, що запропонована інформаційна технологія може бути застосована в різних галузях, таких як транспорт, охорона здоров'я та промисловість, для підвищення рівня безпеки та ефективності управлінських рішень. Використання запропонованої методології допомагає знижувати ризики, підвищувати якість управління та адаптивність до змін зовнішніх умов, що є ключовими вимогами у сучасному управлінні.

Ключові слова: безпекоорієнтоване управління, нечітка логіка, інформаційні технології, управлінські системи, невизначеність, адаптивність, соціо-економічні системи.

Introduction

In today's world, characterized by high complexity and uncertainty of management processes, ensuring effective and reliable management is extremely important. Methodologies based on classical techniques often prove to be insufficient to work in conditions of incomplete information and changing circumstances. The use of fuzzy logic in security-oriented management systems offers new ways to solve these problems, allowing decisions to be made based on fuzzy and incomplete data, ensuring flexibility and sustainability of management processes. The study of the methodology for the development and application of information technology based on fuzzy logic is a relevant and important step towards improving the efficiency of management decisions in difficult conditions. The use of fuzzy logic in control systems allows taking into account various uncertain factors and provides flexible decision-making. The basics of fuzzy logic were developed by Lotfi Zadeh in his classic works, in particular in the

article "Fuzzy sets"[1]. This methodology allows modeling complex processes and systems where classical methods are not effective enough.

Many studies point to the effectiveness of using fuzzy logic in security-oriented systems. For example, the works of scientists such as Mamdani and Sugeno have expanded the use of fuzzy systems to real-world practical tasks, in particular in risk management. Study [2] shows how fuzzy systems allow creating effective algorithms for risk assessment and management.

The development of information systems based on fuzzy logic is very popular in the research of modern scientists. For example, the authors' work on the integration of fuzzy systems into information technology [3] confirms the growing interest in the use of this methodology in complex systems management technologies.

Scientific studies [4,5,6] demonstrate how the use of fuzzy logic methodology can increase the sustainability and safety of management decisions in technological processes.

Thus, the study of the methodology for the development and application of information technology for safety-oriented management using fuzzy logic is important for improving management systems in areas of high uncertainty, such as transportation, healthcare, and industry. Given the importance of safety and the need to make decisions in the face of complex and changing data, this approach is not only modern, but also necessary for the development of information technology.

Safety-oriented management

Security-oriented management is one of the new elements of the formation of the economic security system and requires certain specific conditions for its implementation in practice. Taking into account the conditions for the implementation of security-oriented management of socio-economic systems, special attention should be paid to the targeted managerial influence of a strategic nature, which is realized through the formation of an effective system of management decision-making, taking into account current threats [7]. At the same time, it is necessary to emphasize the system of managerial decision-making within a particular socio-economic system, decision-making within the economic security system, as well as the combination and interaction of such systems. Accordingly, the issue of methodological, organizational and resource support for the implementation of security-oriented management arises, which determines the prospects for further research. At the same time, it should be emphasized that for each field of activity and directly for a particular socio-economic system, the specifics of the formation and implementation of security-oriented management will significantly affect the composition of its elements and internal organizational processes.

Consider the following system model of security-oriented management:

$$\{S, G, X, Z, B, C, U\}$$

where S is a component of the security system: military, political, international, economic, information, social, environmental, etc.G is the object of research: world, country, economic sector, industry, cluster, region, type of economic activity, subject of research, process, personality; X is a set of characteristics (factors) describing the state of the system: indicators, indicators, stimulants; Z is the target values of indicators: critical, limit and threshold values; upper, lower limits, intervals, etc.; B - sphere of influence: internal, external; real, potential; permanent, temporary; direct, indirect; objective, subjective; controlled, uncontrolled; periodic, systematic, etc.; C - state of security: sufficient, insufficient, critical, catastrophic, etc.; U - management variable: risk, level, etc.

Methodology for the development and application of information technology for security-oriented management

Based on the developed system model, in order to form the theoretical foundations, we will build a methodology for the development and application of information technology for security-oriented management. The generalized structure of such a methodology is shown in Fig. 1.

The components of the structure are:

- security systems: military, political, international, economic, information, social, environmental, etc;
- Subject areas: finance, seismology, social protection, medical diagnostics, project financing;
- Object of research: world, country, economic sector, industry, cluster, region, type of economic activity, subject of research, process, personality;
- a set of characteristics (factors) that describe the state of the system: indicators, indicators, stimulants;
- Target values of indicators: quantitative, qualitative, critical, limit and threshold values; upper, lower limits, intervals, etc;
- spheres of influence: internal, external, real, potential, permanent, temporary, direct, indirect, objective, subjective, controlled, uncontrolled, periodic, systematic, etc;
- security statuses: sufficient, insufficient, critical, catastrophic, etc;
- management variable: risk, level, cluster, class, etc.

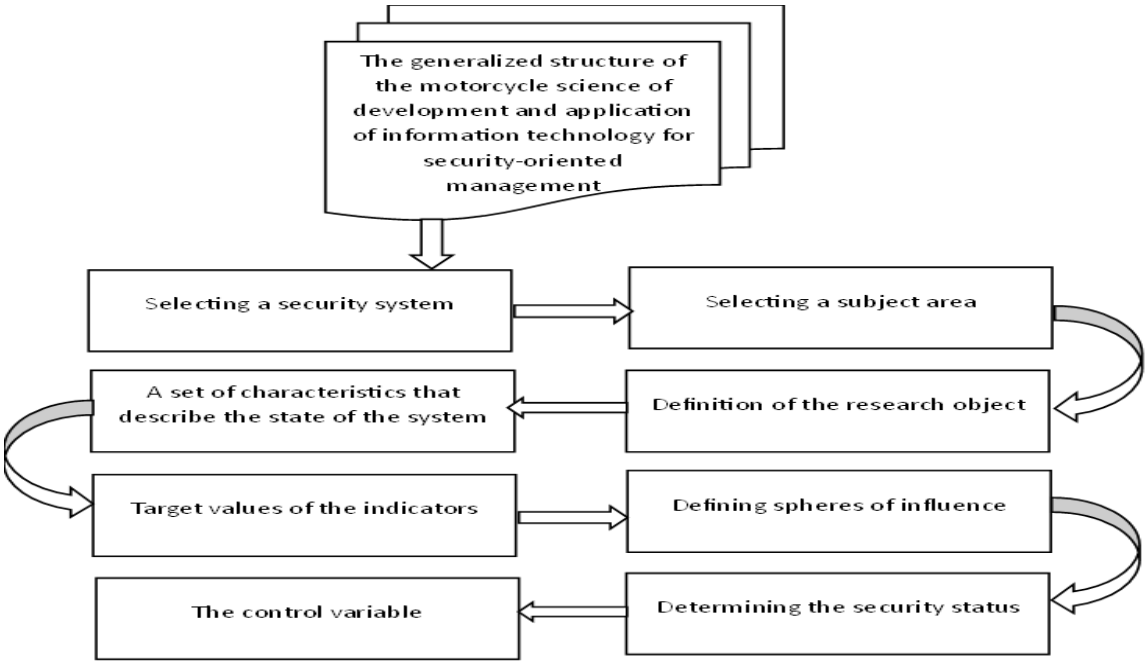

Fig. 1. Generalized structure of the methodology for the development and application of information technology for security-oriented management

A fairly large number of publications in foreign and domestic journals investigate the problems of strategic management through the prism of applying classical tools in a fuzzy formulation. In the last decade, one of the most promising areas of applied research in strategic management has been the use of methods and models of fuzzy set theory [6-11], which have a high adaptive capacity to expert data, are flexible enough and adequate to the input information.

Applied research[7-11] should be focused on the use of models for extracting knowledge from data, in particular, finding hidden repetitive patterns and structures in data, identifying patterns in data of various types, including unstructured data, based on deep learning modeling technologies: linear factor models, autoencoders, representation learning, structural probability models, Monte Carlo methods, statistical sum, approximate inference, deep generative models, etc. Traditional components of data analysis can be actively used: regression, classification, bootstrapping, bootstrapping repeated samples, regularization, decision trees, support vector machines, clustering, etc.

The creation and implementation of a security-oriented management technology based on fuzzy logic is a necessary step to ensure the effective functioning of socio-economic systems in the complex and changing conditions of the modern world. It allows to reduce the level of uncertainty, improve the safety and quality of management, ensuring flexibility and adaptability of management processes.

Modern socio-economic systems include many interconnected elements that influence each other, often in unpredictable ways. Traditional methods may be insufficient for effective management of such systems, as they are unable to fully take into account all possible scenarios and factors.

In complex systems, many processes are uncertain or have unpredictable outcomes. The use of fuzzy logic can reduce the impact of uncertainty, as it can handle fuzzy, incomplete, and contradictory data, providing a more flexible approach to modeling and decision-making.

Given the growing complexity and risks in the modern world, security is becoming a key aspect of management. Information technology that takes into account possible threats and models security scenarios allows you to prepare for potential crises and respond quickly to changes.

Many previously used management methods are based on rigid rules and precise numerical models that are not always able to adequately reflect real-world processes. Fuzzy logic makes it possible to adapt these methods to specific conditions and new challenges.

The socio-economic environment is constantly changing under the influence of economic crises, political changes, natural disasters, and other factors. Technologies that use fuzzy logic have the ability to adapt to new data and scenarios, which allows for continuous system operation even in unstable conditions.

By integrating different data sources and working with fuzzy concepts, this technology can support more informed and balanced decision-making, which increases management efficiency and minimizes risks.

The system's ability to predict and analyze possible scenarios helps to avoid crises and support the sustainable development of the economy, social sphere, and other important aspects of society.

Modern socio-economic systems face significant challenges due to their complexity, uncertainty and increased security requirements. In this context, the introduction of information technology for security-oriented

management based on fuzzy logic is an important step to ensure the effective and sustainable functioning of such systems. The use of this technology allows processing incomplete and fuzzy data, predicting possible risks and modeling various scenarios. This increases the adaptability and flexibility of management, allowing managers to make informed decisions even in unstable conditions. The introduction of such technology helps to minimize risks, increase security and support the sustainable development of socio-economic systems.

The information technology of security-oriented management of complex socio-economic systems based on fuzzy logic is designed to ensure the sustainable functioning and development of systems under conditions of uncertainty and risks. This technology integrates fuzzy logic tools for modeling and decision-making when traditional analytical methods cannot provide accurate results due to the complexity and uncertainty of the socio-economic environment.

Let us consider the main characteristics of this technology.

Fuzzy logic is used to describe and process uncertain information. In cases where conventional logic is unable to cope with data ambiguity, fuzzy logic allows you to create models that take into account flexible boundaries between different system states.

Security orientation. Focus on risk management and maintaining system security in the face of external and internal threats. This is achieved by assessing risks based on fuzzy criteria and building adaptive management strategies.

Data integration. It is used to combine information from different sources, which can be of different nature (quantitative and qualitative). This allows you to create a more complete picture for making informed management decisions.

Scenario modeling. The use of fuzzy logic allows you to predict the development of events under different scenarios. It helps to determine the probability of certain outcomes depending on a set of input parameters that can only be partially estimated.

Decision support. Provides tools to enable managers and analysts to make decisions based on simulations and estimates that take into account unclear and incomplete data.

Such information technologies are especially useful for managing large socio-economic systems, such as government agencies, municipal governance systems, large corporations, and organizations operating in a rapidly changing economic and social environment.

Thanks to its features, fuzzy logic technology ensures adaptability and stability of management, increases the efficiency of the system under conditions of uncertainty, reducing risks and increasing security.

Thus, using the proposed methodology for the development and application of information technology for security-oriented management, the scheme of information technology for security-oriented management of complex socio-economic systems based on fuzzy logic is shown in Fig. 2.

Lets provide a detailed description of all components of the structure of information technology for security-oriented management based on fuzzy logic.

Data collection and integration. Data sources may include statistical data, economic indicators, sensor data, reports, social media, third-party data, and other sources that reflect internal and external influences. Pre-processing is performed to normalize, clean, and prepare data for analysis. This may include removing noise, processing missing values, and creating a common data format.

Formation of a knowledge base. Fuzzy logic rules are a set of expert rules that establish connections between inputs and outputs. For example, "If economic stability is low and political tensions are high, the risk of system destabilization is high." Linguistic variables are included in the model as variables described by linguistic terms that reflect the values of indicators in the form of "low", "medium", "high", etc. Membership functions determine how well a given variable value corresponds to a particular linguistic term. They are the key element that transforms clear data into fuzzy sets.

Fuzzy inference module. The Rule Analysis Module applies a set of fuzzy logic rules to the phased input data using fuzzy inference methods (e.g., Mandani or Sugeno). The rules describe how the input variables interact and influence each other to form an output value. Aggregation of results: after each rule is evaluated, the system combines the results to form a single output fuzzy value. Defuzzification: converting fuzzy outputs into crisp values. After applying the rules and analyzing the output, the system uses a defuzzification method (e.g., the center of gravity method) to convert the fuzzy outputs into clear values that can be understood and applied by users.

Modeling and forecasting. The Simulation models element allows you to create various scenarios based on variable input parameters and assess their possible consequences. Modeling helps to determine how various factors (economic, political, social) can affect the system. Scenario analysis is defined as tools for assessing possible risks and outcomes when parameters and conditions in the system change. This part helps to identify weaknesses and potential threats.

Decision-making support. Generating recommendations - based on clear results, the system provides recommendations for actions that will help minimize risks or improve management efficiency. A user-friendly interface is provided for analysts and managers that visualizes data, scenarios, and analysis results. This helps to make informed decisions faster and with greater accuracy.

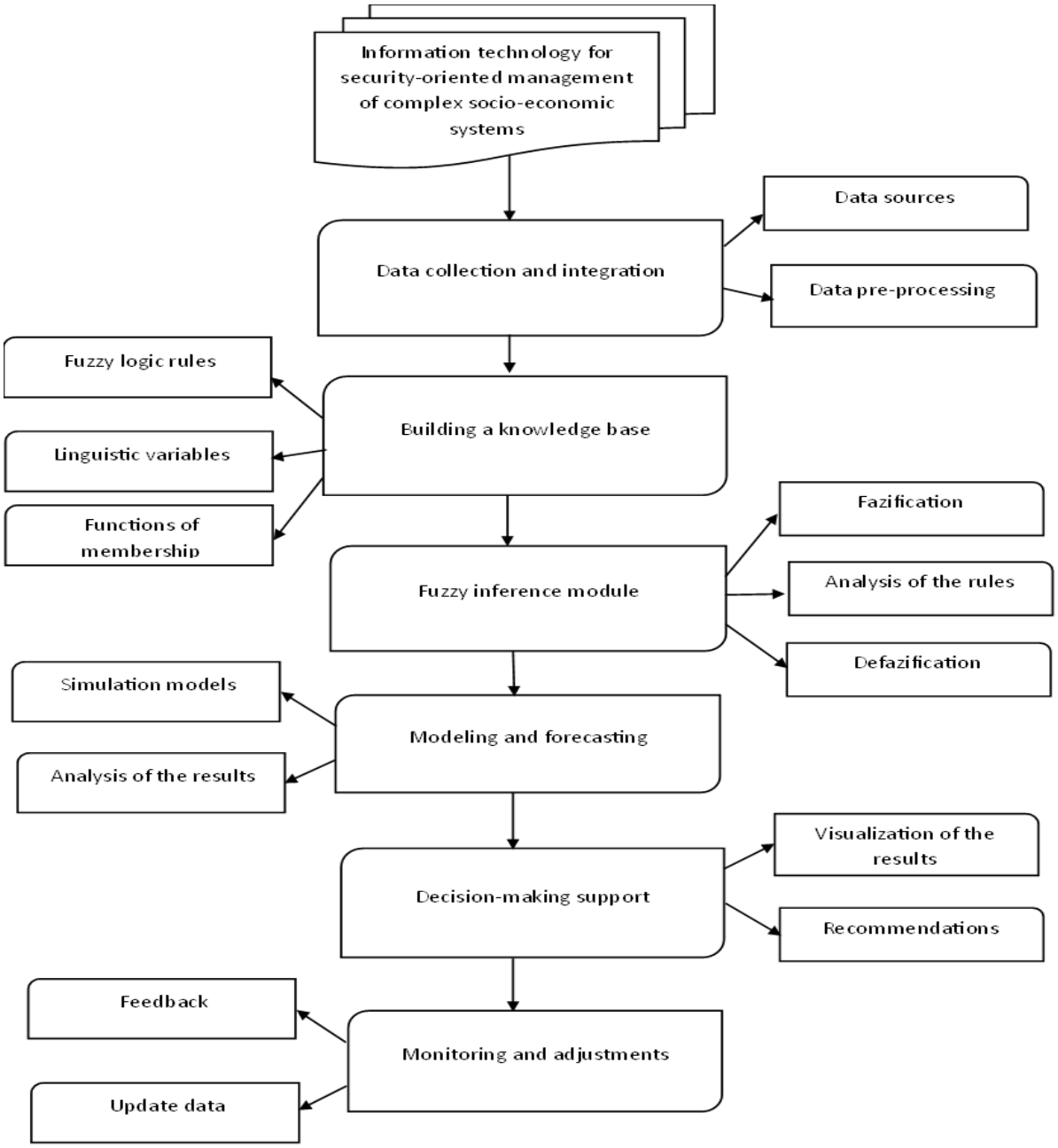

Fig. 2. Block diagram of information technology for security-oriented management of complex socio-economic systems

Monitoring and adjustment. Feedback: after implementing the recommendations, the system receives data on the effectiveness of the implemented solutions. This helps to evaluate the accuracy of forecasts and, if necessary, adjust the rules and membership functions. Knowledge base update: the system automatically updates the knowledge base or allows analysts to make changes to keep the information up-to-date. Integration of new inputs and variables to maintain high accuracy and relevance of the system.

This framework provides a comprehensive approach to managing complex socio-economic systems under conditions of uncertainty, increasing management efficiency and helping to reduce risks.

Summarizing the above, we note that the need to develop tools for modeling and managing security is in demand at the current stage of society's development towards the information economy, the latest advances in Big Data, Data Science, machine learning, etc. The actively implemented research infrastructure, consisting of theory, modeling tools and deep learning technologies, will convert "big data" of monitoring the behavior of the socio-economic system into a security and management strategy.

Conclusions

As a result of the study, it can be concluded that the methodology for the development and application of information technology for security-oriented management based on fuzzy logic is an effective tool for increasing the reliability and flexibility of management systems. The use of fuzzy logic allows taking into account various

uncertainty factors and ensures decision-making in difficult conditions, which is especially important for areas with increased security requirements.

The study has shown that methodologies based on fuzzy logic ensure the adaptability of management systems, which helps to reduce risks and increase the efficiency of responding to unforeseen situations. It is confirmed that the use of information technologies with integrated fuzzy models can significantly improve the processes of analysis, forecasting and planning in management systems.

Thus, the implementation of the developed methods has the potential for wide application in various sectors of the economy and industry, ensuring the reliability and security of management under conditions of uncertainty. The results of this study create the basis for further research and development in the field of security-oriented technologies and contribute to the development of information systems that meet modern challenges and needs.

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