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ENHANCING STRATEGIC FLEXIBILITY FOR SUSTAINABLE AGRO-INDUSTRIAL ENTERPRISES IN TRANSITION ECONOMIES: A FUZZY MULTICRITERIA APPROACH

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Abstract. The article demonstrates that managing an enterprise's strategic flexibility effectively is key to its competitiveness and market sustainability. The authors have developed a comprehensive model of strategic flexibility management of an agro-industrial enterprise operating in the Ukrainian agricultural market. This model integrates modern strategic analysis tools with fuzzy set theory, multicriteria evaluation, and fuzzy matrix analysis. Specifically, the Fuzzy PIPRECIA (PIvot Pairwise RElative Criteria Importance Assessment) method is used to prioritize the assessment directions of internal (ISF) and external (ESF) strategic flexibility. The Fuzzy Delphi method is used to harmonize expert opinions. In contrast, the Fuzzy SAW (Simple Additive Weighting) method, incorporating a 7-level term set, triangular fuzzy numbers, and triangular membership functions, calculates the fuzzy values of ISF and ESF levels. Based on the constructed "ISF – ESF" fuzzy matrix, generalized recommendations for improving and managing the enterprise's strategic flexibility are proposed. Considering the specifics of the studied agro-industrial enterprise's activities and expert assessments for each component of its internal and external flexibility, a list of refined proposals, initiatives, and measures to enhance its strategic flexibility has been formulated.

Keywords: sustainable enterprise development, strategic flexibility, transition economies, agro-industrial sector, fuzzy set theory, multicriteria decision-making, fuzzy matrix analysis, market competitiveness, Ukraine agricultural market.

JEL Classification: Q13, Q01, P27, L21, C61, C65.

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1. Introduction

The end of the first quarter of the 21st century is characterized by unprecedented changes, disruptions, and challenges across all areas of human activity, particularly in the economy. According to Cascio (2020), an American futurist, senior research officer at the Institute for the Future, and professor at the University of California notes that the environment in which enterprises operate is becoming increasingly dynamic, uncertain, complex, unpredictable,

and unstructured. Cascio (2020) confirms that this shift signifies a transition from a VUCA (Volatility, Uncertainty, Complexity, Ambiguity) environment to a BANI (Brittle, Anxious, Nonlinear, Incomprehensible) environment (see Figure 1).

To ensure that enterprises are prepared for change, maintain flexibility, and achieve market sustainability, it is crucial to transform and enhance business practices and the decision-making processes of company management. This necessitates a significant modernization of traditional management tools, incorporating modern modeling technologies and drawing on the experience and insights of theorists and practitioners who contribute to developing fundamental principles of organizational management. This necessitates the development of a new paradigm in strategic management. While it is not required to view strategic management within a completely different "framework", it should be evaluated and guided using modern methods and tools that are more adaptable and capable of accommodating the vagueness, inaccuracy, and limitations inherent in management information. It does not mean an objection or rejection of the contributions made by previous generations of researchers. Instead, it highlights the need for significant enhancements to classical models and the development of qualitatively new methodological approaches. These approaches should be grounded on modern achievements in emerging fields, such as the rapid development of fuzzy set theory, soft computing, neuro-fuzzy networks, fuzzy cognitive modeling, fuzzy multicriteria analysis, and expert technologies utilizing artificial intelligence over the past decade (Pimenow et al., 2024a).

Strategic flexibility is one of the most important determinants of market sustainability and competitiveness of an enterprise, achieving its success in the competitive struggle in a dynamic, complex, and turbulent business environment (Akhtar & Asim, 2024; Asare et al., 2023; Balan & Sitnicki, 2008; Bashir, 2023; Chanphati & Thosuwanchot, 2023; Chen et al., 2023; Dwikat et al., 2023; Lungu, 2020; Monyei et al., 2021; Palanisamy et al., 2021; Singh et al., 2014;

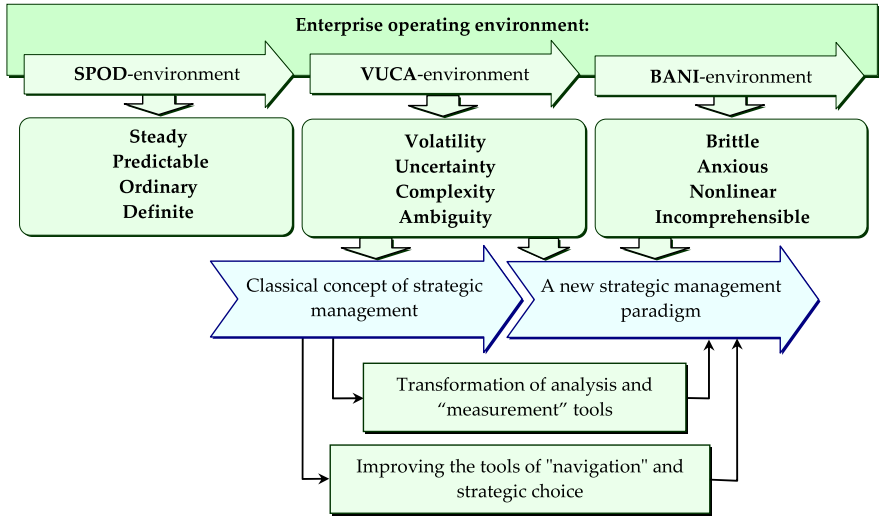

Figure 1. Transformation of the paradigm of strategic management of enterprise (developed by the authors)

Vaszkun & Sziráki, 2023; Yang & Gan, 2021; Zahoor & Lew, 2023). The article (Shimizu & Hitt, 2004) states that "maintaining strategic flexibility is one of the most important, but also the most difficult tasks of managers and organizations in a dynamic environment". The research results presented by the author Sull (2009) indicate that 86% of scientists and business owners consider strategic flexibility one of the most critical and decisive components of enterprise competitiveness and market sustainability under current conditions. The management of this flexibility should be integrated into the enterprise's strategic management system and should be grounded in the "right combination" of resources and capabilities that are both essential and limited (Ahlbäck et al., 2017; Brosseau et al., 2019).

In the works of Asare et al. (2023), Balan and Sitnicki (2008), Chen et al. (2023), Lungu (2020), Monyei et al. (2021), Palanisamy et al. (2021), Yang and Gan (2021), Zahoor and Lew (2023), conclusions have been drawn about the role of strategic flexibility, and its impact on the efficiency of enterprises operating in various sectors across different countries has been analyzed. Specifically: in Asare et al. (2023) – for manufacturing firms in Ghana, Chen et al. (2023) – for manufacturing enterprises engaged in export activities in China, Monyei et al. (2021) – for small enterprises in southeastern Nigeria, Lungu (2020) – for IT sector enterprises in Romania, Palanisamy et al. (2021) – for SMEs in the manufacturing sector in Malaysia, Balan and Sitnicki (2008) – for Ukrainian machine-building enterprises, Yang and Gan (2021) – for Chinese corporations, and Zahoor and Lew (2023) – for International Strategic Alliances (ISAs).

Experts in strategic management, including Long (2020), Doz and Kosonen (2008a, 2008b, 2010), highlight three fundamental capabilities that an organization must possess to maintain flexibility, growth, and competitive advantage:

1) strategic sensitivity: this refers to an organization's ability to understand and perceive its external and internal environments and the changes occurring within them. It involves openness, perception, understanding, and taking advantage of opportunities more rapidly than competitors;
2) partnership in responsibility and commitment to teamwork: this emphasizes collaborative decision-making with flexible and highly skilled teams, empowering them to solve problems and make decisions effectively;
3) resource mobility is an institution's ability to attract and dynamically reallocate resources, skills, and expertise essential for survival, sustainable growth, and competitive advantage.

Although strategic flexibility is a relatively new management concept, emerging and evolving over the past few years in both the literature and the practices of leading companies as a new management paradigm, its foundational concepts and principles were thoroughly proposed in the earlier works of strategic management guru (Ansoff, 1979). He regarded flexibility management as one of the most effective tools for reducing an enterprise's strategic vulnerability, emphasizing its application on internal and external "fronts".

According to Ansoff (1979), the nature of external flexibility management is shaped by the company's management style and decision-making approaches:

- for a conservative approach, the focus is on distributing risk on the external "front". This involves ensuring that the enterprise is not overly dependent on any of its Strategic Business Areas (SBAs), strategic resource areas, or influence groups to the extent that

it faces significant threats. Additionally, the interaction between these SBAs, resources, and groups mustn't create vulnerabilities where a single strategic problem could cause extensive damage by impacting multiple SBAs simultaneously;

- for management inclined towards offensive actions, the strategy is also to distribute risk but with a focus on securing positions in specific SBAs, strategic resource areas, and influence groups, mainly if these areas are unstable and present opportunities to use for advantageous changes;
- for management prone to entrepreneurial risk, the objective is to establish a foothold in different SBAs with the potential for favorable surprises.

Diverse economic activities can achieve the enterprise's flexibility in the external environment. These activities allow the enterprise to engage in the most promising projects within its strategic economic area while minimizing the negative impact of catastrophic events and threats that may affect this area (Ansoff, 1979).

Internal flexibility can be pursued by implementing intra-firm coordination that enables the rapid and seamless transfer of the firm's capacity, material, professional, and managerial resources from one SBA to another. Most firms can enhance their internal flexibility only to the extent of mobility supported by the characteristics of their technology, personnel skills, equipment, buildings, facilities, and inventories (Ansoff, 1979).

Internal flexibility is decisive in an enterprise's preparedness for various changes. According to I. Ansoff, the key elements of internal flexibility include:

- management flexibility: this involves awareness of the external environment, its trends and changes, psychological readiness to confront strategic surprises and unfamiliar phenomena, the ability to solve novel problems, and a capacity for creative action;
- flexibility of the management system and organizational structure: this enables the enterprise to respond fast and effectively to a wide range of changes;
- flexibility of support systems and resources: this includes the mobility of resources, employees with diverse qualifications, a modular production structure, and other adaptable elements).

In the context of I. Ansoff's findings and the authors' perspective (Herhausen et al., 2020) are particularly relevant. They prove that an enterprise can exhibit strategic flexibility by being either reactive – responding to changes faster and more effectively than competitors – or proactive – anticipating changes, preparing in advance, and/or creating new opportunities. This flexibility can be demonstrated through the variety of available strategic options and/or the speed of implementing these options. Additionally, the enterprise can respond internally, through the deployment of resources, or externally, through competitive actions.

In Peeters and Arnst (n.d.), the authors observe that "companies in today's environment are dealing with a turbulent environment where the speed, disruptiveness, and unpredictability of change threaten established business models and success formulas". They identify five key adaptive capabilities that, in their view, can ensure an enterprise's strategic flexibility:

- awareness: this involves understanding the impact of external changes on the business, including the ability to identify relevant changes in markets, industries, technologies, or countries that could influence key trends affecting business development. Adaptive organizations continuously seek new, pertinent information and are adept at interpreting it to determine the need and timing for change;

- experimentation: this refers to testing new ideas to facilitate rapid learning and improvement based on initial market feedback;
- partnering: this entails leveraging both internal and external resources and capabilities;
- ambidexterity: this represents a balance between exploring new business opportunities and innovating while simultaneously leveraging the core business;
- decisiveness: this involves timely decision-making and implementation. Adaptive organizations challenge traditional planning methods that treat strategy development as a routine event independent of market changes. Instead, they strive to synchronize their strategic decision-making processes with the market's rhythm.

The Dynamic Capabilities Theory (DCT) (Teece, 2007; Teece et al., 1997, 2016) aligns closely with these concepts, defining it as the ability of a company to assimilate, create, and reorganize internal and external competencies to adapt to rapidly changing circumstances. The theory also examines how organizations respond to fluctuations in the volatile business environment by transforming their firm-specific competencies into new ones (Teece, 2007). Defined DCT (Esbach, 2009) as the ability of a firm to effectively create, scale, and expand its resource base to achieve a competitive advantage and enhance overall efficiency.

Antisympathetic management is crucial for managing strategic flexibility, especially when taking a proactive approach. This approach involves analyzing both the internal and external environments to identify weak signals.

Cyber risks significantly influence strategic flexibility in agricultural enterprises. In Sitnicki et al. (2024b), an assessment of existing cyber risks in the farm sector was conducted, and a classification of these risks was proposed based on their potential consequences, such as data theft or alteration, cyberterrorism, cyberwarfare, software hacking or modification, and market blocking or operational disruptions.

In transition economies, enhancing strategic flexibility is vital for the sustainability of agro-industrial enterprises facing institutional instability, limited financing, and policy inconsistency. Entrepreneurial orientation and organisational ambidexterity strengthen adaptability and innovation capacity in SMEs, improving their resilience to external shocks (Abu Taleb et al., 2025). Systemic resilience also relies on understanding liquidity and risk dynamics, for which modelling approaches like Navier-Stokes equations are useful (Gondauri et al., 2025). Clean and digital technology adoption is crucial but hindered by financing constraints and regulatory barriers (Artyukhov et al., 2024; Halynskyi et al., 2024). Strategic crisis management, including the use of bankruptcy models, supports enterprise continuity and leadership in turbulent contexts (Kozlovskyy & Garafonova, 2025).

Fuzzy multicriteria approaches are well suited to support strategic decisions in uncertain agro-industrial environments. These methods integrate sustainability metrics such as health and environmental impacts, aligning with the goals of organic farming and efficient resource use (Huzenko & Kononenko, 2024; Hroma, 2024; Huzenko, 2024). Agro-industrial firms, seen as complex systems, benefit from agile mindsets, corporate responsibility, and adaptive leadership (Borissov, 2024; Tessema, 2025). Economic resilience and inclusive governance, including AI-driven female empowerment in agriculture, further enhance development potential (Mehrotra & Chadha, 2025; Moutik, 2025). Persistent financing challenges among SMEs highlight the urgency of supportive financial and institutional ecosystems (Wansi & Burrell, 2023).

The issue of managing an enterprise's strategic flexibility is quite complex and unstructured, both in terms of assessment tools, the development of strategic initiatives, and the selection of effective means for their implementation. In addition to methodological challenges in choosing tools, this issue is characterized by phenomenological features (ambiguity of expert evaluations, influence of various internal and external factors, uncertainties, and risks) and cognitive barriers. These barriers arise due to linguistic discrepancies, the peculiarities of individual reasoning systems and expert preferences, and differences in their professional experience. Addressing these aspects requires the application of fuzzy technologies and systems, which are advantageous due to their ability to qualitatively and verbally describe the parameters being analyzed, process heterogeneous information, and incorporate expert knowledge.

The article aims to develop a methodological framework for managing the strategic flexibility of agro-industrial enterprises. It focuses on integrating fuzzy set theory and advanced fuzzy modeling techniques. The study emphasizes the dual evaluation of internal and external strategic flexibility to enhance enterprise adaptability, competitiveness, and market sustainability in a volatile and complex business environment.

This research hypothesizes that applying fuzzy set theory and fuzzy multicriteria evaluation methods can significantly improve the accuracy and effectiveness of strategic flexibility assessments in agro-industrial enterprises. By providing precise evaluations of internal and external flexibility, enterprises can develop targeted strategies to proactively respond to environmental changes, enhancing their competitive advantage and market stability.

2. Materials and methods

This article uses strategic analysis tools, fuzzy-multiple theory, and fuzzy multi-criteria evaluation to achieve the research goals.

Let us consider some crucial relations and assertions of the theory of fuzzy sets, which will be necessary for solving the tasks of this study.

This paper will use the triangular representation of a fuzzy number $\tilde{A} = (a_1; a_2; a_3)$ (Figure 2) with the corresponding membership functions – Eq. (1). However, a representation in a trapezoidal form, for example, can also be used.

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a_1; \\ (x - a_1)/(a_2 - a_1), & x \in [a_1; a_2]; \\ (x - a_3)/(a_2 - a_3), & x \in [a_2; a_3]; \\ 0, & x > a_3. \end{cases} \quad (1)$$

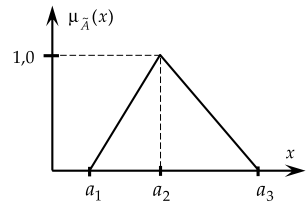

Figure 2. Graphical representation of fuzzy numbers with a triangular membership function (developed by the authors)

Note that if $\tilde{A}=(a_1; a_2; a_3)$ and $\tilde{B}=(b_1; b_2; b_3)$ – fuzzy numbers, then:

$$\tilde{A}\oplus\tilde{B}=(a_1; a_2; a_3)\oplus(b_1; b_2; b_3)=(a_1+b_1; a_2+b_2; a_3+b_3); \quad (2)$$

$$\tilde{A}(-)\tilde{B}=(a_1; a_2; a_3)(-)(b_1; b_2; b_3)=(a_1-b_3; a_2-b_2; a_3-b_1); \quad (3)$$

$$\tilde{A}\otimes\tilde{B}=(a_1; a_2; a_3)\otimes(b_1; b_2; b_3)=(a_1\times b_1; a_2\times b_2; a_3\times b_3); \quad (4)$$

$$\tilde{A}(\div)\tilde{B}=(a_1; a_2; a_3)(\div)(b_1; b_2; b_3)=(a_1/b_3; a_2/b_2; a_3/b_1); \quad (5)$$

$$c\times\tilde{A}=c\times(a_1; a_2; a_3)=(ca_1; ca_2; ca_3),\ c\geq 0,\ c-\text{const}; \quad (6)$$

$$c\times\tilde{A}=c\times(a_1; a_2; a_3)=(ca_3; ca_2; ca_1),\ c<0,\ c-\text{const}. \quad (7)$$

If $\tilde{A}_i=(a_{1i}; a_{2i}; a_{3i})$ $i=\overline{1,n}$ so, then

$$\bigoplus_{i=1}^{n}\tilde{A}_i=\bigoplus_{i=1}^{n}(a_{1i}; a_{2i}; a_{3i})=\left(\sum_{i=1}^{n}a_{1i}; \sum_{i=1}^{n}a_{2i}; \sum_{i=1}^{n}a_{3i}\right). \quad (8)$$

To denazify a fuzzy number $\tilde{A}=(a_1; a_2; a_3)$, the following Equation is used:

$$\text{Def}(\tilde{A})=\frac{a_1+4a_2+a_3}{6}. \quad (9)$$

One of the latest methods of fuzzy multicriteria analysis, Fuzzy PIPRECIA (PIvot Pairwise RElative Criteria Importance Assessment), was applied to calculate the weighting coefficients of the components of internal and external strategic flexibility (evaluation criteria). This method was initially developed in its crisp form in Stanujkić et al. (2017) and extended for fuzzy numbers in Stević et al. (2018).

The Fuzzy Delphi method was employed to reconcile expert evaluations and to calculate the fuzzy values of the enterprise's strategic flexibility levels; the Fuzzy SAW method was used.

3. Results

Based on the foregoing, the contemporary interpretation and recognition of strategic flexibility as a critical element of strategic management underscore its increasing significance. Strategic flexibility plays a crucial role in enabling management to proactively respond to changes in the enterprise's external and internal environments, thereby enhancing its competitiveness and market stability. This evolving understanding highlights the need to develop models for managing strategic flexibility and leveraging the extensive capabilities offered by fuzzy set theory, which was proposed by the authors (Figure 3).

The application of the developed strategic flexibility management model will be illustrated using the case of Private Joint-Stock Company MHP (PRJSC MHP), an agro-industrial enterprise operating in Ukraine's grain market. Notably, the Ukrainian grain industry has continued to grow despite the military actions that began on February 24, 2022, reflecting its high stability and the flexibility of state and corporate management. The loss of a significant portion of agricultural land in Donetsk, Luhansk, Kherson, Mykolaiv, and Zaporizhzhia regions, along with the destruction of grain infrastructure and part of the logistics network, poses challenges to the strategic development plans of agricultural companies. Ukraine, a major

grain exporter to Western Europe, Central Asia, and Africa, has gradually increased in the sown area, expanding from 22968 thousand hectares in 2017 to 24084 thousand hectares in 2021. This expansion has led to a corresponding 14.4% increase in production, accounting for 10% of the country's GDP by the sectors. For instance, Ukraine's share of global wheat exports in 2020/2023 is 7%, making it the sixth largest exporter worldwide. Simultaneously, these

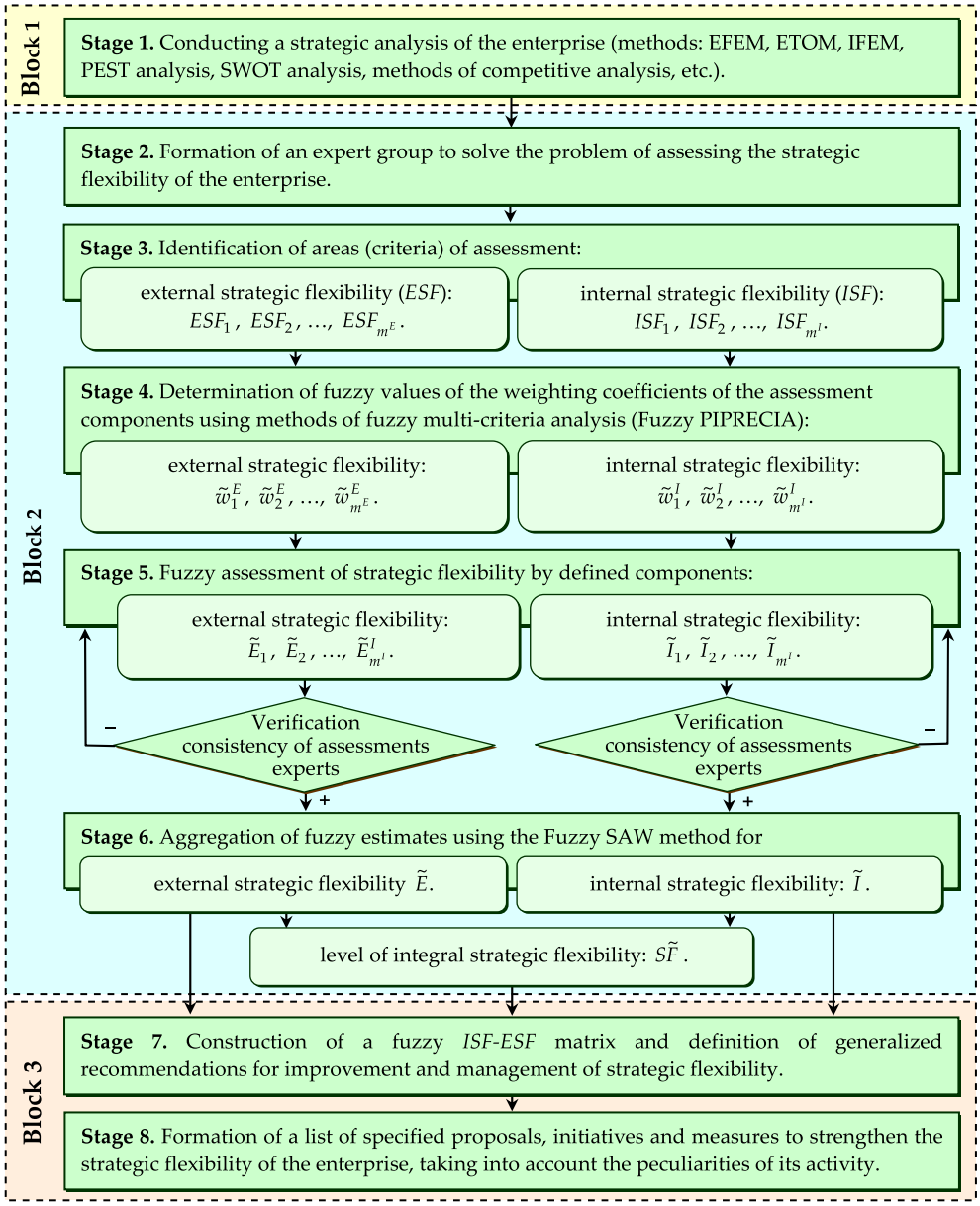

Figure 3. Strategic flexibility management model for enterprises based on the fuzzy matrix approach (developed by the authors)

challenges impact all market participants' internal and external strategic flexibility. Recovery efforts can be primarily supported through the internal resources of enterprises and assistance from EU donors and other international institutions. The allocation of these investments and the prioritization of their distribution are contingent upon the level of strategic flexibility exhibited by the enterprises.

The agribusiness sector is characterized by various business entities, with agriholdings (having a land bank of over 100.000 hectares) leading in financial performance and influence on industry trends. Figure 4 presents information on the most significant agricultural holdings in Ukraine, categorized by the size of their land banks (Large Scale Agriculture, 2021):

Agriholdings play a significant role in supporting Ukraine's balance of payments, which is especially important due to the country's export deficit. Despite a decline, global grain prices are rising, indicating the substantial potential of this sector within the national economy (Pimenova & Fyliuk, 2014).

PRJSC MHP is among the top five producers and exporters of grain products in Ukraine. Strategic analyses of this enterprise, submitted in works (Buchak, 2022; Moldavan & Pimenova, 2021; Pysarenko & Gerasymchuk, 2020; Pysarenko et al., 2020; Polova, 2021), reveal that its primary strategic areas include:

- crop production, including entities such as Spf Urozhay LLC, PJSC Agrofort, LLC Zakhid-Agro MHP, MHP-Agrokryazh LLC, MHP-Ahro-S LLC, LLC MHP-Urozhayna Kraina, PrJSC Zernoproduct MHP, the Perspektiv Branch of PrJSC Zernoproduct MHP, and the Ridnyi Krai Branch of PrJSC Zernoproduct MHP.
- mixed fodder production, with key players including PrJSC Myronivsky Plant of Manufacturing Feeds and Groats, Katerynopilskyi Elevator LLC, and Vinnytska Ptakhofabryka LLC.
- chicken breeding and poultry production, represented by Starynska Ptakhofabryka LLC, SE Poultry Farm Peremoga Nova, PrJSC Myronivska Ptitsefabryka, PrJSC Oril-Leader, and Vinnytska Ptakhofabryka LLC.
- auxiliary activities include MHP-Baffalo LLC, PrJSC MHP Eko Energy, PrJSC Ukrainian Becon, and Myronivsky Meat Processing Plant Legko. This structure facilitates a closed production cycle and embodies vertical integration within the holding. This integra-

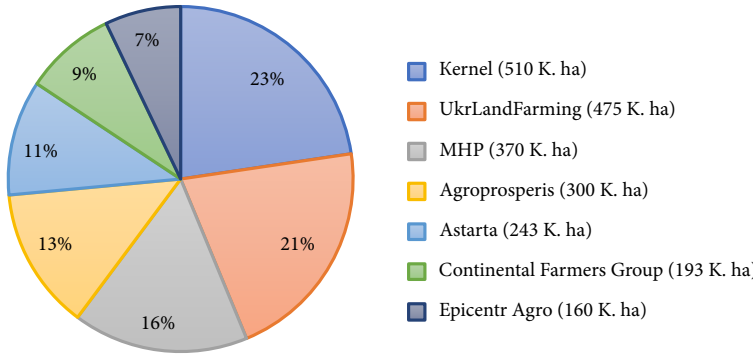

Figure 4. Ukrainian agricultural holdings by land bank size (thousand hectares), 2024 (developed by the authors)

tion helps settle antitrust risks, distributes regional responsibilities, and enables a fast response to market demands. Before the war, the agricultural holding strategy was competitive but shifted to a defensive stance post-war. Despite substantial operational losses, the holding remains actively upgrading production technology by investing in management areas that enhance its internal strategic flexibility.

The proposed model for managing strategic flexibility consists of three blocks:

Block 1 (Stage 1): Strategic analysis of the external environment and internal context. In the *first stage* of the developed model, the company's specialists (strategic analysts) diagnose the enterprise using various strategic analysis tools, including EFEM, ETOM, IFEM, PEST analysis, SWOT analysis, competitive analysis methods, and others.

Block 2 (Stages 2–6): Assessing external and internal strategic flexibility levels. From a methodological perspective, this issue is unstructured and quite complex.

In Demkiv (2015), five primary methodological approaches to assessing enterprise flexibility are identified:

- Integral indicator approach: this approach calculates a comprehensive indicator by integrating estimates of partial flexibility indicators.
- Financial flexibility approach: this method prioritizes assessing financial flexibility within the overall system of flexibility types.
- Multiplicative model approach: this approach involves constructing multiplicative models of the integral flexibility indicator, with a mandatory focus on the financial support block for flexibility.

Business process approach: This perspective analyzes flexibility from the standpoint of the business process as a whole, providing a comprehensive analysis of all its components and implementing advanced management technologies to optimize business processes.

Multifactorial assessment approach: This method evaluates flexibility through correlation and regression analysis, including constructing regression models to determine the resulting indicator's dependence on the influencing factors.

To measure a firm's strategic vulnerability, Ansoff (1979), proposes two methods: a blitz test, which assesses the degree of concentration of the firm's sales and profits, and the analytical technique of "impact analysis". While the blitz test is relatively straightforward, it fails to provide a comprehensive evaluation of the firm's vulnerability or flexibility, as it does not consider critical parameters of the enterprise. The second step involves identifying a list of strategic surprises and factors that may impact the enterprise's Strategic Business Areas (SBAs) in the short and long term. Experts then assess the probability and magnitude of positive and negative impacts of these factors and surprises that may have on the enterprise's Strategic Business Units (SBUs). An integrated assessment of flexibility (or vulnerability) is calculated for each SBU and the enterprise. While this approach provides a thorough analysis of how strategic surprises might affect the enterprise and its SBUs, it may introduce uncertainty in determining appropriate levels of flexibility for the enterprise. Therefore, it is preferable to thoroughly consider and analyze the impact of potential strategic surprises and future scenarios (both short-term and long-term) within a proactive framework for strategic change management.

The authors of Balan and Sitnicki (2008) developed a methodological approach for assessing strategic flexibility based on expert evaluations of its components using the AHP and SAW methods, specifically for machine-building enterprises in Ukraine. In Singh et al. (2014), a model was proposed based on applying a fuzzy logic and knowledge-based framework for assessing strategic flexibility in Indian manufacturing organizations. The main contribution of Akhtar and Asim (2024) lies in developing a fuzzy model using the Fermatean Fuzzy DEMATEL method to analyze causal relationships and interdependencies among various types of enterprise flexibility.

In the *second stage*, specialists are selected to form an expert group to assess the enterprise's strategic flexibility.

The *third stage* involves developing a list of areas (criteria) for assessing internal and external strategic flexibility. This is a very important, complex, and highly responsible task requiring identifying a concept capable of balancing quantitative and qualitative indicators.

Based on the analysis of scientific literature on assessing internal strategic flexibility, an approach that highlights five key elements of the enterprise management system (Córdova & Yanine, 2013) is advisable: enterprise management, organizational structure, culture, infrastructure, and technology. According to the authors, these elements enable the identification of flexibility requirements and the development of flexible actions in response to environmental changes.

In this study, the assessment of internal flexibility will be carried out according to the following areas (criteria):

ISF_1 – production flexibility (through production program performance indicators);

ISF_2 – business process flexibility (through efficiency indicators);

ISF_3 – innovation and investment flexibility;

ISF_4 – management flexibility / managerial flexibility;

ISF_5 – financial flexibility;

ISF_6 – marketing system flexibility;

ISF_7 – informational flexibility.

The list of criteria for assessing external flexibility can be identified on the basis derived from the conclusions of Kotler and Keller (2016, p. 34), who identifies six groups of factors comprising the external environment: economic, natural, demographic, political, and legal, socio-cultural and technological. However, focusing on flexibility indicators that are specifically relevant to agricultural enterprises is essential. For instance, Srour et al. (2016, p. 383) combine indicators of both external and internal flexibility of the enterprise, such as the business unit's ability to respond to resource reallocation demands, new market opportunities, emerging market threats, changing environmental conditions, evolving technological requirements and the need to adjust business partnerships (formation/termination of alliances, ventures, etc.). We also emphasize the study by Herhausen et al. (2020, p. 438), who attempted to conduct a multidimensional conceptualization of strategic flexibility and found that an enterprise can respond to changes through the use of resources internally (flexible use of resources to create a product, the ability to adapt capabilities to environmental requirements, building dynamic core competencies, internal structural changes in the alliance, development of

flexible capabilities) or through competitive actions externally (in the market) (coordination of resources for goods and services, ability to influence the environment, exploitation of global markets, adaptation to environmental changes and adaptation to market threats and opportunities). For example, the authors Mazur and Kubaj (2020, pp. 48–51) emphasize factors such as the stability of the national economy, the level of tax pressure, rising energy and mineral fertilizer prices, increasing costs of plant protection products, favorable natural and climatic conditions for production, stable product demand, and the presence of regular customers.

Based on these considerations, we will establish the following list of criteria for assessing external strategic flexibility, which will be used in this paper:

ESF_1 – political and legal flexibility;

ESF_2 – socio-cultural flexibility;

ESF_3 – natural flexibility;

ESF_4 – demographic flexibility;

ESF_5 – market flexibility (market share, expansion opportunities);

ESF_6 – technological flexibility;

ESF_7 – supply flexibility (reliable supplier network).

Defines (Akhtar & Asim, 2024; Balan & Sitnicki, 2008) the essence of the main components of internal and external strategic flexibility.

In this model, at stage 4, to calculate the fuzzy values of the weighting coefficients of the directions (criteria) for assessing internal and external strategic flexibility, one of the methods of fuzzy multicriteria analysis – Fuzzy PIPRECIA (Fuzzy PIvot Pairwise Relative Criteria Importance Assessment) can be applied (Stević et al., 2018). The main advantage of the PIPRECIA method is that it allows the criteria to be evaluated without preliminary sorting them by importance. Generally, the fuzzy PIPRECIA method for a set of criteria C_1, C_2, ..., C_m consists of 11 steps, shown below in Figure 5.

Let's examine the steps involved in applying the Fuzzy PIPRECIA method in a general case.

"Direct Approach"

Step 1. To determine the relative importance of the criteria, each expert independently assesses the pre-sorted criteria (without considering their relative importance), starting with the second criterion: C_2 з C_1; C_3 з C_2; ...; C_m з C_{m-1} based on the Eq. (10):

$$\tilde{s}_j^k = \begin{cases} > \tilde{1}, \text{ if } C_j \succ C_{j-1}; \\ = \tilde{1}, \text{ if } C_j \approx C_{j-1}; \\ < \tilde{1}, \text{ if } C_j \prec C_{j-1} \end{cases} = (x_j^k; y_j^k; z_j^k), \tag{10}$$

where $\tilde{s}_j^k$ is fuzzy assessment C_j and C_{j-1} criteria k-м by the expert based on the scales provided in Tables 1–2.

If a criterion is more important than the previous one, the assessment is conducted using the scale provided in Table 1. When a criterion is less important than the previous one, the evaluation is conducted using the scale in Table 2.

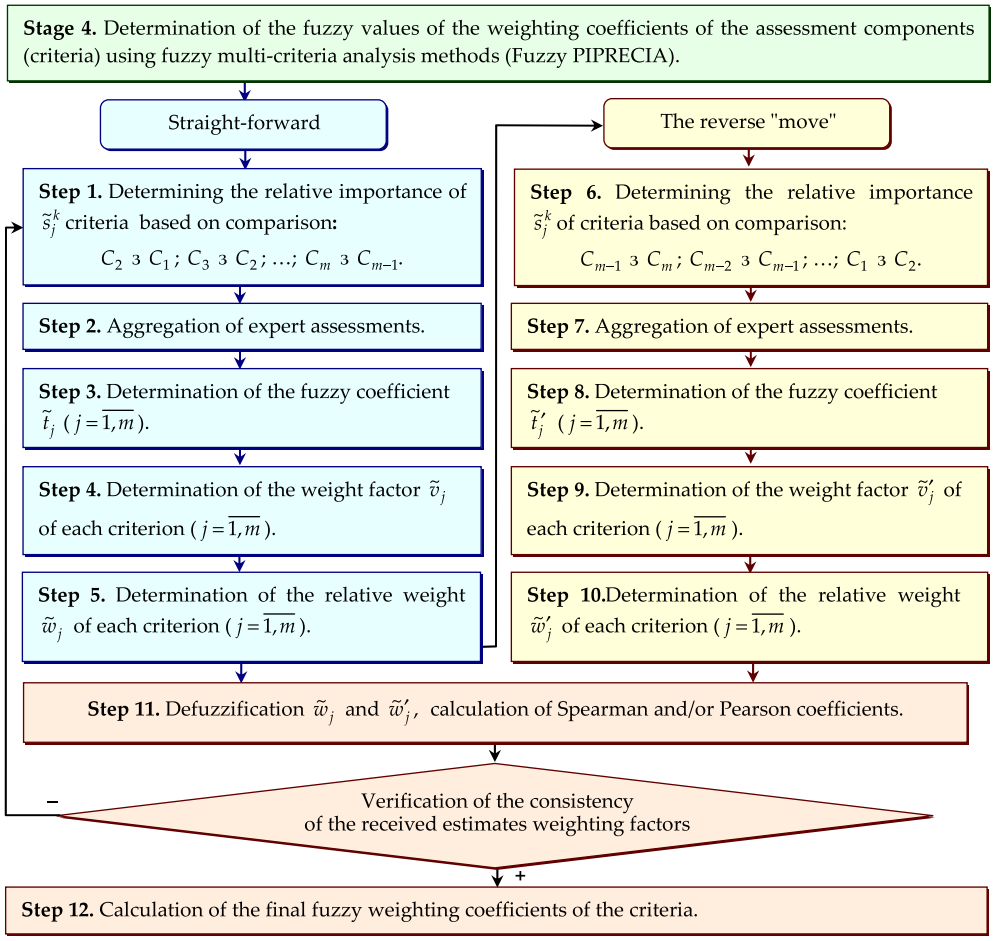

Figure 5. Scheme of application of the Fuzzy PIPRECIA method (developed by the authors based on Stević et al., 2018)

Table 1. Scale (1.000 – 2.000) for assessing the relative importance of the criteria

Linguistic scale	Fuzzy number (TFN) scale (1.000 – 2.000)	Def
Almost Equal Value (AEV)	(1.00; 1.00; 1.05)	1.008
Slightly More Significant (SMS)	(1.10; 1.15; 1.20)	1.150
Moderately more significant (Mms)	(1.20; 1.30; 1.35)	1.292
More Significant (MS)	(1.30; 1.45; 1.50)	1.433
Much More Significant (MMS)	(1.40; 1.60; 1.65)	1.575
Dominantly More Significant (DMS)	(1.50; 1.75; 1.80)	1.717
Absolutely More Significant (AMS)	(1.60; 1.90; 1.95)	1.858

Table 2. Scale (0.000 – 1.000) for determining the relative importance of the criteria

Linguistic scale	Fuzzy number (TFN) scale (1.000 – 2.000)	Def
Weakly Less Significant (WLS)	(0.667; 1.000; 1.000)	0.944
Moderately Less Significant (MLS)	(0.500; 0.667; 1.000)	0.694
Less Significant (LS)	(0.400; 0.500; 0.667)	0.511
Really Less Significant (RLS)	(0.333; 0.400; 0.500)	0.406
Much less significant (Mls)	(0.286; 0.333; 0.400)	0.337
Dominantly Less Significant (DLS)	(0.250; 0.286; 0.333)	0.288
Absolutely Less Significant (ALS)	(0.222; 0.250; 0.286)	0.251

In the case of consensus among the experts' assessments, **Step 2** involves aggregating the experts' evaluations by calculating the geometric mean:

$$\tilde{s}_j = \sqrt[K]{\prod_{k=1}^{K} \tilde{s}_j^k} = \left(\sqrt[K]{\prod_{k=1}^{K} x_j^k}; \sqrt[K]{\prod_{k=1}^{K} y_j^k}; \sqrt[K]{\prod_{k=1}^{K} z_j^k} \right) = (x_j; y_j; z_j). \quad (11)$$

Step 3. To determine the fuzzy coefficient $\tilde{t}_j$ for all criteria $j = \overline{1,m}$ using the Equation:

$$\tilde{t}_j = \begin{cases} \tilde{1}, \text{ if } j = 1; \\ \tilde{2} - \tilde{s}_j, \text{ if } j > 1 \end{cases} = \begin{cases} (1;1;1), \text{ if } j = 1; \\ (2 - z_j; 2 - y_j; 2 - x_j), \text{ if } j > 1. \end{cases} \quad (12)$$

Step 4. To determine the weight $\tilde{v}_j$ of each criterion:

$$\tilde{v}_j = \begin{cases} \tilde{1}, \text{ if } j = 1; \\ \dfrac{\tilde{v}_{j-1}}{\tilde{t}_j}, \text{ if } j > 1 \end{cases} = \begin{cases} (1;1;1), \text{ if } j = 1; \\ \dfrac{\tilde{v}_{j-1}}{(2 - z_j; 2 - y_j; 2 - x_j)}, \text{ if } j > 1 \end{cases} = (a_j; b_j; c_j). \quad (13)$$

Step 5. To determine the relative weight $\tilde{w}_j$ of each criterion:

$$\tilde{w}_j = \frac{\tilde{v}_j}{\bigoplus_{j=1}^{m} \tilde{v}_l} = \frac{(a_j; b_j; c_j)}{\left(\sum_{l=1}^{m} a_l; \sum_{l=1}^{m} b_l; \sum_{l=1}^{m} c_l \right)} = \left(\frac{a_j}{\sum_{l=1}^{m} c_l}; \frac{b_j}{\sum_{l=1}^{m} b_l}; \frac{c_j}{\sum_{l=1}^{m} a_l} \right) = (\alpha_j; \beta_j; \gamma_j). \quad (14)$$

Next, applying the "reverse approach" of the Fuzzy PIPRECIA method is necessary.

"Reverse Approach"

Step 6. To perform the assessment using the above applied scale, starting with the penultimate criterion: C_{m-1} with C_m; C_{m-2} with C_{m-1}; ...; C_1 з C_2.

$$\tilde{s}_j'^k = \begin{cases} > \tilde{1}, \text{if } C_j \succ C_{j+1}; \\ = \tilde{1}, \text{ if } C_j \approx C_{j+1}; \\ < \tilde{1}, \text{ if } C_j \prec C_{j+1} \end{cases} = (x_j'^k; y_j'^k; z_j'^k). \quad (15)$$

Step 7. To aggregate the experts' assessments using the Equation for calculating the geometric mean (16):

$$\tilde{s}'_j = \sqrt[K]{\prod_{k=1}^{K} \tilde{s}'^{k}_j} = \left(\sqrt[K]{\prod_{k=1}^{K} x'^{k}_j}; \sqrt[K]{\prod_{k=1}^{K} y'^{k}_j}; \sqrt[K]{\prod_{k=1}^{K} z'^{k}_j} \right) = (x'_j ; y'_j ; z'_j). \quad (16)$$

Step 8. To determine the fuzzy coefficient for all criteria. $j = \overline{1,m}$ Using the Eq. (17):

$$\tilde{t}'_j = \begin{cases} \tilde{1}, \text{ if } j = m; \\ 2 - \tilde{s}'_j, \text{ if } j < m \end{cases} = \begin{cases} (1;1;1), \text{ if } j = m; \\ (2 - z'_j ;\ 2 - y'_j ; 2 - x'_j), \text{ if } j < m. \end{cases} \quad (17)$$

Step 9. To determine the weight of each criterion:

$$\tilde{v}'_j = \begin{cases} \tilde{1}, \text{ if } j = m; \\ \dfrac{\tilde{v}'_{j+1}}{\tilde{t}'_j}, \text{ if } j < m \end{cases} = \begin{cases} (1;1;1), \text{ if } j = m; \\ \dfrac{\tilde{v}'_{j+1}}{(2 - z'_j ;\ 2 - y'_j ; 2 - x'_j)} = (a'_j ; b'_j ; c'_j), \text{ if } j < m. \end{cases} \quad (18)$$

Step 10. To determine the relative weight of each criterion:

$$\tilde{w}'_j = \frac{\tilde{v}'_j}{\bigoplus_{j=1}^{m} \tilde{v}'_l} = \frac{(a'_j ; b'_j ; c'_j)}{\left(\sum_{l=1}^{m} a'_l ;\ \sum_{l=1}^{m} b'_l ;\ \sum_{l=1}^{m} c'_l \right)} = \left(a'_j \Big/ \sum_{l=1}^{m} c'_l ;\ b'_j \Big/ \sum_{l=1}^{m} b'_l ;\ c'_j \Big/ \sum_{l=1}^{m} a'_l \right). \quad (19)$$

Step 11. To check the consistency of the results obtained from the direct and reverse approaches. It is necessary to denazify the obtained weighting coefficients of the criteria and calculate the Spearman and/or Pearson correlation coefficients. Alternatively, a more straightforward approach can be used by comparing both approaches' corresponding computed values of the weighting coefficients. If significant discrepancies are found, the experts' assessments should be reviewed (for example, by applying the Fuzzy Delphi method), and steps 1–11 of the Fuzzy PIPRECIA method should be reapplied.

Step 12. If the consistency check results are satisfactory, we calculate the final fuzzy weighting coefficients for the criteria using the Equation:

$$\tilde{W}_j = \frac{1}{2}(\tilde{w}_j + \tilde{w}'_j) = (\alpha_j ; \beta_j ; \gamma_j), \quad j = \overline{1,m}. \quad (20)$$

Table 3 presents the results of an expert comparison of the importance of the evaluation criteria for the enterprise's external and internal strategic flexibility, using the linguistic scales of the Fuzzy PIPRECIA method (Tables 1 and 2).

Table 3. Comparison by experts (e_1, e_2, e_3) of the importance of components (evaluation criteria) for external and internal strategic flexibility of the enterprise using the Fuzzy PIPRECIA method

	Direct approach			Reverse approach		
	e_1	e_2	e_3	e_1	e_2	e_3
ESF_1	–	–	–	MLS	WLS	WLS
ESF_2	AEV	AEV	SMS	MLS	MLS	WLS
ESF_3	SMS	SMS	SMS	WLS	MLS	WLS
ESF_4	SMS	Mms	AEV	MLS	MLS	LS
ESF_5	SMS	SMS	AEV	AEV	WLS	AEV
ESF_6	AEV	WLS	AEV	SMS	SMS	Mms
ESF_7	MLS	MLS	MLS	–	–	–

End of Table 3

	Direct approach			Reverse approach		
	e_1	e_2	e_3	e_1	e_2	e_3
ISF_1	–	–	–	MLS	MLS	MLS
ISF_2	AEV	SMS	SMS	MLS	MLS	WLS
ISF_3	Mms	AEV	AEV	MLS	WLS	MLS
ISF_4	AEV	SMS	SMS	SMS	MLS	MLS
ISF_5	MLS	AEV	AEV	Mms	Mms	Mms
ISF_6	LS	RLS	LS	MLS	WLS	MLS
ISF_7	SMS	SMS	SMS	–	–	–

By applying Eqs. (11)–(19) of the Fuzzy PIPRECIA method to the criteria for evaluating external and internal flexibilities, the weighting coefficients for these criteria can be determined: $\tilde{w}_j^E = (\alpha_j^E; \beta_j^E; \gamma_j^E)$, $j = \overline{1, m^E}$ ($m^E = 7$) and $\tilde{w}_j^I = (\alpha_j^I; \beta_j^I; \gamma_j^I)$, $j = \overline{1, m^I}$ ($m^I = 7$) accordingly. Table 4 presents the calculated intermediate results from the "direct approach," while Table 5 shows the results from the "reverse approach" of the Fuzzy PIPRECIA method.

Next, we will directly examine the procedure of fuzzy evaluation of strategic flexibility levels carried out in **Stage 5** of the developed methodological approach. For this purpose, each of the identified evaluation criteria is considered as a linguistic variable, the term set of which can be defined as follows: *TS* = {Extremely Low (EL), Very Low (VL), Low (L); Medium (M); High (H); Very High (VH), Extremely High (EH)}. The semantics of the terms are defined by fuzzy numbers within the interval [0; 6] (Figure 6) with corresponding membership functions and fuzzy numbers represented in triangular form: EL: (0; 0; 1); VL: (0; 1; 2); L: (1; 2; 3); M: (2; 3; 4); H: (3; 4; 5); VH: (4; 5; 6); EH: (5; 6; 6).

Table 4. Calculation and results of the application of fuzzy PIPRECIA "Direct approach"

	$\tilde{s}$	$\tilde{t}$	$\tilde{v}$	$\tilde{w}$	def
ESF_1	–	(1.000; 1.000; 1.000)	(1.000; 1.000; 1.000)	(0.088; 0.108; 0.127)	0.108
ESF_2	(1.032; 1.048; 1.098)	(0.902; 0.952; 0.968)	(1.033; 1.050; 1.108)	(0.091; 0.114; 0.141)	0.115
ESF_3	(1.100; 1.150; 1.200)	(0.800; 0.850; 0.900)	(1.148; 1.235; 1.385)	(0.101; 0.134; 0.176)	0.136
ESF_4	(1.097; 1.143; 1.194)	(0.806; 0.857; 0.903)	(1.271; 1.442; 1.718)	(0.112; 0.156; 0.219)	0.159
ESF_5	(1.066; 1.098; 1.148)	(0.852; 0.902; 0.934)	(1.361; 1.598; 2.016)	(0.119; 0.173; 0.257)	0.178
ESF_6	(0.874; 1.000; 1.033)	(0.967; 1.000; 1.126)	(1.208; 1.598; 2.085)	(0.106; 0.173; 0.265)	0.178
ESF_7	(0.550; 0.763; 1.000)	(1.000; 1.237; 1.450)	(0.833; 1.293; 2.085)	(0.073; 0.140; 0.265)	0.150
Sum			(7.855; 9.217; 11.399)		
ISF_1	–	(1.000; 1.000; 1.000)	(1.000; 1.000; 1.000)	(0.105; 0.135; 0.153)	0.133
ISF_2	(1.066; 1.098; 1.148)	(0.852; 0.902; 0.934)	(1.070; 1.108; 1.173)	(0.112; 0.149; 0.180)	0.148
ISF_3	(1.097; 1.143; 1.194)	(0.806; 0.857; 0.903)	(1.185; 1.294; 1.455)	(0.124; 0.174; 0.223)	0.174
ISF_4	(1.032; 1.048; 1.098)	(0.902; 0.952; 0.968)	(1.225; 1.359; 1.613)	(0.129; 0.183; 0.247)	0.185
ISF_5	(0.630; 0.763; 1.016)	(0.984; 1.237; 1.370)	(0.894; 1.099; 1.640)	(0.094; 0.148; 0.251)	0.156
ISF_6	(0.376; 0.464; 0.606)	(1.394; 1.536; 1.624)	(0.551; 0.715; 1.176)	(0.058; 0.096; 0.180)	0.104
ISF_7	(1.100; 1.150; 1.200)	(0.800; 0.850; 0.900)	(0.612; 0.842; 1.470)	(0.064; 0.113; 0.225)	0.124
Sum			(6.536; 7.416; 9.528)		

Table 5. Calculation and results of the application of fuzzy PIPRECIA "Reverse approach"

	$\tilde{s}$	$\tilde{t}$	$\tilde{v}$	$\tilde{w}$	def
ESF_1	(0.606; 0.874; 1.000)	(1.000; 1.126; 1.394)	(0.228; 0.538; 0.918)	(0.034; 0.088; 0.193)	0.097
ESF_2	(0.550; 0.763; 1.000)	(1.000; 1.237; 1.450)	(0.318; 0.606; 0.918)	(0.047; 0.099; 0.193)	0.106
ESF_3	(0.606; 0.874; 1.000)	(1.000; 1.126; 1.394)	(0.461; 0.749; 0.918)	(0.069; 0.123; 0.193)	0.126
ESF_4	(0.464; 0.606; 0.874)	(1.126; 1.394; 1.536)	(0.642; 0.844; 0.918)	(0.096; 0.139; 0.193)	0.141
ESF_5	(0.874; 1.000; 1.033)	(0.967; 1.000; 1.126)	(0.987; 1.176; 1.034)	(0.147; 0.193; 0.218)	0.190
ESF_6	(1.100; 1.150; 1.000)	(1.000; 0.850; 0.900)	(1.111; 1.176; 1.000)	(0.166; 0.193; 0.211)	0.192
ESF_7	–	(1.000; 1.000; 1.000)	(1.000; 1.000; 1.000)	(0.149; 0.164; 0.211)	0.169
Sum			(4.747; 6.090; 6.707)		
ISF_1	(0.500; 0.667; 1.000)	(1.000; 1.333; 1.500)	(0.304; 0.667; 1.923)	(0.027; 0.096; 0.390)	0.133
ISF_2	(0.550; 0.763; 1.000)	(1.000; 1.237; 1.450)	(0.456; 0.889; 1.923)	(0.041; 0.127; 0.390)	0.157
ISF_3	(0.550; 0.763; 1.000)	(1.000; 1.237; 1.450)	(0.661; 1.099; 1.923)	(0.059; 0.158; 0.390)	0.180
ISF_4	(1.100; 1.150; 1.200)	(0.800; 0.850; 0.900)	(0.958; 1.359; 1.923)	(0.085; 0.195; 0.390)	0.209
ISF_5	(1.200; 1.300; 1.350)	(0.650; 0.700; 0.800)	(0.862; 1.155; 1.538)	(0.077; 0.166; 0.312)	0.175
ISF_6	(0.550; 0.763; 1.000)	(1.000; 1.237; 1.450)	(0.690; 0.809; 1.000)	(0.061; 0.116; 0.203)	0.121
ISF_7	–	(1.000; 1.000; 1.000)	(1.000; 1.000; 1.000)	(0.089; 0.143; 0.203)	0.144
Sum			(4.931; 6.978; 11.231)		

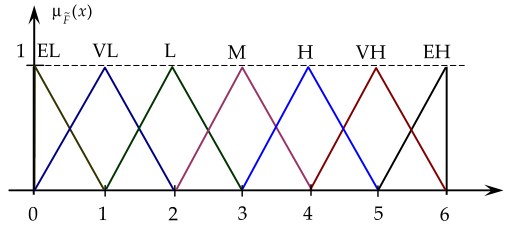

Figure 6. Membership functions of the terms for evaluating levels of strategic flexibility (developed by the authors)

Table 6 presents the linguistic expert assessments of the levels of the agricultural enterprise's external and internal strategic flexibility, while Table 7 provides the corresponding fuzzy values in triangular form.

Table 6. Linguistic assessment by experts of the enterprise's strategic flexibility level (both external and internal) using the Fuzzy SAW method

	e_1	e_2	e_3
E_1	M	M	H
E_2	L	M	M
E_3	M	M	L
E_4	M	H	M
E_5	L	M	M
E_6	M	H	M
E_7	H	H	VH

End of Table 6

	e_1	e_2	e_3
I_1	H	M	H
I_2	H	H	VH
I_3	VH	H	VH
I_4	H	H	H
I_5	M	M	H
I_6	H	VH	H
I_7	VH	VH	H

Table 7. Fuzzy expert assessments of the enterprise's strategic flexibility level (both external and internal) using the Fuzzy SAW method

	e_1	e_2	e_3	average
$\tilde{E}_1$	(2; 3; 4)	(2; 3; 4)	(3; 4; 5)	(2.333; 3.333; 4.333)
$\tilde{E}_2$	(1; 2; 3)	(2; 3; 4)	(2; 3; 4)	(1.667; 2.667; 3.667)
$\tilde{E}_3$	(2; 3; 4)	(2; 3; 4)	(1; 2; 3)	(1.667; 2.667; 3.667)
$\tilde{E}_4$	(2; 3; 4)	(3; 4; 5)	(2; 3; 4)	(2.333; 3.333; 4.333)
$\tilde{E}_5$	(1; 2; 3)	(2; 3; 4)	(2; 3; 4)	(1.667; 2.667; 3.667)
$\tilde{E}_6$	(2; 3; 4)	(3; 4; 5)	(2; 3; 4)	(2.333; 3.333; 4.333)
$\tilde{E}_7$	(3; 4; 5)	(3; 4; 5)	(4; 5; 6)	(3.333; 4.333; 5.333)
$\tilde{I}_1$	(3; 4; 5)	(2; 3; 4)	(3; 4; 5)	(2.667; 3.667; 4.667)
$\tilde{I}_2$	(3; 4; 5)	(3; 4; 5)	(4; 5; 6)	(3.333; 4.333; 5.333)
$\tilde{I}_3$	(4; 5; 6)	(3; 4; 5)	(4; 5; 6)	(3.667; 4.667; 5.667)
$\tilde{I}_4$	(3; 4; 5)	(3; 4; 5)	(3; 4; 5)	(3.000; 4.000; 5.000)
$\tilde{I}_5$	(2; 3; 4)	(2; 3; 4)	(3; 4; 5)	(2.333; 3.333; 4.333)
$\tilde{I}_6$	(3; 4; 5)	(4; 5; 6)	(3; 4; 5)	(3.333; 4.333; 5.333)
$\tilde{I}_7$	(4; 5; 6)	(4; 5; 6)	(3; 4; 5)	(3.667; 4.667; 5.667)

In **Stage 6**, the aggregation of fuzzy expert assessments of the strategic flexibility level (both external and internal) is performed using the Equations provided below in case there is consensus among the evaluations (21)–(22):

$$\tilde{E}_j = \frac{1}{K}\bigoplus_{k=1}^{K}\tilde{E}_{jk} = \left(\frac{1}{K}\sum_{k=1}^{K}a_{jk}^{E}; \frac{1}{K}\sum_{k=1}^{K}b_{jk}^{E}; \frac{1}{K}\sum_{k=1}^{K}c_{jk}^{E}\right) = (a_j^E; b_j^E; c_j^E); \quad (21)$$

$$\tilde{I}_j = \frac{1}{K}\bigoplus_{k=1}^{K}\tilde{I}_{jk} = \left(\frac{1}{K}\sum_{k=1}^{K}a_{jk}^{I}; \frac{1}{K}\sum_{k=1}^{K}b_{jk}^{I}; \frac{1}{K}\sum_{k=1}^{K}c_{jk}^{I}\right) = (a_j^I; b_j^I; c_j^I). \quad (22)$$

Next, using the Equations of the Fuzzy SAW method, the integral fuzzy values of external and internal strategic flexibility levels can be calculated as follows:

$$\tilde{E} = \bigoplus_{j=1}^{m^E} \tilde{w}_j^E \otimes \tilde{E}_j = \bigoplus_{j=1}^{m^E} (\alpha_j^E; \beta_j^E; \gamma_j^E) \otimes (a_j^E; b_j^E; c_j^E) =$$

$$\left(\sum_{j=1}^{m^E} \alpha_j^E a_j^E; \sum_{j=1}^{m^E} \beta_j^E b_j^E; \sum_{j=1}^{m^E} \gamma_j^E c_j^E \right) = (A^E; B^E; C^E); \quad (23)$$

$$\tilde{I} = \bigoplus_{j=1}^{m^I} \tilde{w}_j^I \otimes \tilde{I}_j = \bigoplus_{j=1}^{m^I} (\alpha_j^I; \beta_j^I; \gamma_j^I) \otimes (a_j^I; b_j^I; c_j^I) =$$

$$\left(\sum_{j=1}^{m^I} \alpha_j^I a_j^I; \sum_{j=1}^{m^I} \beta_j^I b_j^I; \sum_{j=1}^{m^I} \gamma_j^I c_j^I \right) = (A^I; B^I; C^I). \quad (24)$$

To refine the obtained fuzzy assessments, the α – cut (α = 0.8) is used. Note that if a fuzzy number $\tilde{u} = (a, b, c)$ is given, its α – cut is defined as follows:

$$\tilde{u}_{\alpha} = (a(1-\alpha) + \alpha b,\ b,\ c(1-\alpha) + \alpha b)).$$

Accordingly, we obtain fuzzy evaluations of the components of external and internal (Figure 7) strategic flexibility, as well as their integral fuzzy values under α = 0.8:

$\tilde{E}_{0.8} = (2.901; 3.220; 3.762)$ and $\tilde{I}_{0.8} = (3.589; 4.139; 5.640)$.

The integral value of strategic flexibility can be determined using the weighted assessment Equation (25):

$$S\tilde{F} = \lambda \tilde{I} \oplus (1-\lambda)\tilde{E}, \quad (25)$$

where λ – coefficient ($\lambda \in [0;1]$) is determined through expert judgment (indicating the relative importance of internal strategic flexibility).

Block 3 (**Stages 7–8**) – development of general and refined recommendations for enhancing the strategic flexibility of the enterprise.

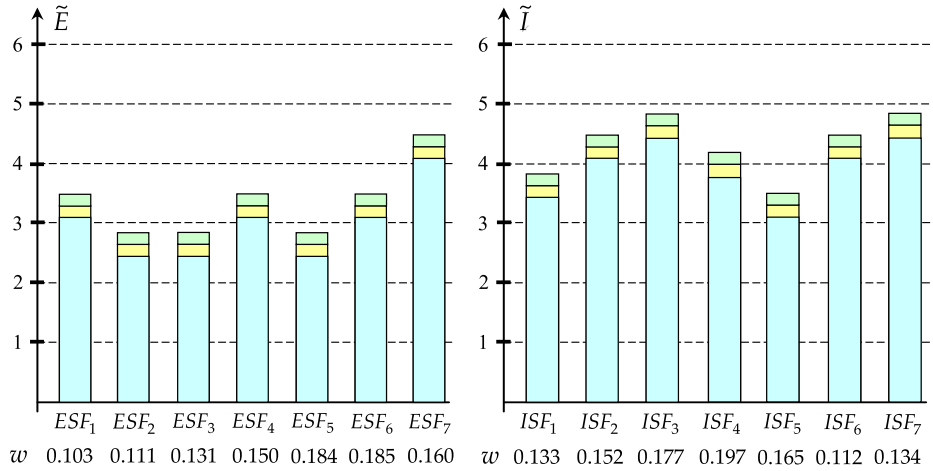

Figure 7. Fuzzy evaluates the components of the enterprise's external and internal strategic flexibility (developed by the authors)

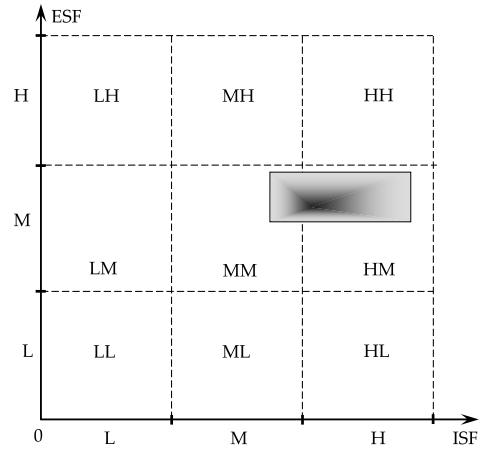

Figure 8. Fuzzy matrix for managing the enterprise's strategic flexibility (developed by the authors)

Stage 7. Following this, an extended fuzzy matrix can be constructed "ISF – ESF" (Figure 8):

Let us examine the sections of the constructed matrix that present potential strategic recommendations for enhancing the enterprise's strategic flexibility:

LL – low levels of ISF and ESF characterize this area: to arrange reengineering of business processes; to identify opportunities of finding external investors; to optimize administrative costs, to bankrupt unprofitable business segments or sell them;

ML – this area is characterized by a low level of ESF and an average level of ISF: revision of the marketing strategy; updating the information support of the infrastructure; development of new markets through the production of new products (unrelated diversification);

HL – this area is characterized by low levels of ESF and high levels of ISF: improving operational efficiency and optimizing the use of existing assets; increasing agricultural production; investing in innovations and modeling of logistics scenarios;

LM – this area is characterized by a low level of ISF and a medium level of ESF: product diversification ("10 Cereals") based on the climate principle; strengthening procurement activities to provide quality fertilizers; optimization of product distribution channels; use of corporate information systems (Oracle Applications, SAP R/3); development of ship-loading infrastructure;

MM – this area is characterized by an average level of ISF and ESF: reorganization of the procurement process – online procurement; use of energy-saving technologies in the production processes of agricultural holdings; participation in international organizations to increase the presence of the farm holding in the global information space; reduction of production costs;

HM – this area is characterized by a high level of ISF and an average level of ESF: developing horizontal diversification programs and entering new markets; investing in the development of river infrastructure that will be effective in the long term; intensifying brand management policy;

LH – this area is characterized by a low level of ISF and a high level of ESF: increasing of the land bank – aggressive policy; social responsibility of business in target areas; expansion of the dealer network to retail; opening new types of business to export of finished products (alcohol, biofuel, etc.);

MH – this area is characterized by a medium level of ISF and a high level of ESF: staff training as a key competitive advantage; revision of product policy; expansion of product certification; use of the "lean manufacturing" concept;

HH – this area is characterized by a high level of ISF and a high level of ESF: implementation of collective decision-making practices; decentralization; environmental orientation of production; intensification of mergers and acquisitions of suppliers and competitors; export of not only products but also services.

It should be noted that the developed methodological approach can also be applied to compare and evaluate the strategic flexibility of the enterprise's Strategic Business Units (SBUs).

The principles for managing strategic flexibility, formulated in (Wade et al., 2021) and based on qualitative and quantitative data from hundreds of organizations, can be valuable guidelines for managing strategic flexibility. As the authors note, these principles are not definitions, rules, laws, tools, or frameworks but guidelines that can assist enterprises in proactively leveraging disruptions to their advantage.

Principle 1: Prioritize speed over perfection. Since opportunities are fleeting, organizations must be prepared to act quickly, even if this means compromising quality and predictability.

Principle 2: Prioritize flexibility over planning. Strategic plans can quickly become an anchor that blocks an organization to a path that may lose relevance. However, when properly structured, these plans can enhance an organization's ability to absorb shocks without preventing productivity.

Principle 3: Prioritize diversification and "efficient slack" as effective shock absorbers over-optimization. Many problems arise from insufficient diversification or an excessive focus on efficiency and optimization.

Principle 4: Prioritize empowerment over hierarchy.

Principle 5: Prioritize learning over assigning blame.

Principle 6: Prioritize resource modularity and mobility over resource lock-in (it is essential to create modular and/or mobile resources that can be changed or moved as needed).

Step 8. Developing a list of refined proposals, initiatives, and measures aimed at strengthening the strategic flexibility of an agro-industrial enterprise should consider the specific characteristics of the enterprise and the partial assessments of both external and internal strategic flexibility (Pimenowa et al., 2020, 2023). To address the identified weak aspects of strategic flexibility (components of EFS and ISF with low expert evaluations) and to focus on the elements that have the most significant importance for the integral values of EFS and ISF (those with the highest weight coefficients), the following components of external flexibility that require substantial improvement can be highlighted: market, technological, and demographic flexibility.

To enhance market flexibility for MHP, it is necessary to conduct continuous monitoring of changes in the market environment, which can be implemented by assessing the attractiveness of market segments (Balan & Tymchenko, 2024) and developing pessimistic, optimistic, and most likely scenarios/strategies for development, considering trends in demand for agricultural products. It is also essential to invest in innovative development to ensure a complete technological cycle with its digitalization.

Technological flexibility, a component of external flexibility, allows the enterprise to gain competitive advantages by producing finished goods. MHP should seek external financing and grants to automate production processes since the agribusiness is involved in various agricultural activities. It is also necessary to incorporate information technologies based on artificial intelligence (sensors, GPS navigation, the creation of portable laboratories, and modern control systems), which will significantly enhance the company's resilience in global markets.

Demographic flexibility at MHP requires the development of an active policy for retaining and reserving employees. The outflow of skilled workers, mainly men, both abroad and through mobilization, can negatively impact agribusiness's ability to achieve competitive advantages and ensure sustainability.

The components of internal flexibility that require strengthening are:

Managerial flexibility. To support and enhance it, MHP management should encourage all holding participants to use their knowledge and experience in the agricultural sector, implement an LMS-type system for the management level, optimize the organizational structure by introducing electronic document management systems, eliminate duplication, and develop corporate social responsibility to improve the company's reputation and ensure sustainable development.

Innovation-investment flexibility can be strengthened by combining core assets and risk distribution in forming innovation-investment projects (for example, developing river transport or creating a fleet of railway wagons to ensure autonomy and transportation safety for the company's products).

Financial flexibility. It indicates the enterprise's stability in international markets; solvency and liquidity enable the company to effectively respond to changes in the dynamic market environment and implement the agribusiness's long-term strategy. To strengthen this component, it is first necessary to update the financial plan to changes in external environmental conditions (e.g., the growing global food crisis and climate challenges), implement a financial risk management system, and monitor the company's financial performance indicators. It is advisable to use a balanced scorecard system.

It is advisable for agroholding to focus on enhancing the external flexibility of supply chains and ensuring their alignment with the internal flexibility of supply chains within the operations of vertical agroholding. According to research (Yang et al., 2022), a high level of supply chain flexibility may serve as a prerequisite for mergers and acquisitions involving suppliers. This increased flexibility can subsequently enhance the competitiveness of the agricultural holding in both international and domestic agricultural markets.

Enhancing external flexibility through brand management practices, such as advertising the brand, will enable the agricultural holding to broaden its presence to a diverse consumer base. Utilizing social networks is advisable for this purpose. Additionally, this strategy is

beneficial for expanding the agroholding's land bank, as it is likely to increase the support of potential landlords.

The business's commitment to social responsibility can improve external flexibility (Lu et al., 2024). While the agro holding currently works with charitable foundations, increasing positive feedback requires expanding the range of programs and improving the budgets of these foundations.

Strengthening internal strategic flexibility should also be integrated into formulating the agricultural holding's long-term development plans, considering current trends in agriculture. Specifically, MHP should concentrate on digitalization within its production strategy (Collins et al., 1998; Yuan et al., 2024), particularly by incorporating additive manufacturing technologies into its operations.

Implementing the "lean production" concept, which emphasizes strict production discipline as a foundation for efficiency and effectiveness, can enhance internal flexibility. This controlled use of flexibility should be integrated into the organizational structure and culture of the agricultural holding (Sitnicki et al., 2024a).

4. Discussion

The agricultural sector is a pivotal driver of the Ukrainian economy at its current stage of development. Farming enterprises' competitiveness and market sustainability are achieved through effective strategic management. In this context, managing the strategic flexibility of enterprises is a crucial component.

This study aims to address the methodological gaps in managing the strategic flexibility of enterprises in complex and multifaceted processes. A qualitative assessment of both external and internal strategic flexibility can provide valuable insights for enhancing the management process, thereby improving the enterprise's capacity to proactively adapt to changes in its external and internal environments and strengthening its competitiveness and market stability. The developed model accounts for the ambiguity and imprecision of information provided by experts and specialists and can be utilized in strategic management to develop strategies for enhancing strategic flexibility and refining specific aspects of enterprise operations.

Future research could focus on testing the developed model across agricultural enterprises of varying sizes and types, adapting the criteria system for assessing strategic flexibility to the specific characteristics of their operations and relational business environments. Additionally, developing a framework to facilitate the assessment of internal and external strategic flexibility levels and constructing a corresponding fuzzy matrix would be valuable.

5. Conclusions

The study highlights the crucial role of strategic flexibility in enhancing the competitiveness and sustainability of agro-industrial enterprises, particularly in the volatile Ukrainian agricultural market. By integrating fuzzy set theory and advanced fuzzy modeling techniques, authors have developed a robust framework that enables the precise evaluation and management of internal and external strategic flexibility (Sitnicki et al., 2024a). Applying Fuzzy

PIPRECIA, Fuzzy Delphi, and Fuzzy SAW provides a comprehensive and adaptable approach to prioritizing key areas of flexibility, thereby facilitating proactive decision-making.

The study's case analysis of PRJSC MHP, a leading agro-industrial enterprise, underscores the relevance of this model in navigating external challenges, such as geopolitical instability and infrastructure loss, while leveraging internal resources for recovery and growth (Pimenova et al., 2023; Pimenow et al., 2024b). Accordingly, the performance indicators are above the industry average, and the agribusiness holding is multi-profile, allowing it to achieve results under various conditions. In this case, the scale effect will influence the strategy formulation policy for enhancing strategic flexibility compared to medium and small enterprises in the agricultural sector. At the same time, when assessing the strategic flexibility of the large agribusiness holding MHP, the key aspects can be adapted for smaller enterprises in the industry. For example, practices in managerial flexibility, such as continuous learning, and innovation-investment flexibility, such as the cooperation of agricultural enterprises through the shared use of core assets, can be implemented. Incorporating practical results from industry leaders into the development strategies of medium and small enterprises will enhance their strategic flexibility and resilience in the agricultural product market.

The authors have developed a universal model that can be used as a primary tool for managing strategic flexibility or as a complement to those already employed in agricultural enterprises. Furthermore, applying this methodology to agricultural enterprises with different industrial and technological cycles will expand and complement the results obtained, ensuring their practical value for the industry and their universality.

The authors propose a structured approach to balancing internal and external strategic flexibility, emphasizing the role of vertical integration, resource optimization, and diversification in maintaining market leadership.

Author contributions

Conceptualization, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; methodology, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; validation, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; formal analysis, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; investigation, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; data curation M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; writing – original draft preparation, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; writing – review and editing, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; visualization, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; supervision, M. W. S., N. W., V. B., I. T., M. W., O. P., S. S.; project administration, M. W. S., O. P., S. S.

Disclosure statement

The authors of this study declare that they have no competing financial, professional, or personal interests that could influence the content, findings, or conclusions presented in this study.

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