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MODEL FOR PRODUCT STRATEGY ANALYSIS OF AN IT COMPANY USING FUZZY INFERENCE

The subject *of study is the strategic analysis process of product strategy based on an IT company's key performance indicators.* ***The objective*** *is to improve the product strategy's analysis process by implementing a model for evaluating and analyzing the product strategy based on the IT company's key performance indicators system.* ***The tasks*** *are to investigate methods and tools for strategic analysis of IT product strategy; to develop a model for evaluating an IT company's product strategy based on a system of key performance indicators, which characterizes the results of strategy implementation in three aspects: financial results, level of customer orientation of the product; effectiveness of the sales team and marketing activities; and to investigate the results of implementing the model for improving the product strategy to achieve the IT company's strategic goals.* ***Methods*** *of data normalization, fuzzy logic, and the Mamdani method for constructing a fuzzy inference system were used. The following* ***results*** *were obtained. Unlike existing models, the developed model of strategic analysis of product strategy is the result of a hierarchical combination of fuzzy inference systems for evaluating product strategy in three aspects: financial result, level of customer-orientation of IT product, and effectiveness of sales and marketing activities. As a result of the model implementation, an analysis of the product strategy is conducted regarding the possibility of its further implementation to achieve the IT company's strategic objective. The use of a strategic analysis model based on fuzzy inference systems enables the product manager to obtain product strategy assessments and analyze KPIs, which generally represent the financial and market results of strategy implementation. Ways to improve the product strategy, considering the IT company's goals, are identified based on the analysis results.* ***Conclusions****. The scientific novelty of the results obtained is as follows: a model for evaluating and analyzing product strategy, based on the KPI system of the IT company, has been developed for the first time. Implementing this model in the strategic analysis of an IT product will enable the development of a product strategy aligned with the IT company's strategic goals. Unlike existing models, the developed model of strategic analysis of product strategy is the result of a hierarchical combination of fuzzy inference systems for evaluating product strategy across three aspects: financial results, the level of customer orientation of the IT product, and the effectiveness of sales and marketing activities. As a result of the model's implementation, an analysis of the product strategy is conducted to assess the feasibility of its further implementation to achieve the IT company's strategic objective.*

Keywords*:* *IT product, product strategy, analysis, modeling, artificial intelligence, fuzzy logic, model, key performance indicator, fuzzy inference system.*

1. Introduction

1.1. Motivation

At present, the IT industry is the leading one in the Ukrainian economy. The IT market is growing rapidly due to the increase in the number of companies and software development projects.

There are also new software market segments developed by Ukrainian companies. Therefore, product companies need to implement new management mechanisms compared with outsourcing to IT companies. Many new management tasks require modern methods and specialized software to solve them. Such tasks include project management [1], software development process management [2], company asset and financial management [3, 4], and other management decision-making tasks [5].

The creation and implementation of IT products involve a structured, iterative, anduser-centered process aimed at transforming ideas into functional software. This software solves specific customer problems and satisfies their needs. The key features of IT product development include: identifying market needs, creating minimum viable products (MVP) to test assumptions about the product's value to users, identifying and considering user experience (UX), and implementing agile development methodologies (e.g., Scrum, Kanban); ensuring continuous integration/continuous deployment (CI/CD) for rapid iteration after the product is launched in a specific software environment.

The creation of IT products is closely related to the principle of the "pull system", which is mainly implemented through Agile methodologies, Kanban frameworks, and DevOps practices. Unlike "push" systems, which create products based on forecasts, the pull system ensures that development begins only when there is a real demand (e.g., a customer request or a need for a new feature). Therefore, maintaining the competitiveness of an IT product requires constant analysis of customer needs, assessment of customer loyalty to the product, monitoring of the effects of marketing activities, and analysis and improvement of the IT product to adapt it to changing market conditions.

Successful IT companies are constantly reviewing their product strategies based on the results of customer feedback studies and real-time competitive market analysis, considering future IT market changes. This requires a flexible approach to the use of new technologies, the development and improvement of IT products, and their promotion in the IT market.

An IT company maintains a certain level of product competitiveness by constantly improving product strategies, which contributes to long-term profit receipt and growth.

Product strategy analysis is carried out as part of the strategic analysis of the IT company's activities [6].

Therefore, if an IT company aims to maintain its competitiveness in the long term, conducting an ongoing strategic analysis of product strategies is an urgent task. In the uncertainty conditions, blurring, and inaccuracy of market data, it is necessary to introduce modern information technologies for extracting and processing market data using artificial intelligence methods, such as machine learning methods, fuzzy logic, and evolutionary modeling.

1.2. State of the art

Strategic analysis tools are frequently used to analyze product strategies [6]. Product strategies are improved based on the analysis results.

For example, a description of the basic approaches (frameworks) of VRIO, Resource-Based View (RBV), SWOT, Value Chain and PESTEL, which are used as tools for analyzing and developing effective strategies for the company's development, is provided in [7]. Consider adapting them to the strategic analysis of the IT product strategy.

As a result of the analysis of a company's or product's activities with the VRIO framework, such aspects as Value, Rarity, Imitability, and Structure or Organization are determined [8]. The application of these aspects to product strategy has certain features.

The first element is Value. Value describes the extent to which a company's available resource capabilities can add value to its products or services [8]. Using original resources, such as innovative developments, to expand a product's value functionality can help a company differentiate its product from competing products. Using unique techniques for developing, deploying, and maintaining a product can reduce the cost of expanding functionality, improving quality characteristics, etc. Such resource capabilities can contribute to the satisfaction of customer needs and desires, which can increase the company's customers. Therefore, it is possible to assess whether an IT company has certain resources, the use of which will give the product a competitive advantage compared to similar products that exist in the IT market, using the Value analysis element. Competitive advantage is considered in terms of quality, functionality, price, and, ultimately, satisfaction of the needs of the IT company's customers and product users.

The second element of VRIO analysis is Rarity. Analyzing this element reveals how rare and complex a resource or the ability to use it to improve an IT product is. If an IT company's resource is rare, it means that few competitors have it or they do not have it at all. Therefore, using such a resource to develop and improve the product, you can obtain its competitive advantages. For example, resource rarity is characterized by the fact that an IT company has copyrights for software development, patents for unique models, methods, equipment, etc. This analysis element considers exclusive partnerships with other companies or the company's specialists' unique knowledge. Assessing the rarity of resources or the unique opportunity to use such resources helps an IT company assess and understand its unique functionality and product differentiation in the IT market.

The third element of the VRIO analysis is imitability, which reflects the difficulty competitors or other companies face in reproducing or obtaining unique resources. If a resource (e.g., a technique, model, or algorithm, etc.) is easily imitated by competitors or can be easily copied, then this reduces the potential of this resource as the company's competitive advantage is reduced. If a resource is difficult to imitate, then its use provides a stable competitive advantage over a certain period. Therefore, an IT company must constantly monitor the availability of unique resources in competing companies, direct its efforts to create its unique resources, and ensure their protection.

The level of organization and structure of the company in terms of the effective use of its unique resources and other value opportunities can be assessed using the fourth element of Organization. The continuous creation of unique resources and their use and coordination are ensured only under conditions of effective organizational management. In this case, aspects such as the structure of the IT company's business processes, the level of corporate culture, and the development of communication channels and coordination mechanisms are considered. An effectively organized IT company can effectively use its unique resources and realize opportunities to gain a competitive advantage for its product.

Therefore, if we use the VRIO tool from the point of view of IT product strategic analysis, the available resource capabilities and potential of an IT company to maintain a certain level of competitiveness in the IT market can be qualitatively assessed.

A resource-based approach (RBV) is a holistic approach to analyzing a company's resources and capabilities to understand its competitive advantage [9]. Strategic analysis is used to identify reserves of organizational resources and other resource opportunities as a means of obtaining competitive advantage and productivity and, as a result, obtaining a long-term competitive advantage. Thus, constant analysis of the company's resources allows us to assess their reserves and use them to stimulate innovation in the development of new unique IT products, contributes to the improvement of existing products and IT services, and promotes the efficient use of resources to optimize development processes and the effective promotion of IT products on the market.

SWOT analysis, as a common tool for identifying a company's strengths, weaknesses, opportunities, and threats, can be used to evaluate an IT product or product areas [6].

Value Chain analysis helps understand the various actions an IT company takes to create a product or service and shows how these actions are related to each other. For example, the article [10] proposes constructing a value chain for an IT outsourcing company to provide a detailed analysis of the stages of software development at which product value is created and where costs can be minimized. Cost optimization can be achieved through technological modernization, the use of high-quality licensed software, and the adaptability of the company's corporate policy and culture to its business partners' policies. A Value Chain analysis for an IT product can be performed by considering its development and implementation process. As a result of such an analysis, it is possible to obtain options for improving certain stages to reduce the cost of IT products. In this case, the company can get a reduction in the product price in the market compared to the competitor's product price as a competitive advantage of an IT product. Therefore, using the value chain strategic analysis tool in conditions of price competition in certain segments of the IT market is advisable.

External macroenvironment factors that may affect the performance of the IT company are investigated using PESTEL analysis. Factors are divided into the following groups: Political, Economic, Social, Technological, Environmental, Legal. PESTEL analysis is used to identify external threats to an IT company as a result, weaknesses in the company's activities to counter these factors. This analysis is carried out according to the same scheme as the SWOT analysis part, but more attention is paid to a detailed analysis of the influence of each factor of certain groups. Conducting such an analysis can provide additional information about the IT product's competitive advantages. If there are forecasts for changes in any factors, IT products should be developed considering these changes, such as changes in legislation and the impact of generative artificial intelligence [11].

Therefore, when the company chooses which method of strategic analysis should be used to analyze and develop a marketing and product strategy, the analysis purpose, availability, and relevance of existing market data needed for this analysis must be considered. For example, an important issue in IT product strategic analysis is the analysis of existing and potential users' needs, preferences, and budget capabilities. The task is to analyze their existing needs and predict their changes during the strategic period. However, there is a need to develop or improve a strategy for retaining these users, a strategy for constant communication with users (or in other words, establishing feedback with the IT company's customers). Such an analysis is impossible without the use of specialized software.

In the modern IT market, software products are available for analyzing client strategies. Consider two popular products that are used as tools for analyzing the success of IT products.

The HEART Framework, developed by Google, is designed to support the work of software designers and user experience (UX) researchers, namely, to improve the quality of products and services based on the level of satisfaction of software users [12]. Product development teams can also use HEART to prioritize software features, generate new features, and improve them. The five elements of the framework and the "Targets-Signals-Metrics" model are the basis of HEART, which can be used by product managers to analyze competing products to determine the features that have the greatest strategic value for IT product users.

Five key indicators are represented by letters in the abbreviation "HEART" [13]:

- Happiness is an aggregate indicator that measures users' overall satisfaction and emotional response to a product or service. Usually, the following indicators are used to assess the level of happiness: NPS (Net Promoter Score), CSAT (Customer Satisfaction Score), OSAT (Overall Satisfaction Score);
- Engagement is a set of indicators that measure user engagement and interaction with a product. This set includes indicators that track the number of unique users during a day (DAU, Daily Active Users) and a month (MAU, Monthly Active Users) as well as a Traffic Indicator, a Bounce Rate, Stickiness, and Average Session Duration;
- Adoption is an aggregated indicator that assesses how quickly and easily new users start using the product and its main features; indicator can consider the

Conversion Rate and the Customer Effort Score (CES);

- Retention is an indicator that assesses the ability of an IT product or service to retain users for a long time; it is calculated based on User Retention and Churn Rates;
- Task success is an indicator that measures the effectiveness of user interaction with an IT product. It considers the ability of users to perform specific tasks and the ability of the user to achieve their goals using this product. This indicator is calculated based on parameters such as the level of task completion, the time of completion, and the frequency of errors during the task.

The AARRR framework uses the model to analyze various stages of the customer lifecycle (IT product user behavior), from their engagement with the product to profiting from retaining this customer. It was introduced in 2007 by Dave McClure, a Silicon Valley investor and founder of 500 Startups and Practical Venture Capital. This framework is also known as Pirate Metrics or the Pirate Framework [13]. The first letters of the customer lifecycle stages determine the framework name, namely: acquisition, activation, retention, revenue, and referral. Each stage is evaluated using a set of key indicators:

- the key indicator set for tracking the effectiveness of the Acquisition stage, new customers to an IT product or service, includes CAC (Customer Acquisition Cost), which covers all costs spent on attracting customers, such as marketing activities, sales resources, advertising, commissions, etc., Conversion Rate, Traffic, and Daily Active Users (DAU);
- KPIs that are calculated for the Activation stage take into account the benefits received by users from using the IT product, the first positive experience with the product, and the assessment of product value to the user, such KPIs include the number of customers, the Customer Effort Score (CES), the Duration of the Session, and the Bounce Rate;
- the indicators set of Retention stage includes Retention Rate, Churn Rate, Persistence or Stickiness, and the Number of Sessions Per User;
- the indicators set of the Revenue stage includes Average Revenue Per User (ARPU), Monthly Recurring Revenue (MRR), Annual Recurring Revenue (ARR), and CLTV (Customer Lifetime Value (CLTV or LTV) to monitor revenue generation from each customer;
- at the stage of providing a user recommendation for using an IT product (Referral stage), indicators such as NPS, EGR, and CSAT/OSAT are calculated, which can help assess customer satisfaction with an IT product.

The AARRR framework is an effective tool for assessing the success of startups and projects of SaaS (software as a service) companies [14]. It cannot be effectively used for business models such as e-commerce.

Therefore, the above frameworks represent scorecards for evaluating an IT product or service. The product manager can see the "weaknesses" in the functionality from the point of view of the product's value to the user and the shortcomings in the marketing strategy for promoting and presenting the product or service on the IT market using these indicators. The product manager will be able to develop measures to improve the product strategy in certain aspects, such as adding or improving some product functionality based on the results of calculating such indicators. However, the product manager will not get a complete picture of the product strategy implementation's future results.

This is because these frameworks do not show the relationship between all indicators and the extent to which they reflect product success in the market. Product success in the market can be measured by various indicators, depending on the company's goals, such as the planned profit, profitability level, and market share.

Additionally, such scorecards use qualitative and quantitative KPIs across different dimensions, which complicates their unification for a comprehensive strategic analysis of product strategy implementation results.

Therefore, to answer the question of which measures to implement to improve the KPI used to evaluate the product strategy, it is necessary to develop a system of relationships among product strategy KPI assessments to avoid worsening other indicators.

1.3. Objective and tasks

This article aims to improve the process of evaluating a product strategy by introducing a strategic analysis model based on key performance indicators.

To achieve the goal, the following tasks must be solved:

- formation of key performance indicators for evaluating product strategy; and
- development of models for evaluating an IT company's product strategy based on key performance indicators that characterize the results of product strategy implementation in three aspects: financial results, level of product orientation toward the customer, sales team performance, and marketing activities;
- development of a strategic analysis method of the product strategy to improve it to achieve the goals of the IT company.

The development of key performance indicators to evaluate the IT product strategy is discussed in the authors' article [15].

Since the task of evaluating the strategy is based on many indicators, the measurement of which requires statistical data and expert assessments, and it is necessary to combine these results, which will be presented in different dimensions into an evaluation system, using a fuzzy logic tool, namely, hierarchical fuzzy systems (or Fuzzy Inference System Tree, FIS tree) is proposed [16].

As hierarchical structures, Trees describe several levels of a fuzzy inference system; each level consists of several subsystems. These subsystems are called fuzzy units for the hierarchical fuzzy design. In addition to the raw inputs and the lowest level, the exit from the previous level becomes the input to the next level. The fuzzy inference system (FIS) uses fuzzy logic to map inputs to outputs. It includes basification, logical inference, and defuzzification stages. Phasification uses membership functions to convert clear inputs into fuzzy sets. The logical inference mechanism applies fuzzy rules to the fuzzy sets. The fuzzy initial value is transformed into a crisp value during the defuzzification step, which completes the process. Common FIS types include the Mamdani and Sugeno systems [17].

Since fuzzy logic tools are used to develop software systems for various purposes, they are implemented in modern programming languages. For example, Python libraries, such as scikit-fuzzy (skfuzzy), simpful, and fuzzython, implement FIS [18, 19]. These libraries offer tools for defining fuzzy sets, rules, and logical inference processes. Aspects of the implementation of the FIS in Python are given special attention by developers of artificial intelligence systems, for example, in the article [20].

Let's substantiate the choice of a FIS tree to build a model of a product strategy's strategic analysis. The Fuzzy Inference System Tree toolkit is often used to make management decisions and evaluate the results of solving various problems in various industries [21].

A multi-stage fuzzy inference system to assess the risk impact on the performance of public-private partnership projects in terms of cost, time, and quality are proposed in the study [22]. The purpose of this study was to assess different types of risk and analyze project performance based on an integrated analysis of various indicators, including expert assessments. The critical factors influencing the decrease in project productivity, which became the basis for making informed decisions on project management, were identified with the help of the built fuzzy inference system.

FIS is an effective tool for assessing the stability of low and medium voltage power cable systems because of its flexibility in handling uncertainty, ease of use, and ability to integrate expertise used in the work [223]. FIS simulates uncertainties about the performance of system actions using expert-defined rules and affiliation functions to categorize risk levels and assess the consequences of system failures. Critical risks were identified, and measures were developed to mitigate them based on the results of applying the proposed FIS-based methodology.

Fuzzy logic tools are used to assess the quality of software products in the IT field. For example, a hierarchical quality model based on fuzzy logic for measuring and evaluating the maintainability of microservices considering the ISO/IEC 250xy SQuaRE standards – Software Product Quality Requirements and Evaluation (SQuaRE) – Data Quality Model is proposed in [24]. Using the proposed fuzzy hierarchical model, relationships between high-level maintainability characteristics and various low-level software-oriented properties of microservices (i.e., quality characteristics, testing, modifiability, and maintainability) were identified. As a result, recommendations were obtained for developers to assess the quality of microservices support.

FIS tools are also used to solve other problems where it is necessary to process various statistical data together with data obtained based on the opinions of specialists, experts, etc. [25, 26].

The model in [27], which is based on fuzzy inference systems, provides a practical decision support tool for system operators and policymakers in energy markets. It has been proven that fuzzy logic effectively considers real-world uncertainties without complex data requirements.

A fuzzy inference system is presented in [28]. A fuzzy inference system with linguistic terms, membership functions, and expert-defined rules processes input data such as operating conditions, maintenance history, and environmental variables to estimate equipment failures and reduce risks. The results of the study improve the decision-making process by integrating expert knowledge into equipment failure calculations.

Therefore, many scientific studies have proven that fuzzy inference systems are useful tools for multi-criteria decision-making [29, 30].

Figure 1 shows the general process of the fuzzy output system [17].

Thus, the hierarchical fuzzy system is an effective tool for overcoming the problem of high dimensionality of the fuzzy inference system parameters and several logical rules [17].

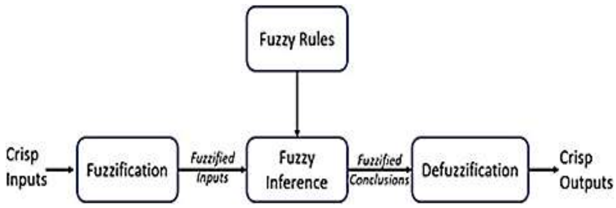

Fig. 1 The general process of the fuzzy output system

The article is structured as follows:

Section 2 presents the materials and research methods for the research tasks. A model for evaluating the product strategy and deciding on its improvement, based on a fuzzy inference system, is considered. A general description of the elements of the fuzzy inference system is provided.

Section 3 presents the results of applying the strategic analysis model of product strategy to the IT company's defined strategic objective, and discusses changes to the model's rules in response to changes in the company's goal. The fuzzy inference system was modeled in the Fuzzy Logic Designer application of the MATLAB R2025a environment.

Section 4 concludes by summarizing the findings, emphasizing the practical significance of the results, and providing perspectives for further research.

2. Materials and methods of research

Toward the aim of the study, the following research questions are asked:

RQ1. Is it possible to use a Fuzzy Inference System Tree to improve the strategic analysis process of an IT company's product strategy?

RQ2. How can the capabilities of a Fuzzy Inference System be used to evaluate and identify ways to improve an IT company's product strategy?

We suggest an experimental study to answer these research questions.

Let us consider the model of solving the Product Strategy Score problem for deciding on improving the strategy and using it during the planning period. The method's basis is the implementation of the fuzzy inference system (FIS) as the Fuzzy Tree Model [31].

The Aggregated Structure FIS trees were used, and the FIS trees were modeled in the Fuzzy Logic Designer app of the MATLAB R2025a [31]. The product strategy evaluation system is constructed according to the following steps:

1. Choose KPIs to evaluate the IT product.
2. Group KPIs according to the criteria for evaluating the company's performance, for example, economic criterions, the financial results assessment of product sales in the IT market, customer focus criteria (assessment of the loyalty of IT product users or company's customers), and marketing effectiveness criteria (assessment of resource opportunities for product promotion, evaluation of sales team results, pre-sale performance, etc.).
3. Make a fuzzy inference system in the form of a FIS tree, namely: build a tree, fuzzy rules for each system element, final rules for evaluating a product strategy, and a logical inference model.
4. Check the quality of the Fuzzy Inference System Tree (efficiency, completeness, etc.) is checked.
5. Improve the FIS tree.

Based on the analysis methods and frameworks for the strategic analysis of IT products, many KPIs are used to assess the effectiveness of the product strategy. Each of these indicators can provide a different assessment of the product strategy.

A decision tree model is proposed as a tree of interconnected fuzzy inference systems to analyze the impact of these indicators on the generalized strategy assessment [32].

IT product development is characterized by intangibility, continuous iteration, and low marginal reproduction costs, which makes it fundamentally different from traditional physical production. Unlike other tangible products that are "ready" at the time of their launch on the corresponding product market, IT products are entities that develop in real time based on market data, in particular user feedback. Therefore, this study proposes considering customer-centricity indicators at the same level of significance as financial indicators.

It is necessary to ensure a certain level of product innovation for the IT product to be competitive in the fast-changing IT market. The main competitive aspect of an IT product is its innovation. The innovation of a product is determined by the novelty of its components [33, 34].

Innovations can be related to product functionality, which will be reflected in the product's customer-centric indicators. For example, the emergence of new product features and the use of unique technologies to present existing product features will increase user satisfaction with the product. If a company has unique technologies and resources that are used in the development of an IT product, then this will help reduce the cost of an IT project, which will lead to an increase in financial results.

Therefore, the introduction of unique, innovative technologies into the implementation process and the promotion of an IT product to the market will increase sales and marketing effectiveness.

Three aspects of evaluating an IT product's strategy are considered: financial result, customer satisfaction, and sales and marketing efficiency. Then, the use of aggregate indicators, which characterize three aspects of the effectiveness of the strategy implementation in a certain (planned) period, is proposed to evaluate the product strategy:

– the Aggregated Financial Indicator (AFI);
– the Average customer satisfaction indicator (ACSI);
– the Average Sales Performance and Marketing Effectiveness Indicator (ASPI).

Since each aspect can affect the overall effectiveness of the product strategy on different ratios, it is proposed to first build subsystems to obtain local assessments of the product strategy using the aggregate financial indicator, the average customer satisfaction indicator, and the average sales performance.

Previously, the AFI, ACSI, ASPI indicators were previously normalized to one interval of values [0, 1] using minimum and maximum scaling. For example, for the AFI indicator, normalization is performed according to the following formula:

$$\mathrm{AFI}_{norm} = \frac{\mathrm{AFI}_i - \mathrm{AFI}_{min}}{\mathrm{AFI}_{max} - \mathrm{AFI}_{min}} \quad (1)$$

where AFI_i – i-th current value of the indicator AFI;

AFI_{min}, AFI_{max} – respectively, the maximum and minimum values of the AFI indicator, which are determined either expertly or according to statistical data.

Similar to formula (1), the values of ACSI and ASPI indicators were normalized.

Local assessments of the strategy based on the corresponding values of the aggregate indicators of strategy implementation (AFI, ACSI, ASPI) are obtained by implementing the constructed subsystems of fuzzy conclusion AFI_fis, ACSI_fis, and ASPI_fis. These subsystems' output values are the input parameters for the FIS subsystem, which outputs an aggregate score (PS_Score) of the product strategy, considering its local scores on three aspects.

The result is a two-level FIS tree for evaluating the product strategy (Fig. 2).

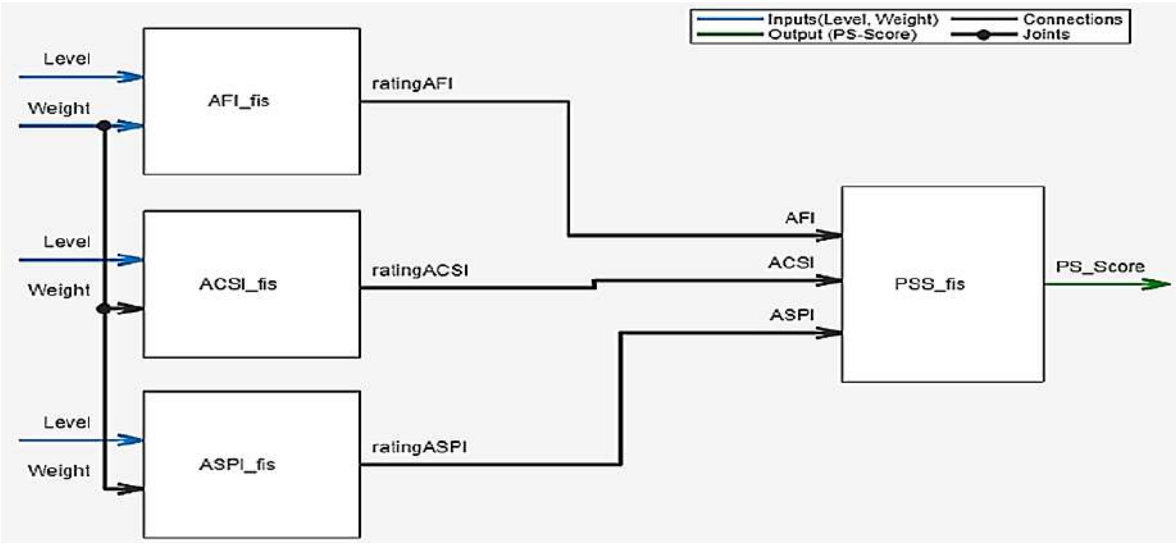

Fig. 2. Fuzzy Tree Model as a fuzzy inference system for evaluating product strategy

Fuzzy models were developed using the Mamdani-type inference system [35, 36]. Mamdani's approach was chosen against the Sugeno-type system because of its greater interpretation and better ability to represent rules in linguistic terms, which is necessary to represent decision-making problems that require human thinking and expert presentation of conclusions in conditions of inaccuracy. Mamdani algorithm includes the following steps:

1.Definition of a fuzzy rule base. A rule can include one or more conditions (prerequisites) that are combined by logical operations "and" (conjunction, Boolean multiplication, denoted by the symbol $\wedge$) and «or» (disjunction, Boolean addition, denoted by the symbol $\vee$).

In general, fuzzy rules can be written as follows:

RULE 1: If «Condition 1» Then «Conclusion 1» (F1);

RULE 2: If «Condition 2» AND «Condition 3» Then «Conclusion 2» (F2); …

RULE n: If «Condition K-1» OR «Condition K» Then «Conclusion (n-1)» (Fn-1) AND «Conclusion n» (Fn),

where F1, F2, … Fn – weight coefficients, which indicate the degree of confidence in the truth of the obtained conclusion, and can take values from the interval [0,1], which is assumed to be equal to 1.

Therefore, the input array $X = \{x_1, ..., x_m\}$ enters the input of the fuzzy output system, where m is the number of inputs. Then a rule base is formed $R = \{R_1, ..., R_n\}$, the rules contain conditions (Condition 1, Condition 2 etc.), that form the plural, $Con = \{Con_1, ..., Con_K\}$, where K – number of all conditions in the rule system. The number of conditions is usually greater than the number of rules, i.e. $K \geq n$. As an example, consider two rules for two inputs *x, y,* and one output variable *z*:

RULE 1: IF x is A_1 AND y is B_1 THEN z is C_1,
RULE 2: IF x is A_2 AND y is B_2 THEN z is C_2,

where A_1, A_2 – linguistic terms (fuzzy sets) used respectively in the first, second rules for the input variable x;

B_1, B_2 – linguistic terms (fuzzy sets) used respectively in the first and second rules for the input variable y;

C_1, C_2 – linguistic terms (fuzzy sets) used in the first and second rules for the output variable z, respectively.

2. The fuzzy representation of input data is the representation of input data in a fuzzy form using

membership functions. For this FIS (Fig. 2), the input data are represented using triangular and trapezoidal membership functions (MF). This is due to the simplicity of their presentation and interpretation of computational results [35].

The triangular membership function ($\mu(x)$) for the input given x is mathematically defined as [37]:

$$\mu(x) = \begin{cases} 0, & x \le a \text{ or } x \ge c \\ \frac{(x-a)}{(b-a)}, & a < x \le b \\ \frac{(c-x)}{(c-b)}, & b < x < c \end{cases} \quad (2)$$

where a, b, c – some numerical parameters that take real values and are ordered by the ratio $a \le b \le c$.

The trapezoidal membership function for the input given x is defined mathematically as follows:

$$\mu(x) = \begin{cases} 0, & x \le a \text{ or } x \ge d \\ \frac{(x-a)}{(b-a)}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{(d-x)}{(d-c)}, & b \le x \le d \end{cases} \quad (3)$$

where a, b, c, d – some numerical parameters that take arbitrary real values and are ordered by the ratio $a \le b \le c \le d$.

The purpose of this step is to obtain the values of the MF of the input data, which are included in each of the conditions Con_k (k=1,2, …K). The result is the values $\mu_i = \mu(x_i)$, i = 1,2, …K, which form a set of membership function values M = {μ_i , i = 1,2, …K).

In the above example with two rules, as a result of phasification with a clear value of the input data x_0 and y_0, the values of the corresponding membership functions will be found:

- $\mu_{A1} = \mu(x_0)$, $\mu_{B1} = \mu(y_0)$ (the rule1);
- $\mu_{A2} = \mu(x_0)$, $\mu_{B2} = \mu(y_0)$ (the rule 2).

So, as a result of fuzzification, a correspondence is established between a specific (usually numerical) value of a separate input variable of the fuzzy inference system and the value of the membership function of the corresponding linguistic term (fuzzy set) of the input linguistic variable.

3. Aggregation of subconditions and activation of fuzzy rules for inference. The objective is to determine the degree of truth of each rule's conditions and establish the strength of the rule. The cutoff levels for each rule of the fuzzy inference system are determined using the minimum operation.

For the given example, the operation "min" is defined as follows:

$$\alpha_1 = A_1(x_0) \wedge B_1(y_0);$$
$$\alpha_2 = A_2(x_0) \wedge B_2(y_0).$$

where α_1, α_2 are the minimum truth values of conditions (aggregation of subconditions 1 and 2) for ferst and second conditions;

$A_1(x_0)$, $A_2(x_0)$ – linguistic terms used respectively in the first and second rules for the input variable x_0;

$B_1(y_0)$, $B_2(y_0)$ – linguistic terms used respectively in the first and second rules for the input variable y_0;

For example, the "min" operation for membership function values:

$$\alpha_1 = \min\{\mu_{A_1}(x_0), \mu_{B_1}(y_0)\},$$
$$\alpha_2 = \min\{\mu_{A_2}(x_0), \mu_{B_2}(y_0)\},$$

where $\mu_{A_1}(x_0), \mu_{B_1}(y_0)$ – values of membership functions for input variables x_0 and y_0 for subconditions 1 and 2 of the first rule;

$\mu_{A_2}(x_0), \mu_{B_2}(y_0)$ – values of membership functions for input variables x_0 and y_0 for subconditions 1 and 2 of the second rule.

The "truncated" membership functions of the rule outputs are found using the following minimum operation:

$$C_1'(z) = (\alpha_1 \wedge C_1(z));$$
$$C_2'(z) = (\alpha_2 \wedge C_2(z)).$$

where $C_1(z)$, $C_2(z)$ – linguistic terms used in the first and second rules for the output variable z, respectively.

4. The composition step (the accumulation step) is the process of finding the values of the output membership function or of activating the conclusions of all rules by combining the strength of each rule, which includes subrules (subconditions). The conclusions of all fuzzy rules are accumulated at this step. The accumulation step is considered complete when the final membership functions of the fuzzy sets of their values are determined for each initial linguistic variable. The found truncated output functions are combined using the "max" operation, which results in the receipt of a finite fuzzy subset for the output variable:

$$C(z) = C_1'(z) \vee C_2'(z) = (\alpha_1 \wedge C_1(z)) \vee (\alpha_2 \wedge C_2(z)).$$

In this example, the accumulated membership function of the output based on the "max" operation is calculated as follows:

$$\mu_\Sigma(z) = \mu_{C_1}(z) \vee \mu_{C_2}(z) = (\mu_{A_1}(x_0) \wedge \mu_{B_1}(y_0)) \vee (\mu_{A_2}(x_0) \wedge \mu_{B_2}(y_0)),$$

where $\mu_\Sigma(z)$ – the membership function of the output z;

$\mu_{C_1}(z), \mu_{C_2}(z)$– the membership functions of the output z, which is represented by the linguistic terms C1(z), C2(z).

5. Defuzzification step. Defuzzification in fuzzy inference systems is a process of finding a crisp value for each of the original linguistic variables. The defuzzification procedure is performed as follows. Before starting this step, the membership functions of all the input linguistic variables are assumed to be known in the form of fuzzy sets: C_1' ,C_2' ,...,C_M', where M – total number of output linguistic variables based on the rules of the fuzzy inference system. The defuzzification result for the original linguistic variable in the form of a quantitative value obtained from a certain formula is determined.

The defuzzification step is considered complete when the final quantitative values for each of the initial linguistic variables are determined in the form of some real number, i.e., in the form $z_1, z_2,..., z_M$. The center of gravity method, in which the value of the j-th output variable is calculated using the centroid formula (center of gravity), is used in the Mamdani algorithm [38, 39]:

$$z_C = \frac{\sum_{j=1}^{M} z_j \cdot \mu_\Sigma(z_j)}{\sum_{j=1}^{M} \mu_\Sigma(z_j)},$$

where z_C – the defuzzified output value;

$\mu_\Sigma(z_j)$ – the value of the accumulated membership function of the output variable z;

z_j – j-th value of the output variable;

M – number of values of the output fuzzy variable.

So, each element of the Fuzzy Tree Model (Fig. 2) - subsystems of fuzzy inference AFI_fis, ACSI_fis and ASPI_fis for obtaining local estimates of product strategy is implemented on the basis of the Mamdani algorithm.

It should be noted that all parameters for each membership function were calibrated using the empirical distribution of normalized parameter values in these fuzzy inference subsystems, from which the strategy score was determined using formula (1). For example, for the input variable Level, three fuzzy sets are considered: "unsatisfactory", which is defined from 0 to 0.4; "average" – from 0.2 to 0.9; "excellent" – from 0.7 to 1 (Fig. 3).

This approach ensures that each fuzzy term has well-defined coverage over the observed data distribution and remains consistent with the defined thresholds for the normalized values of the parameters presented, which are used to evaluate the product strategy.

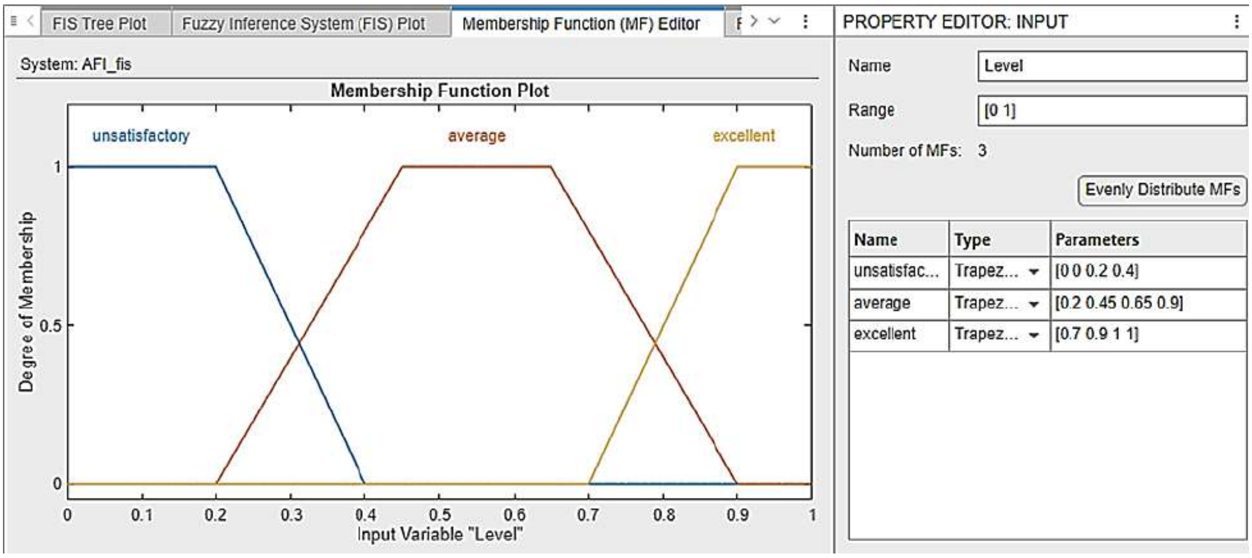

Fig.3. Membership functions of the fuzzy variable Level for the fuzzy inference subsystem AFI_fis

3. Results and Discussion

A fuzzy inference tree was created to assess the product strategy of the electronic document management system (EDS) of the Ukrainian IT company Smart-Business LLC. Data on aggregated KPIs were taken as close to real ones, since real data represents a commercial secret. All fuzzy inference system rules are built with the real strategic objective of the IT company and the product manager's knowledge of this product in mind, who is a co-author of this article.

A brief description of the EDS product strategy is provided. The product strategy for EDS is to create a product to automate the business process of document management, in particular, creation, approval, definition of responsible persons, deadlines, legal support, etc.

Product name: SmartPoint DMS – corporate electronic document management system for medium and large companies.

Product vision: create a single digital platform for working with internal and external documents, where documents are not only stored but also created, approved, signed, controlled, and integrated into the company's operational activities. Target customers: medium and large companies with 200 or more employees, which:

– have many documents that need to be approved, such as contracts, orders, personnel documents, and financial applications;

– the deadlines for creating, approving, and approving documents must be controlled, and responsible employees must be controlled for working with documents;

–there is a need to streamline, structure, and automate document workflow processes. There are requirements for information security, which are recorded in relevant documents and regulations. There is a need to determine the compliance of documents with certain internal and external standards for document processing and storage.

Companies' priority industries are determined based on market and industry research.

Key business needs that are met by implementing the software product:

– accelerating the search for necessary documents;

– reducing the time for approval that takes too long;

– increasing the transparency of the document processing process;

– simplifying control of SLA and deadlines for completing tasks in the document processing process;

– ensuring integration with the company's ERP/CRM/HRM systems;

– providing legal significance to the document, in particular the use of a qualified electronic signature;

IT product positioning: "An electronic document management system reduces document approval time, operational chaos, and document workflow process transparency."

Value proposition:

1) for business: significant reduction in document approval time; reduction of operating costs due to reduction of errors and delays in document processing; control of executive discipline;

2) for company employees: simple document approval route; clear what to do next with the document; less manual work on document preparation, correction and approval; reminders on document actions, use of templates, determination of document status, etc.;

3) for IT and security: ensuring controlled access to documents; logging of user actions; setting up a role model; ensuring integration via API; scaling the system and secure data storage.

Next, we will consider a description of each FIS subsystem. The AFI_fis fuzzy inference subsystem to evaluate product strategy based on the aggregate financial indicator (AFI) is built.

The AFI_fis subsystem has two fuzzy input variables and one output variable (local evaluation of the product strategy based on financial performance). Consider the description of the input variables and the output variable.

The Input variables are:

‒ variable Level is the level of financial results, which determines the normalized value from 0 to 1 of the aggregate financial indicator as the product strategy implementation's economic result;

‒ variable Weight is AFI relative weight coefficient, which shows the degree of influence of financial results on the overall assessment of the product strategy; determined on the basis of expert assessment within the range [0, 1].

The first fuzzy variable Level is represented by three trapezoidal membership functions (Fig. 3):

– unsatisfactory – unsatisfactory financial result (low financial indicators were obtained based on the results of the implementation of the product strategy for a certain period);

– average – Satisfactory financial results obtained (average level);

– excellent – Excellent level of financial results

Analytically, the trapezoidal functions of belonging to the variable Level are determined by Eq. (3). For example, the following formula is used for the average membership function of the variable Level:

$$\mu_{averege}(Level) = \\ = \begin{cases} 0, \;\; Level \leq 0.2 \;\; or \;\; Level \geq 0.9 \\ \dfrac{(Level - a)}{(b - a)}, \;\; 0.2 \leq Level \leq 0.45 \\ 1, \qquad\qquad 0.45 \leq Level \leq 0.65 \\ \dfrac{(0.9 - Level)}{(0.9 - 0.65)}, \;\; 0.65 \leq Level \leq 0.9 \end{cases}$$

where Level is the input variable determined by the trapezoidal membership function.

Four distributed triangular MFs are used to describe the variable Weight subsystem AFI_fis (Fig. 4):

– highCustomer – this is is the weight value of a financial indicator, which means that the level of user satisfaction with the product should be prioritized more than the financial results;

– highSales – the value of this variable means that the level of sales efficiency (effectiveness of marketing activities) must be given more weight than the financial result;

– equal_Fin_Cust_Sal – the value indicates that financial results are given more weight;

– highFinance – the value means that more weight is given to financial results.

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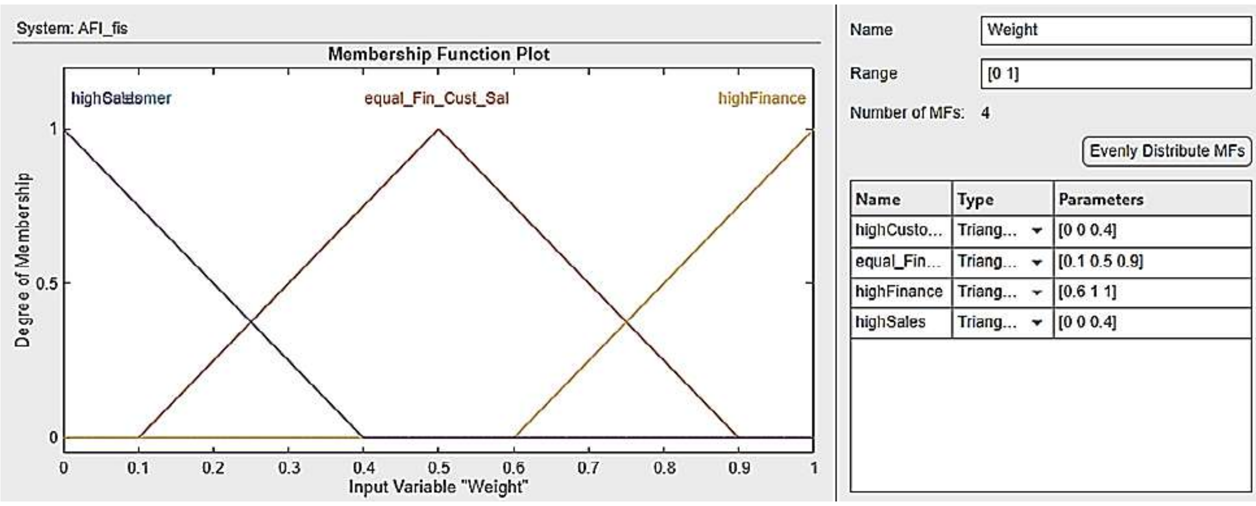


Fig. 4. Membership functions of the fuzzy variable Weight for the fuzzy inference subsystem AFI_fis

Analytically, the triangular membership functions of the variable Weight are determined by formula (2). For example, the membership function equal_Fin_Cust_Sal is represented as follows:

$$\mu_{\substack{equal\\FinCustSal}}(Weight) = \\ = \begin{cases} 0, & Weight \leq 0.1 \ or \ Weight \geq 0.9 \\ \frac{(Weight-0.1)}{(0.5-0.1)}, & 0.1 < Weight \leq 0.5 \\ \frac{(0.9-Weight)}{(0.9-0.5)}, & 0.5 < Weight < 0.9 \end{cases},$$

where Weight is the input variable determined by the triangular membership function.

The membership functions highCustomer, highSales and highFinance are formed similarly. The membership functions for highCustomer, equal_Fin_Cust_Sal, and highSales are graphically presented in Fig. 5.

The output of the AFI_fis subsystem as a result of its implementation is a local assessment of the IT product strategy (ratingAFI) based on the value of the aggregate financial indicator and its weight. The fuzzy variable ratingAFI has a range of [0, 10]. Its description is based on three trapezoidal MFs (Fig. 5):

L – Low rating of product strategy;

M –Medium rating;

H –High rating.

To construct the rules of the fuzzy inference subsystem, the following was AFI_fis considered:

- if we give higher priority to the level of user satisfaction with the product (Weight = highCustomer) or marketing activities (Weight = highSales), then the strategy evaluation will have an average rating (M) with high financial results (Level = excellent), and if the financial results are unsatisfactory (Level = unsatisfactory), then the strategy evaluation level will be low (L);
- if the level of financial results is average (Level = average), then the product strategy score is average, regardless of the weight value;

if all three indicators have equal priority (Weight = equal_Fin_Cust_Sal) when evaluating the strategy, then an unsatisfactory and excellent level of financial results give a very low (VL) and high (H) assessment of the product strategy, respectively;

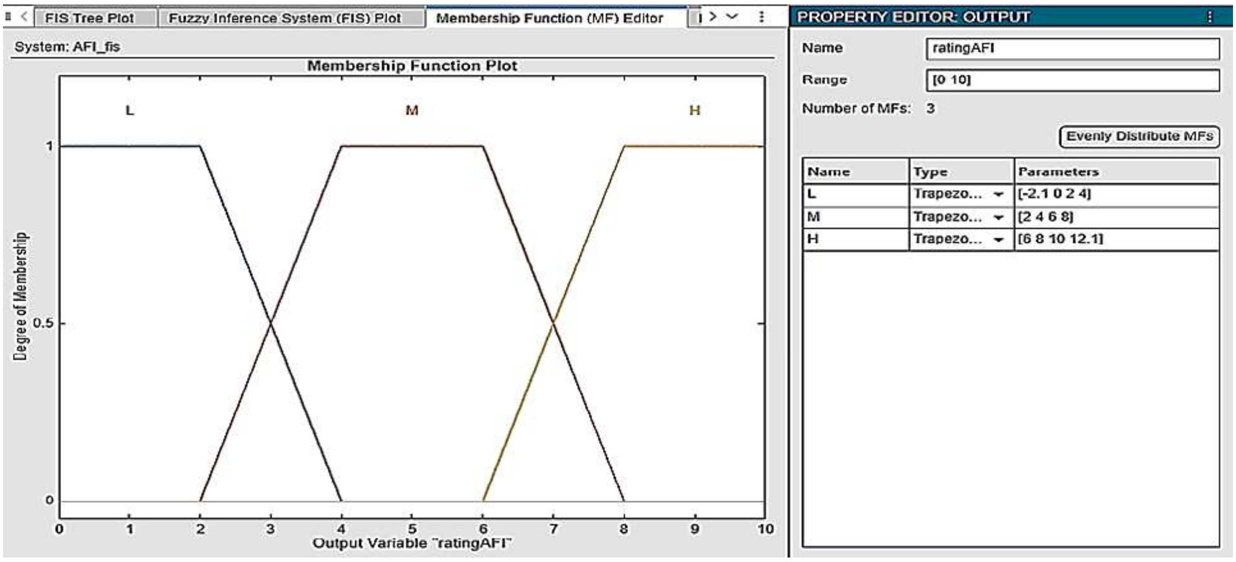


Fig. 5. Membership functions of the output fuzzy variable ratingAFI

– when financial results are prioritized (Weight = highFinance), i.e. the level of financial results has the greatest impact on the strategy assessment, then the strategy assessment will be VL and VH at low and high levels, respectively.

Taking into account these considerations, the defined rules for AFI_fis are given in Table 1.

Table 1

Rules for the fuzzy inference subsystem AFI_fis

Rule	Level	Weight	RatingAFI
1, 2	unsatisfactory	highCustomer or highSales	L
3, 4	excellent	highCustomer or highSales	M
5	average	—	M
6	excellent	equal_Fin_Cust_Sal	H
7	excellent	highFinance	H
8, 9	unsatisfactory	highFinance or equal_Fin_Cust_Sal	L

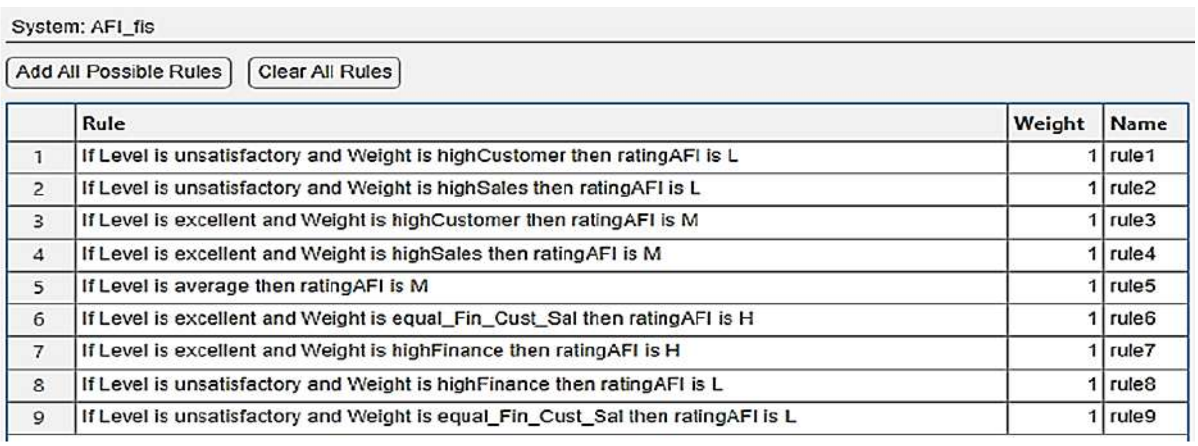
The Level and Weight columns are combined using the logical operation AND, resulting in a strategy evaluation (ratingAFI).

The implemented rule base is shown in Fig.6.

To check the behavior of the AFI_fis rules subsystem, use the Control Surface, which is shown in Fig. 7.

The Control Surface provides a 3D graph (or 2D) representing the entire decision surface of a fuzzy system. It shows the nonlinear mapping between input variables (e.g., level and weight) and output variables (e.g., local score ratingAFI). It is possible to analyze the dependence of the local assessment of the product strategy on the values of the aggregate financial indicator and its weight, marking points on this surface. Let's analyze the AFI_fis subsystem.

Let's consider the case in which product strategy implementation resulted in high financial results. Changing this indicator's weight does not significantly affect the local assessment of the product strategy.


System: AFI_fis

Add All Possible Rules | Clear All Rules

	Rule	Weight	Name
1	If Level is unsatisfactory and Weight is highCustomer then ratingAFI is L	1	rule1
2	If Level is unsatisfactory and Weight is highSales then ratingAFI is L	1	rule2
3	If Level is excellent and Weight is highCustomer then ratingAFI is M	1	rule3
4	If Level is excellent and Weight is highSales then ratingAFI is M	1	rule4
5	If Level is average then ratingAFI is M	1	rule5
6	If Level is excellent and Weight is equal_Fin_Cust_Sal then ratingAFI is H	1	rule6
7	If Level is excellent and Weight is highFinance then ratingAFI is H	1	rule7
8	If Level is unsatisfactory and Weight is highFinance then ratingAFI is L	1	rule8
9	If Level is unsatisfactory and Weight is equal_Fin_Cust_Sal then ratingAFI is L	1	rule9

Fig. 6. Rules for the subsystem AFI_fis

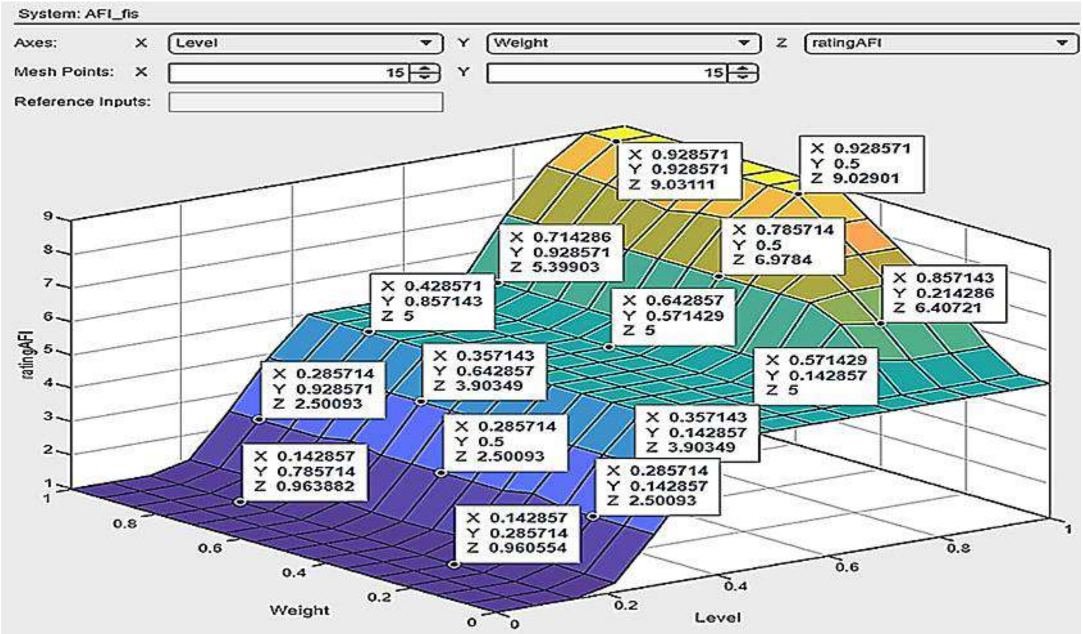


Fig. 7. Control Surface for the subsystem AFI_fis

This is confirmed by the comparison of such points as:

- Level = 0.928 and Weight =0.92, a local evaluation of the strategy RatingAFI = 9.03;
- Level = 0.928 and Weight = 0.5 (Weight reduced compared to the first point) RatingAFI = 9.02 etc.

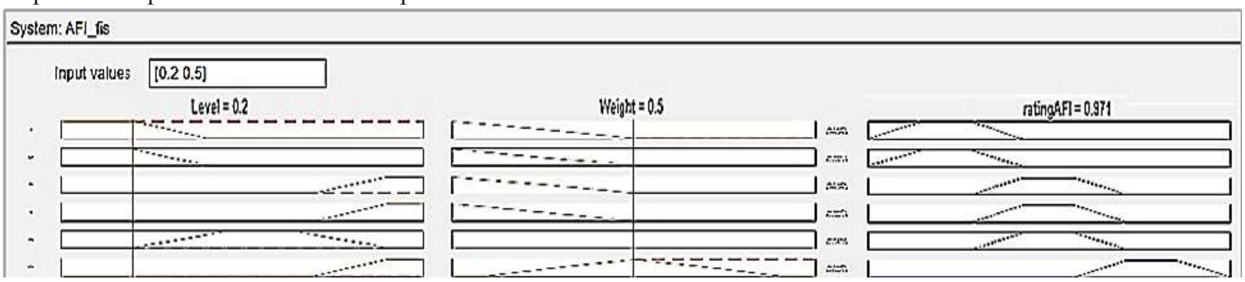
The same trend can be analyzed using the Rule Inference tool. Rules Viewer is a tool for simulating FIS by changing input values using sliders, allowing developers to watch in real time how rules activate and affect the final result. Rules Viewer allows designers to visualize how specific input values trigger rules to produce an output, while the Control Surface displays a 3D mapping of all possible input combinations to output values.

The evaluation of the strategy can be determined according to the system of rules by changing the indicator's value (Level) and its weight (Weight). As shown in Fig. 8, with low financial results, a decrease in the priority of a financial indicator (Fig. 8a) or an increase (Fig. 8b) does not significantly affect the local assessment of the product strategy:

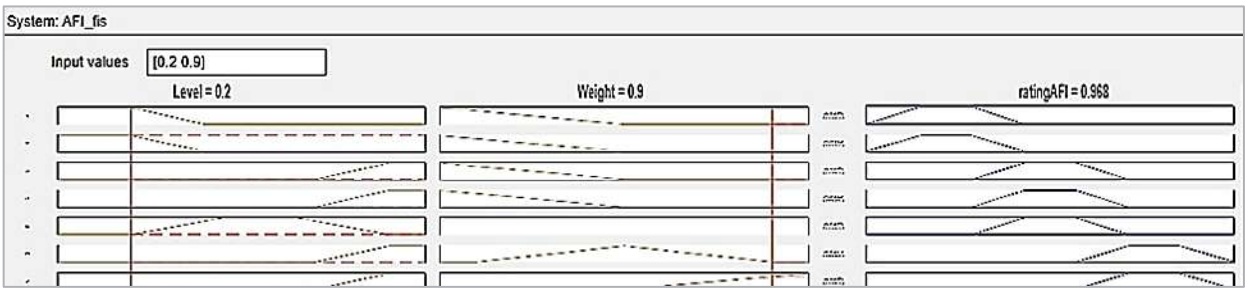
a) RatingAFI =0.971;

b) RatingAFI =0.968).

Only the value of the indicator itself has an impact.



a)



b)

Fig. 8. Rule Inference for the subsystem AFI_fis

Conclusions based on the results of the analysis of the AFI_fis subsystem implementation.

1. It is possible to conclude about the impact of the values of the aggregate financial results indicator and its weight on the product strategy local evaluation according to the built rules, analyzing the points on the Control Surface and using the Rule Inference tool: the main impact on the product strategy evaluation is only the value of the aggregate financial indicator.

2. In the case of developing a new product strategy, it is important to pay more attention to the level of customer satisfaction or marketing activities for its success in the IT market. Then, a decrease in financial indicators can be expected because the implementation of marketing activities requires significant investments by the company. It is also necessary to spend additional resources on studying customer needs and improving the product itself to increase the IT product's level of customer orientation. In this case, reducing the value of highFinance and/or rebuild the system of rules is recommended.

3. It should be considered that the financial results of its implementation should be evaluated after some time when evaluating the product strategy. This is due to specific aspects of the impact of the implementation of the strategy on financial indicators. For example, at the initial intervals of strategy implementation, financial results will be unsatisfactory because a company, as a rule, makes the main investments at the beginning of the product life cycle (LC). That is, the evaluation of the strategy by financial indicators should be done with a shift in time. Only after a certain time can the financial feasibility of the strategy be evaluated. Therefore, the financial indicators of strategy implementation are considered average values for all previous intervals, where the analysis of the effectiveness of the product strategy was analyzed.

Similarly, fuzzy inference subsystems are constructed for local assessment of product strategy based on the average indicators of customer satisfaction with the product (ACSI_fis) and on the indicators of its sales efficiency (ASPI_fis). However, there are some differences in the formation of fuzzy inference rules.

The fuzzy inference subsystem ACSI_fis has two input variables: the level of customer focus of the product strategy (Level) and the weight factor (Weight) of this level for local assessment of the IT product strategy.

The input variable Level of the ACSI_fis subsystem is described in the form of three trapezoidal MFs:

- if the variable Level is described by MF as unsatisfactory, this means that the average customer-oriented indicator of the product strategy for the period being analyzed has a low level;
- If the level is described by the MF average, then the level of the customer focus indicator is the average;
- if the variable Level is described by MF as excellent, then the level of the customer orientation indicator is high, that is, most customers are satisfied with the software product, its quality, and functionality as a result of the implementation of the strategy, and as a result, the level of customer orientation is high.

Three evenly distributed triangular MFs were used to describe the Weight variable of the ACSI_fis subsystem:

- if Weight is described by MF highFinanaceSales, it means that the highest priority is given to financial results and/or the average indicator of sales performance, and customer satisfaction with the product has a low priority (this means that the increase in customer satisfaction was not set at the period for which the strategy analysis is carried out);
- if Weight is described by MF equal_Fin_Cust_Sal, then financial results, user satisfaction results, and sales performance have the same priority when evaluating the strategy;
- if Weight is described by MF highCustomer, then there is a higher priority of customer focus results, i.e., the level of user satisfaction with the product has more weight compared to other results when evaluating the strategy.

The ACSI_fis subsystem's output rating variable is a local assessment of the product strategy based on the aggregate indicator of customer focus (level of customer satisfaction), and its range is in the interval [0, 10].

The variable ratingACSI is described similarly to ratingAFI using trapezoidal MF (Fig. 5).

The rules for the subsystem ACSI_fis are built to evaluate the product strategy based on its level of customer focus. The following was considered to build the rules of ACSI_fis:

- if the level of user satisfaction with the product is low, then the evaluation of the strategy will have a low level (L) for its different weights (Weight = highFinanaceSales or Weight = equal_Fin_Cust_Sal, or Weight = highCustomer);
- if the level of user satisfaction with the product is average, then the evaluation of the strategy will be average for different weight values;
- If the user satisfaction level with the product is excellent, then the evaluation of the strategy is high.

Considering this, the rules for determining local evaluations of the product strategy for the AC-SI_fis subsystem, which are given in Fig. 9, are defined. Fig. 10 illustrates possible local product strategy assessments based on the results of the customer focus indicator (customer satisfaction level) in the form of Control Surface.

FIS Tree Plot | Fuzzy Inference System (FIS) Plot | Membership Function (MF) Editor | Rule Editor | Rule Inference ×

System: ACSI_fis

Add All Possible Rules | Clear All Rules

	Rule	Weight	Name
1	If Level is unsatisfactory and Weight is highFinanceSales then ratingACSI is L	1	rule1
2	If Level is average and Weight is highFinanceSales then ratingACSI is M	1	rule2
3	If Level is excellent and Weight is highFinanceSales then ratingACSI is H	1	rule3
4	If Level is unsatisfactory and Weight is equal_Fin_Cust_Sal then ratingACSI is L	1	rule4
5	If Level is average and Weight is equal_Fin_Cust_Sal then ratingACSI is M	1	rule5
6	If Level is excellent and Weight is equal_Fin_Cust_Sal then ratingACSI is H	1	rule6
7	If Level is unsatisfactory and Weight is highCustomer then ratingACSI is L	1	rule7
8	If Level is average and Weight is highCustomer then ratingACSI is M	1	rule8
9	If Level is excellent and Weight is highCustomer then ratingACSI is H	1	rule9

Fig. 9. Rules for the subsystem ACSI_fis

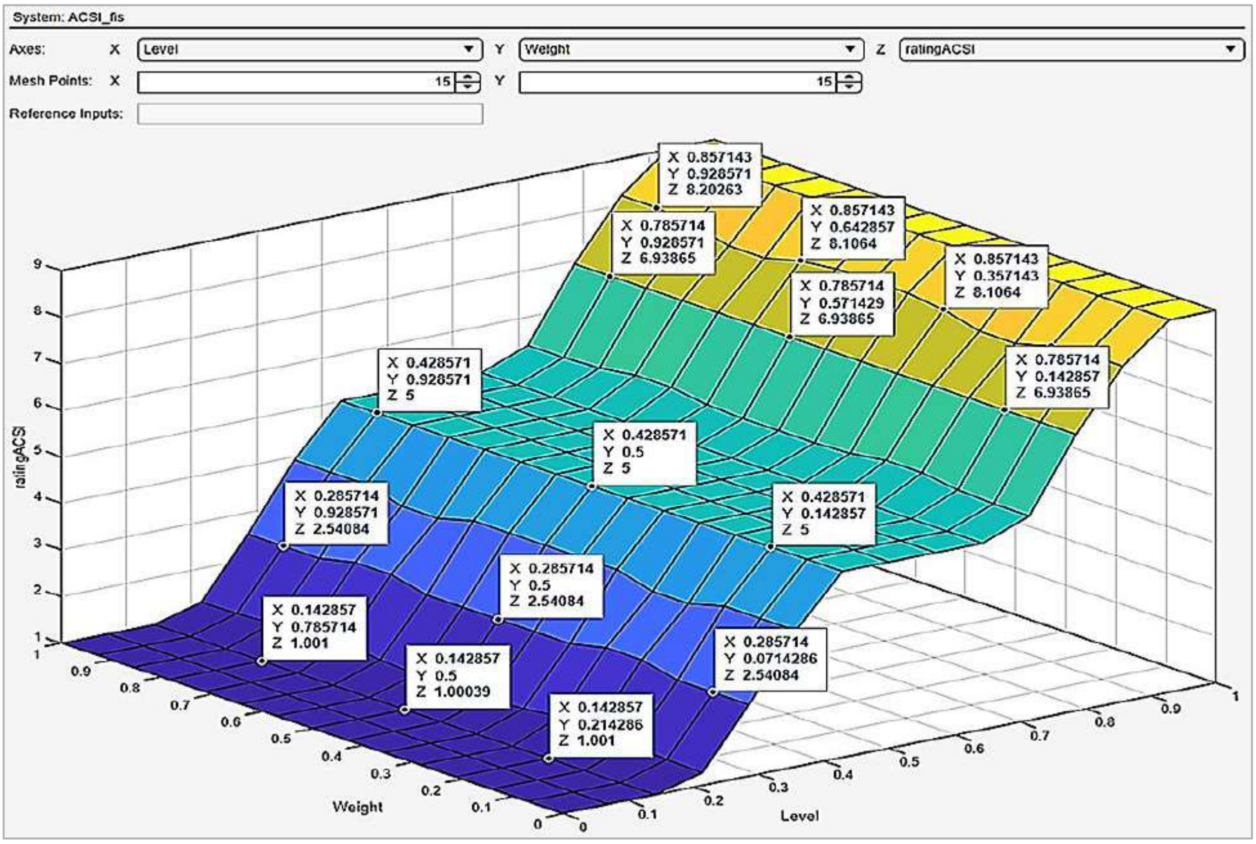


Fig. 10. Control Surface for the subsystem ACSI_fis

Based on the analysis of Control Surface, we can conclude that the values of the customer satisfaction indicator, and not its weight, have a major impact on the local assessment of product strategy.

For example, points with high indicator values and different weights have the same strategy assessment:

- Level = 0.85, Weight = 0.92, ratingACSI = 8.3;
- Level = 0.85, Weight = 0.64, ratingACSI = 8.2;
- Level = 0.85, Weight = 0.35, ratingACSI = 8.1.

Points with medium and low values of this indicator show this trend.

For example, points on the surface (Level = 0.42, Weight = 0.92), (Level = 0.42, Weight = 0.5) та (Level = 0.42, Weight = 0.14) have the same strategy score ratingACSI =5.0.

This trend is determined by the established rules according to IT company’s goals (Fig. 11).

Various options for building rules for the ACSI_fis episystem were modeled depending on the established priorities regarding the product strategy implementation results. These priorities reflect the goal of forming a strategy for an IT product, which can be at different stages of its life cycle.

As an example, consider a case in which rules were formed to evaluate the strategy of a product that has already existed in the IT market for a long time. The management of the IT company has set as its main goal to obtain high financial results by intensifying marketing efforts and expanding product sales (i.e., intensifying the work of the sales department).

Therefore, the product strategy provides for greater market coverage and active attraction of new users through marketing activities. This means that the results of the product's customer orientation have a lower priority. That is, the goal is not to improve the functionality and quality characteristics of the IT product. Then in the system of rules (Fig. 11), changes were made to rules 1-6, namely, ratingACSI = M was changed (Fig. 11).

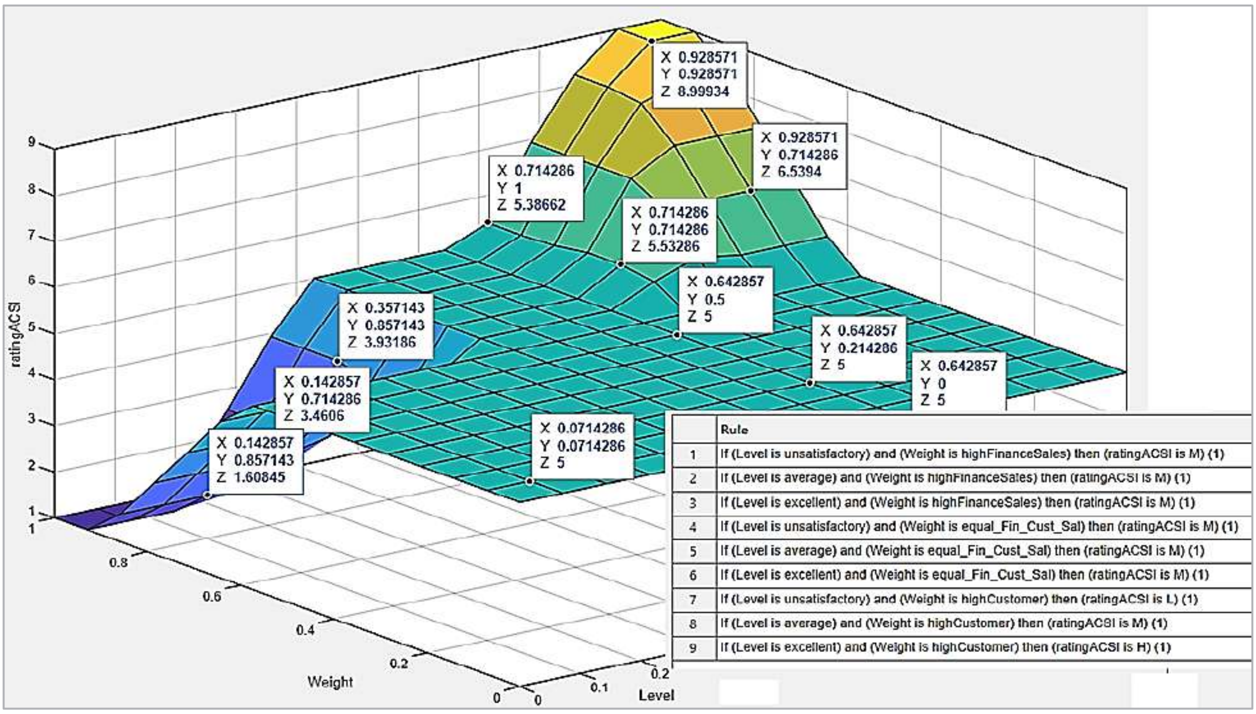


Fig. 11. Control Surface for ACSI_fis for the condition of decreasing significance of customer satisfaction level with the product

Let's consider an example: with a low (Level = 0.1) or high (Level = 0.8) level of customer satisfaction with the product and with an average weight (Weight = 0.5) of this indicator, the evaluation of the strategy will be average (ratingACSI = 5). This is due to the fact that with the changed rules, the overall impact of the level of customer satisfaction on the assessment of the product strategy is lower than other indicators.

However, according to the rules established in advance (Fig. 11), we have other results of the local assessment of the product strategy, namely:

- Level = 0.1, Weight = 0.5, ratingACSI = 1;
- Level = 0.8, Weight = 0.5, ratingACSI =7,2.

Therefore, different local assessments of the strategy can be obtained by changing the rules in the system of logical inference depending on the priority of the indicators of strategy implementation.

Next, we will consider a variant of the rules of the ACSI_fis subsystem (Fig. 9).

The fuzzy inference subsystem ASPI_fis was created for local evaluation of the product strategy based on the average indicator of the effectiveness of the product sales team and marketing activities.

The ASPI_fis subsystem's output variable is the local evaluation of the product strategy ratingASPI, its range is [0, 10], and the affiliation functions are built similarly to ratingAFI(Fig. 5).

Rules for the ASPI_fis subsystem were built considering the effectiveness of marketing activities within the product strategy and its weighting coefficients.

The following was taken into account:

- if you give more weight to financial results and the level of customer satisfaction (Weight = highFinanaceCustomer), then the evaluation of the strategy will have an average rating (M) with a low level of sales efficiency (Level = unsatisfactory) within the implementation of the strategy or at a high level (Level = excellent). This illustrates that when forming the strategy, the main emphasis is placed on obtaining financial results and increasing the product's level of customer orientation;
- if the level of sales performance is average, then the evaluation of the strategy is average, regardless of the weight value;
- if Weight = equal_Fin_Cust_Sal, then the level of sales performance affects the evaluation of the strategy

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equally with user satisfaction indicators and financial results, so the local assessment will be either low (L) or high (H), respectively;

- if the level of sales performance has the greatest impact on the evaluation of the strategy (*Weight* = highSales), then a high and low level of this indicator gives a high (H) and low (L) local assessment of the strategy, respectively.

Considering these considerations, nine rules for the ASPI_fis subsystem are defined.

Considering these considerations, nine rules for the ASPI_fis subsystem are defined, which are given in Fig. 12.

Fig. 13 illustrates how to obtain local product strategy scores in the form of Control Surface based on sales performance. The dependence of the local assessment of the strategy on the level of sales efficiency and the priority of this indicator is analyzed.

System: ASPI_fis

	Rule	Weight	Name
1	If Level is unsatisfactory and Weight is highFinanceCustomer then ratingASPI is M	1	rule1
2	If Level is average and Weight is highFinanceCustomer then ratingASPI is M	1	rule2
3	If Level is excellent and Weight is highFinanceCustomer then ratingASPI is M	1	rule3
4	If Level is unsatisfactory and Weight is equal_Fin_Cust_Sal then ratingASPI is L	1	rule4
5	If Level is average and Weight is equal_Fin_Cust_Sal then ratingASPI is M	1	rule5
6	If Level is excellent and Weight is equal_Fin_Cust_Sal then ratingASPI is H	1	rule6
7	If Level is unsatisfactory and Weight is highSales then ratingASPI is L	1	rule7
8	If Level is average and Weight is highSales then ratingASPI is M	1	rule8
9	If Level is excellent and Weight is highSales then ratingASPI is H	1	rule9

Fig. 12. Rules for the subsystem ASPI_fis

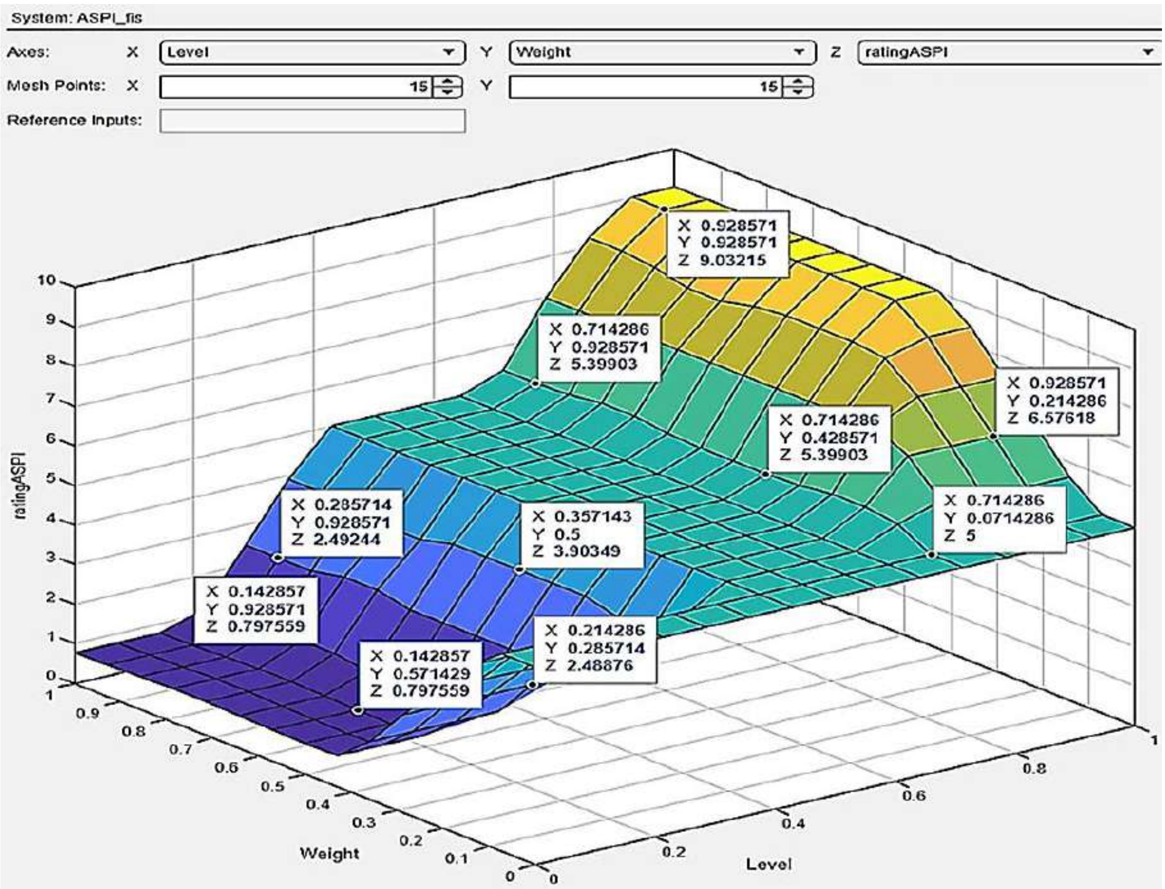


Fig. 13. Control Surface for Subsystem ASPI_fis

The relatively average level of strategy is supported by indicators of financial results and customer orientation with a low priority value of the sales performance indicator. This conclusion is valid subject to certain rules (Fig. 12).

An increase in the weight of the ASPI indicator was implemented, and local estimates were obtained for different Weight and Level values. Once the Weight value exceeds 0.2, the strategy's local evaluation increases in proportion to the Level value.

For example, with a value of Weight = 0.7, the local evaluation of the strategy increases as follows:

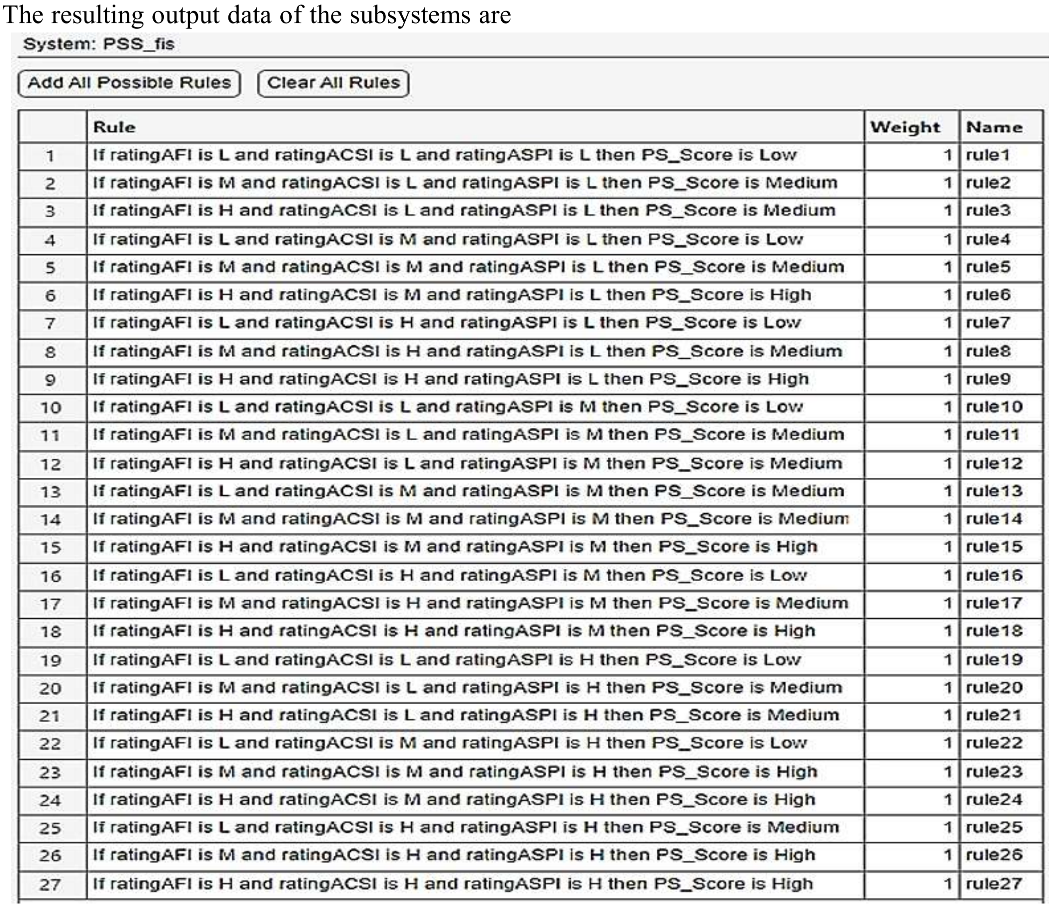
- if Level = 0.2, then ratingASPI = 0.848;
- if Level = 0.5, then ratingASPI = 5;
- if Level = 0.9, then ratingASPI = 9.04.
- Therefore, only the value of the averaged indicator of the effectiveness of the product sales team and marketing activities is important for the local evaluation of the strategy according to certain rules; the weight of this indicator does not greatly affect the local assessment.
- If the strategic objective 1 of promoting an IT product to the market is changed, for example, the objective is to increase the number of customers of the company (i.e., users of the IT product), then the scales must be revised and the system of rules must be rebuilt.
- The resulting output data of the subsystems are local product strategy scores and are inputs to the Product Strategy Score Fuzzy Inference System (PSS_fis subsystem).
- The PSS_fis subsystem calculates a generalized evaluation of a product strategy, considering its local assessments based on the aggregate financial indicator, the average customer satisfaction indicator of the product, and the average performance indicator of the product sales team.

The range of all input variables is [0, 10], all variables are described using three MFs.

A generalized assessment of the product strategy as an initial variable of the subsystem PSS_fis described in the range [0,100] using three trapezoidal MFs:

- Low – Low product strategy score (Low rating);
- Medium – Medium product strategy score;
- High – High product strategy score.

To obtain a generalized assessment of the product strategy, PSS_fis rules were formed (Fig. 14). It is possible to obtain product strategy scores based on different local scores on the three indicators AFI, ACSI and ASPI as a result of the implementation of these rules.


System: PSS_fis

Add All Possible Rules | Clear All Rules

	Rule	Weight	Name
1	If ratingAFI is L and ratingACSI is L and ratingASPI is L then PS_Score is Low	1	rule1
2	If ratingAFI is M and ratingACSI is L and ratingASPI is L then PS_Score is Medium	1	rule2
3	If ratingAFI is H and ratingACSI is L and ratingASPI is L then PS_Score is Medium	1	rule3
4	If ratingAFI is L and ratingACSI is M and ratingASPI is L then PS_Score is Low	1	rule4
5	If ratingAFI is M and ratingACSI is M and ratingASPI is L then PS_Score is Medium	1	rule5
6	If ratingAFI is H and ratingACSI is M and ratingASPI is L then PS_Score is High	1	rule6
7	If ratingAFI is L and ratingACSI is H and ratingASPI is L then PS_Score is Low	1	rule7
8	If ratingAFI is M and ratingACSI is H and ratingASPI is L then PS_Score is Medium	1	rule8
9	If ratingAFI is H and ratingACSI is H and ratingASPI is L then PS_Score is High	1	rule9
10	If ratingAFI is L and ratingACSI is L and ratingASPI is M then PS_Score is Low	1	rule10
11	If ratingAFI is M and ratingACSI is L and ratingASPI is M then PS_Score is Medium	1	rule11
12	If ratingAFI is H and ratingACSI is L and ratingASPI is M then PS_Score is Medium	1	rule12
13	If ratingAFI is L and ratingACSI is M and ratingASPI is M then PS_Score is Medium	1	rule13
14	If ratingAFI is M and ratingACSI is M and ratingASPI is M then PS_Score is Medium	1	rule14
15	If ratingAFI is H and ratingACSI is M and ratingASPI is M then PS_Score is High	1	rule15
16	If ratingAFI is L and ratingACSI is H and ratingASPI is M then PS_Score is Low	1	rule16
17	If ratingAFI is M and ratingACSI is H and ratingASPI is M then PS_Score is Medium	1	rule17
18	If ratingAFI is H and ratingACSI is H and ratingASPI is M then PS_Score is High	1	rule18
19	If ratingAFI is L and ratingACSI is L and ratingASPI is H then PS_Score is Low	1	rule19
20	If ratingAFI is M and ratingACSI is L and ratingASPI is H then PS_Score is Medium	1	rule20
21	If ratingAFI is H and ratingACSI is L and ratingASPI is H then PS_Score is Medium	1	rule21
22	If ratingAFI is L and ratingACSI is M and ratingASPI is H then PS_Score is Low	1	rule22
23	If ratingAFI is M and ratingACSI is M and ratingASPI is H then PS_Score is High	1	rule23
24	If ratingAFI is H and ratingACSI is M and ratingASPI is H then PS_Score is High	1	rule24
25	If ratingAFI is L and ratingACSI is H and ratingASPI is H then PS_Score is Medium	1	rule25
26	If ratingAFI is M and ratingACSI is H and ratingASPI is H then PS_Score is High	1	rule26
27	If ratingAFI is H and ratingACSI is H and ratingASPI is H then PS_Score is High	1	rule27

Fig. 14. Rules for the subsystem PSS_fis.

Let's consider an example of the results of calculating aggregated (generalized) product strategy scores PS_Score taking into account local AFI ratings, ACSI rating, and ASPI rating (Fig. 15).

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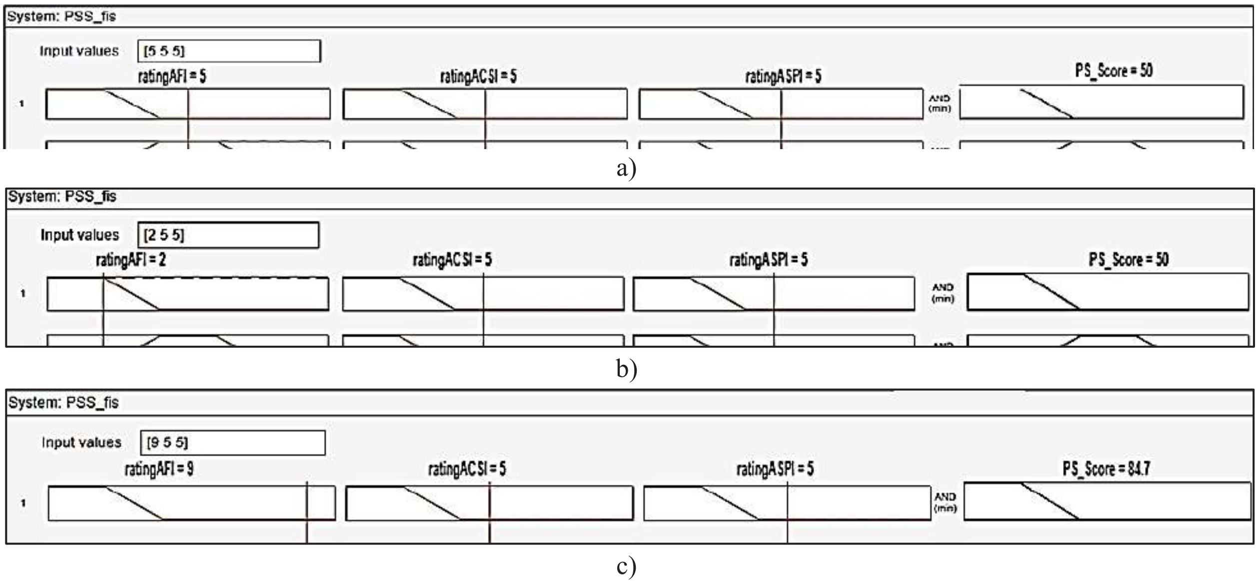

Fig. 15. Rule Inference for PSS_fis Subsystem for Product Strategy Evaluation

If ratingAFI = 5, ratingACSI = 5, ratingASPI = 5, i.e. the average local scores of the product strategy are obtained, then the generalized assessment of the strategy also has an average value PS_Score=50 (Fig.15a).

If the obtained local assessment of the strategy by financial indicator is lower than ratingAFI =2, and other local assessments are unchanged (ratingACSI = 5, ratingASPI = 5), then the generalized assessment has not changed PS_Score=50 (Fig. 15b). This situation shows that a decrease in the local assessment of the product strategy in terms of financial results is not yet the basis for reducing its generalized assessment, because the average estimates for other indicators are obtained.

Therefore, the decrease in financial results may be temporary, for example, significant expenses have been incurred for marketing activities.

If the obtained local assessment of the strategy by financial indicator is higher than the ratingAFI = 9 than other local assessments (ratingACSI = 5, ratingASPI = 5), then we get an increase in the generalized assessment of the strategy PS_Score=84.7 (Fig. 15c).

Therefore, a high assessment of the product strategy was obtained due to strong financial results, with average local assessments for other indicators.

It should be noted that these results were obtained under the condition that building rules prioritize financial results for the company during this period.

The dependence of the aggregate assessment of the strategy on local estimates was analyzed. Table 2 provides several examples that prove that the strategic objective of promoting the product to the IT market is already considered when forming the rules. The strategic objective in this case was to obtain high financial results.

Therefore, the rules in this example are structured such that the priority is to obtain financial results. As shown in Table 2, low financial results, even with high sales, reduce the overall assessment of the strategy.

Table 2.

Evaluation of the strategy

Options	Local Strategy Assessments			Aggregate Score, PS_Score
	Rating AFI	Rating ACSI	Rating ASPI	
1	5	5	5	50
2	2	5	5	50
3	9	5	5	84.7
4	5	2	5	50
5	5	9	5	50
6	5	5	2	50
7	5	5	9	84.7
8	2	5	9	15.3

For example, a low score of PS_Score = 15.3 is obtained even on the basis of average results on product customer focus (ratingACSI = 5) and on high results on sales efficiency (ratingASPI = 9).

This emphasizes the necessity of developing rules that consider the specifics of obtaining financial results, namely: several periods after the period of implementation of the product strategy.

If an analysis of the results of the implementation of the strategy for a certain period is conducted, where the strategy was first applied, then the weight of those rules in the rules that affect the reduction of the assessment due to low financial results can be reduced (Fig. 16).

As part of the study on the impact of the importance of the formed rules on the evaluation of the strategy, the weighting factors of the rules that determine the evaluation of the strategy (M) were reduced and assigned weights of 0.5. It was also decided that the results of customer focus and the implementation of marketing activities have a higher priority, so the rules that determine the strategy's high and low scores, taking into account the importance of these indicators, have become more important. It is appropriate to consider such a situation when simulating the situation is necessary if the objective of expanding the company's market share and protecting its position in certain segments of the IT market is approved. This objective is achieved by increasing the product's customer focus, increasing the company's customer base, and reducing the priority of financial results.

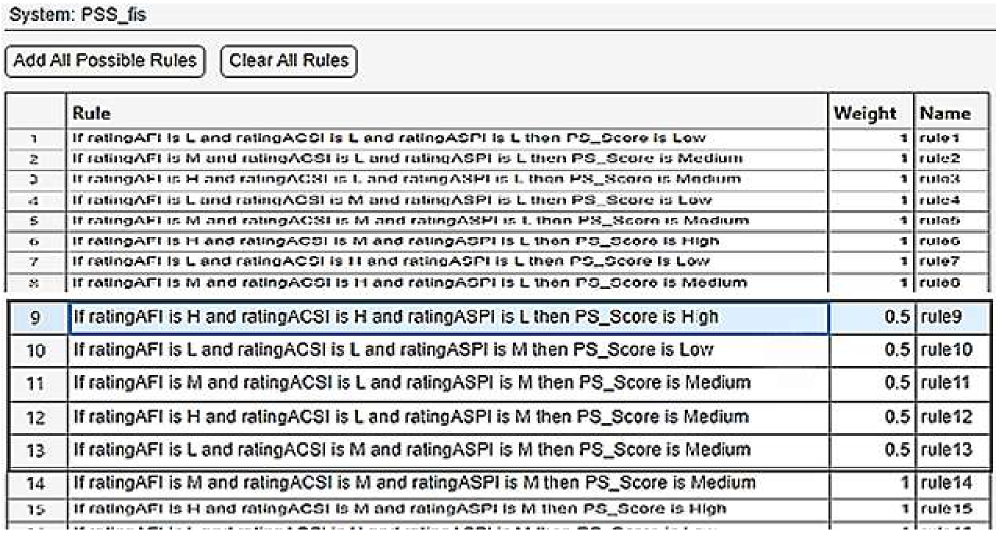

Fig. 16. Reducing the important factors of subsystem rules PSS_fis

Thus, in the example under consideration, the models of strategic analysis of an IT company's product strategy are implemented, provided that the strategic objective of supporting an IT product in the market is to obtain high financial results. Therefore, all the rules of the Fuzzy Inference System Tree were formulated so that financial results significantly influence the generalized assessment of the product strategy.

4. Conclusions

This research focuses on improving the strategic analysis process of product strategy by implementing a product strategy evaluation and analysis model based on an IT company's system of key performance indicators. This article analyzes common methods of strategic analysis advisable for analyzing the strategy for developing an IT product and its market promotion. The use of popular strategic analysis frameworks, such as HEART and AARRR, is expedient, provided that the effectiveness of product market strategies is analyzed at individual stages of the product life cycle. However, for a comprehensive analysis of product strategy, a strategic analysis system must be developed to support the adoption of actions to improve the strategy, taking into account the long-term goals of the IT company. The substantiation of the choice of a fuzzy decision tree for building a model of strategic analysis of the product strategy has been carried out in this study.

Unlike existing models (SWOT, PESTLE, VRIO, etc.), the developed model of strategic analysis of product strategy is the result of a hierarchical combination of fuzzy inference systems for evaluating product strategy in three aspects: financial result, level of customer-orientation of IT product, effectiveness of sales and marketing activities. As a result of the model's implementation, an analysis of the product strategy is carried out regarding the possibility of its further implementation to achieve the IT company's strategic objective.

In response to the first research question, it is determined that using the developed strategic analysis model, based on a constructed fuzzy inference system tree, improves the strategic analysis process of an IT company's product strategy. Improvement is achieved through the systematic evaluation of the product strategy. System assessment is performed based on the implementation of a hierarchical system that combines three fuzzy inference subsystems (FIS trees). Each fuzzy inference subsystem provides local product strategy assessments based on financial results, user satisfaction with the product, and the product sales team's performance. A generalized assessment of the product strategy is obtained through the systematic integration of local assessments based on the rules that are built considering the goals of the IT company for the period during which the strategic analysis of the strategy is carried out.

In response to the second research question, the use of a strategic analysis model based on fuzzy inference systems provides an opportunity for the product manager to obtain local assessments and a generalized assessment of the product strategy for a certain period and to analyze the key performance indicators that represent the generalized financial and market results of the strategy implementation. Based on the results of such an analysis, ways to improve an IT company's product strategy are revealed, considering an IT company's goals. Thus, the constructed model makes it possible to conduct a strategic analysis of the results of the strategy implementation to restructure the rules depending on the new goals of promoting the IT product and the strategic goals of the IT company. Furthermore, the degree of influence of other indicators can be analyzed to increase the evaluation of the strategy.

Practical significance of the results. Applying the strategic analysis model of product strategy at different stages of the IT product life cycle enables the product manager to conduct a continuous analysis of the impact of financial results, the level of user satisfaction with the product, the results of the product sales team, and other marketing activities to achieve the IT company's strategic goals. Based on the results of such analysis, the product manager will be able to develop or adjust measures to improve financial results, increase product customer focus, and increase the effectiveness of marketing activities to achieve the strategic objective in the planning period.

When developing recommendations to improve the strategy, the product manager should identify the risks associated with it. The product manager can obtain additional information about the "hidden" risks by analyzing data on the Control Surface, where it is possible to draw a conclusion about the sensitivity of the overall assessment of the product strategy to the values of local assessments of the strategy by financial results, the level of customer orientation, and marketing effectiveness. For example, the product manager can determine how much the local assessment of customer orientation affects the overall assessment of the product strategy under the existing conditions of its implementation.

Using the Rule Inference tool, the product manager can also determine the minimum level of local assessments that will form the minimum acceptable (satisfactory) level of the generalized assessment of the product strategy. Based on such data, the product manager will be able to identify additional factors influencing the strategy's success in accordance with the strategic goal.

The risks of implementing a product strategy are also identified and analyzed at the stage of determining product areas' competitiveness according to the business process described in the article [15].

In [15], the authors proposed an approach to developing a KPI system for determining aggregated indicators in [15]. The inclusion of product strategy implementation risk indicators in the KPI system will be considered a development of the study.

Future Research. Future research plans include improving the proposed model by training it in various management examples. Since the simulation was conducted in MatLab, the FIS tree was adjusted using the configuration function in Fuzzy Logic Designer [40]. A decision support model for improving product strategy based on a generalized assessment obtained from a strategic analysis model of product strategy using fuzzy inference systems is proposed in the papper [41]. The models considered are components of a strategic analysis of information technology to support an IT company's process of developing product strategies.

Contribution of authors: conceptualization – **Marina Grinchenko**; formulation of tasks – **Marina Grinchenko**; the review and analysis of references - **Marina Grinchenko**, **Valentyna Moskalenko**; prepared rules for the subsystem and analysis of results – **Volodymyr Moskalenko, Valentyna Moskalenko**; verification – **Volodymyr Moskalenko**; analysis of results – **Valentyna Moskalenko, Marina Grinchenko**; visualization – **Volodymyr Moskalenko**; writing – original draft preparation – **Volodymyr Moskalenko**; writing – review and editing – **Valentyna Moskalenko**.

All authors have read and approved the final manuscript for publication.

Conflict of Interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The study was performed without financial support.

Data Availability

The manuscript has no associated data.

Use of Artificial Intelligence

The authors have used artificial intelligence technologies within acceptable limits to provide their own verified data, which is described in the research methodology section.

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МОДЕЛЬ АНАЛІЗУ ПРОДУКТОВОЇ СТРАТЕГІЇ ІТ-КОМПАНІЇ З ВИКОРИСТАННЯМ СИСТЕМ НЕЧІТКОГО ВИСНОВКУ

В. Ю. Москаленко, М. А. Гринченко, В. В. Москаленко

Предметом *вивчення є процес стратегічного аналізу продуктової стратегії на основі ключових показників діяльності ІТ-компанії.* ***Метою*** *дослідження є покращення процесу стратегічного аналізу продуктової стратегії за рахунок впровадження моделі оцінки та аналізу продуктової стратегії на основі системи ключових показників ефективності ІТ-компанії.* ***Завдання:*** *провести дослідження методів та інструментів стратегічного аналізу стратегії ІТ-продукту; розробити модель оцінки продуктової стратегії ІТ-компанії на основі системи ключових показників ефективності, яка характеризує результати реалізації стратегії за трьома аспектами: фінансові результати, рівень клієнтоорієнтованості продукту; ефективність команди з продажів та маркетингових заходів; дослідити результати реалізації моделі для удосконалення продуктової стратегії з метою досягнення стратегічних цілей ІТ-компанії.*

Використовуваними ***методами*** *є: метод нормалізації даних, методи нечіткої логіки, метод Мамдані побудови системи нечіткого висновка.* ***Отримані такі результати****. Розроблена модель стратегічного аналізу продуктової стратегії, на відміну від існуючих моделей, є результатом ієрархічного поєднання систем нечіткого виводу для оцінки продуктової стратегії за трьома аспектами: фінансовий результат, рівень клієнтоорієнтації IT-продукту, ефективність збутової та маркетингової діяльності. У результаті реалізації моделі проводиться аналіз продуктової стратегії щодо можливості її подальшого впровадження для досягнення стратегічної мети IT-компанії. Доведено, що використання моделі стратегічного аналізу на основі систем нечіткого висновку надає можливість менеджеру продукту отримати оцінки продуктової стратегії та провести аналіз KPI, які узагальнено представляють фінансові та ринкові результати реалізації стратегії. За результатами аналізу виявляються шляхи покращення продуктової стратегії з урахуванням цілей IT-компанії.* ***Висновки.*** *Наукова новизна отриманих результатів полягає у наступному: вперше отримана модель оцінки та аналізу продуктової стратегії на основі системи KPI IT-компанії, реалізація якої у процес стратегічного аналізу IT-продукту дозволить формувати продуктову стратегію згідно стратегічних цілей IT-компанії.*

Ключові слова: *IT-продукт, продуктова стратегія, аналіз, модель, моделювання, штучний інтелект, нечітка логіка, ключовий показник ефективності, система нечіткого висновку*.

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