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## Article

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# A Hybrid Fuzzy Approach for Industry Competition Analysis

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## Abstract

The paper suggests a hybrid approach to strategic diagnostics of the industry competition based on the application of M. Porter's model of five forces, tools of logical-linguistic modelling and the theory of fuzzy sets. Two complementary calculation schemes were developed to assess the level of competition in the industry. The first of them is based on fuzzy multicriteria analysis using the Fuzzy SAW method, the second is based on the construction of a logical-linguistic model with fuzzy expert knowledge bases and the use of fuzzy inference using Mamdani Fuzzy Inference System. Fuzzy numbers in triangular form with triangular membership functions are used to represent the linguistic assessments of experts, and the CoA (Center of Area) method is used to defuzzify the obtained values. The study proposes to implement a model in the form of a framework in Excel. The framework allows simulation, depending on the modification of the list of certain factors of the external environment and correction of experts' considerations. The methodological approach can be used in conducting a strategic audit of the microenvironment of an enterprise, in competitive analysis, in strategic planning of enterprise activities as a basis for the development and implementation of effective competitive strategies.

## Keywords

Fuzzy Sets, Fuzzy Multicriteria Analysis, Porter's Force Assessment Model, Fuzzy SAW-method, Logical-linguistic Model, Fuzzy Knowledge Bases, Mamdani Fuzzy Inference System

## JEL Classification

C51, C63, D04

## Introduction

There will be the text of the contribution. The current state of national economies is characterized by an extremely high level of instability, turbulence, and uncertainty. Political, demographic, social, technological, environmental, competitive factors and the long-term coronavirus pandemic, which radically has changed approaches to doing business, intensified competition in global and local markets, and complicated enterprise management processes, have a significant impact on economic processes, especially in a strategic context. Therefore, the management of companies faces the task of developing scientifically sound methods of analysis, evaluation, and consideration of trends in such factors to adequately and timely respond to challenges generated by the external environment. By this, the strategic diagnostics of the external environment of the enterprise is a necessary and extremely important component of its general strategic analysis to identify and assess the main opportunities and threats of the macro and microenvironment. In (Babatunde and Adebisi, 2012), the authors, based on a study of Nestle Nigeria Plc and Cadbury Nigeria Plc, confirm the thesis that continuous monitoring, scanning and evaluation of the external environment can greatly ensure better results and greater efficiency in a competitive business environment. The same idea was expressed by Dieter Zetsche in an interview, the former CEO of Daimler Corporation, who claims to be the one who is committed to sustainable competitiveness and profitability, must constantly evolve and adapt to a rapidly changing environment – technologically, culturally and structurally. To ensure the objectivity of such an analysis, it is necessary to involve both internal strategic analysts and specialists, as well as external experts and consulting firms. According to Craig S. Fleisher (Director of Odette Research) and Babette E. Bensoussan (Director of The MindShifts Group Pty. Ltd.) "effective analysis requires experience, conscientious contribution, intuition and models, and also ... even a shade of calm. It

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requires constant change in the combination of art and science, common sense and information models, intuition and direction" (Fleisher and Bensoussan, 2002). Modern strategic analysis is largely based on expert considerations and assessments that have "blurred", fuzzy character. This in its turn determines the necessity to review the traditional methods that are not sufficiently effective in terms of taking into account the nature of the available and forecast information and the use of fuzzy approaches to the analysis and evaluation of environmental factors.

This study aims to develop a hybrid methodological approach based on the use of the classical model of the five forces of Michael Porter, tools of the theory of fuzzy sets and logical-linguistic modelling for the needs assessment of the level of competition in the industry.

## Literature Review

Theoretical and methodological aspects of the strategic analysis of enterprises in a large number of studies, in particular (Ansoff, 1979), (David, 2011), (Fleisher and Bensoussan, 2002), (Grant, 2016), (Tompson and Strickland, 2003), (Wheelen et al., 2018), (Porter, 1979) and others.

In modern scientific sources, a large number of publications are given on the topic of the practical application of classical tools for strategic analysis of environmental factors (ETOM, EFEM, PESTEL, SWOT-analysis, the model of M. Porter's 5 forces (P5F), etc.). Their analysis, assessment of opportunities using the FAROUT methodology is represented in the fundamental research of Craig Fleisher and Babette Bensoussan (Fleisher and Bensoussan, 2002) and a detailed description and application for the practical needs of well-known companies in (Shtal, 2018).

P5F is used to analyze industries were such well-known companies as The Walt Disney Company, eBay Inc., General Electric Company, General Motors, Verizon Communications, IBM, Procter & Gamble Company, Intel Corporation, Sony Corporation, Microsoft Corporation, Tesla Inc., Amazon.com Inc., Facebook Inc., Nike and others (<http://panmore.com/tag/porters-five-forces-analysis>, 2021).

Competitiveness of Jordan Phosphate Mines Company is examined by an analysis based on the P5F (Alrawashdeh 2013). The authors of the article (Anastasiu et al., 2020) argue in favour of adopting P5F to strategic human resources management. The quality and stability of human capital should be analyzed strategically, based on the influence of five forces that act in the market, for a sustainable approach.

The author of article (Evans, 2015) try to investigate and critically examine P5F and to study up to what extend industry structure changed with the thought of Globalization, Deregulation and Digitalization process. Other publications substantiate the need to revise the classical P5F (Grundy, 2006; Bruijl, 2018; Indiaty et al., 2014; Shokeen, 2016; Isabelle et al., 2020) to take into account the modern realities of digitalization of the business environment by introducing additional forces. In particular, the authors of the article (Isabelle et al., 2020), drawing from research on Porter's Five Forces framework, and through an internationalization lens, propose a modified framework augmented with four additional forces. These additional forces are the competitor's level of innovativeness, exposure to globalization, the threat of digitalization, and industry exposure to deregulation activities. These forces were added by the authors to capture the increased interconnectivity and complexity of businesses operating in the 21st century. The findings aim to incite researchers, managers, entrepreneurs and policymakers to go beyond the traditional five forces as a way to help monitor their business environment and enhance decision-making processes, particularly in a post-COVID-19 world.

As for the application of the theory of fuzzy sets (Zadeh, 1978), which has recently been a promising direction in strategic management for solving the problems of strategic analysis of an enterprise, the following works should be highlighted. A fuzzy approach to assessing the influence of external factors on the strategy of an enterprise (Fuzzy EFEM) using fuzzy triangular numbers and a fairly wide scale in terms of variability of estimates (in the crisp form: from -20 to 20) is proposed (Mohammadi et al., 2011). Gavanelli et al. (2010) suggested two logical-oriented approaches to assessing the external environment. The first is based on logical programming of constraints on real numbers, the second is based on causal-probabilistic logic programming. These approaches were improved in (Gavanelli et al., 2011), where a fuzzy logic approach (SEA-Strategic Environmental Assessment) is proposed, within which four models with different functions and informative capabilities are implemented. These models offer a more qualitative approach than Gavanelli et al. (2010) and show that fuzzy logic is more promising for application in strategic analysis. To identify critical environmental factors, the authors (Deng et al., 2015) used the Fuzzy DEMATEL method. Porter's Fuzzy Force Assessment Model (FFAM) is used to assess the factors of the competitive environment in the Turkish cement industry (Ulubelli, 2017). From the same point of view, the studies carried out in the work of Garashchenko and Kotsyuba (2013) are interesting. This article presents the results of instrumental fuzzy sets based adaptation of P5F. In this paper, the substantive and structural characteristics of the model are analyzed, the algorithm for aggregating the initial data is presented, and alternative methods for recognizing estimates of the levels of competition forces within the framework of an expert qualitative scale are considered. These studies extend classical instruments and demonstrate their effectiveness and flexibility. And yet, despite significant advances in improving the strategic

analysis toolkit, there are significant gaps in certain aspects of research and modelling of scanning problems, assessment and forecasting of changes in the external environment of enterprises. Agreeing with the assertions of many researchers about the need to take into account new trends in the so-called “digital” economy, the authors of this study propose to focus on increasing the efficiency of using P5F by improving the methodological support of its analytical part based on the theory of fuzzy sets and logical-linguistic models. The above, by the way, does not exclude the possibility of supplementing this study with other forces and factors that may affect the level of competition in the industry, in accordance with the specifics of each industry and even a specific market.

## Methods

For the implementation of structural analysis tools may be involved macro strategic diagnosis (PESTEL analysis, ETOM analysis) microenvironment (the classical model of the five forces of Michael Porter, the Rosenbluth and Herfindahl-Hirschman Index, the market concentration index, methods of competitive analysis), the J. Wilson’s matrix and others.

The most famous and effective tool is the model of 5 forces of M. Porter (P5F). According to M. Porter (Porter, 2008) “awareness of the five forces can help a company understand the structure of its industry and stake out a position that is more profitable and less vulnerable to attack”.

The M. Porter’s model analyzes the specifics of industry competition and contains three forces of “horizontal” competition: the threat of substitute products, the threat of new players, the level of competition, and two forces of “vertical” competition: the bargaining power of suppliers and the bargaining power of consumers. The cumulative influence of these factors determines the potential for marginal income in the industry since they affect the prices that firms can dictate, on the costs, and they have to bear the capital investment required to compete in this area. The importance of each of the five forces of competition is determined by the structure of the industry, that is, its main economic and technical characteristics. The numerous competitors can receive high returns on invested capital in those industries where the actions of these forces are developing favourably. In the same industries where one or more forces are acting unfavourably, only a few firms manage to maintain high profits for a long time. This model is based on expert linguistic assessments of factors for each of the certain “forces”. The difficulties arising, in this case, are due to the specific features of this process: the fuzziness and blurring of expert assessments, the informal nature of the assessment procedures, the presence of cognitive barriers arising from the linguistic disagreements of experts and differences in their professional experience, the need to carry out the multi-criteria analysis. Other important factors are the impact of numerous endo and exogenous factors, uncertainties and risks associated with high turbulence and variability of the business environment. This necessitates the use of fuzzy tools and methods of logical-linguistic modelling.

The main provisions of the theory of fuzzy logic, based on the mathematical theory of fuzzy sets, proposed by Lotfi Zadeh in 1965 in the work “Fuzzy Sets”. The objective reason that led to the emergence of the theory of fuzzy sets was the need to describe processes, objects, systems in fuzzy conditions. A very pivotal step in the development of “fuzzy” methodology was proved in 1993 by Bart Kosko “Fuzzy Approximation Theorem” (Kosko, 1993). According to it, any mathematical system can be measure by a fuzzy logic system.

Kosko’s work gave a powerful impetus to further research in this area, and practical advances in the field of the theory of fuzzy logic received theoretical justification. Now the approach based on the theory of fuzzy sets is, in fact, an alternative to the generally accepted quantitative deterministic methods of systems analysis. It has three main features: instead of or in addition to numerical variables, fuzzy values and so-called “linguistic” variables are used; merely relationships between variables are described using fuzzy statements; complex relationships are described by fuzzy algorithms.

Note that operations on fuzzy numbers are carried out using the so-called “soft” calculations.

In this study, to solve the assigned tasks of assessing the level of competition in the industry, it is envisaged to use the tools of the theory of fuzzy sets, in particular, methods of fuzzy multi-criteria analysis (Fuzzy Simple Additive Weighting (SAW) method(Chou et al., 2008)) and Fuzzy Inference Systems (FIS), (Mamdani, 1977). Note that the process of fuzzy inference is a certain procedure or algorithm for obtaining fuzzy conclusions based on fuzzy conditions using the concepts of fuzzy logic. This process combines all the basic concepts of the theory of fuzzy sets: membership functions, linguistic variables, fuzzy logical operations, methods of fuzzy implication and fuzzy composition. FIS serve as the conceptual basis of all modern fuzzy logic.

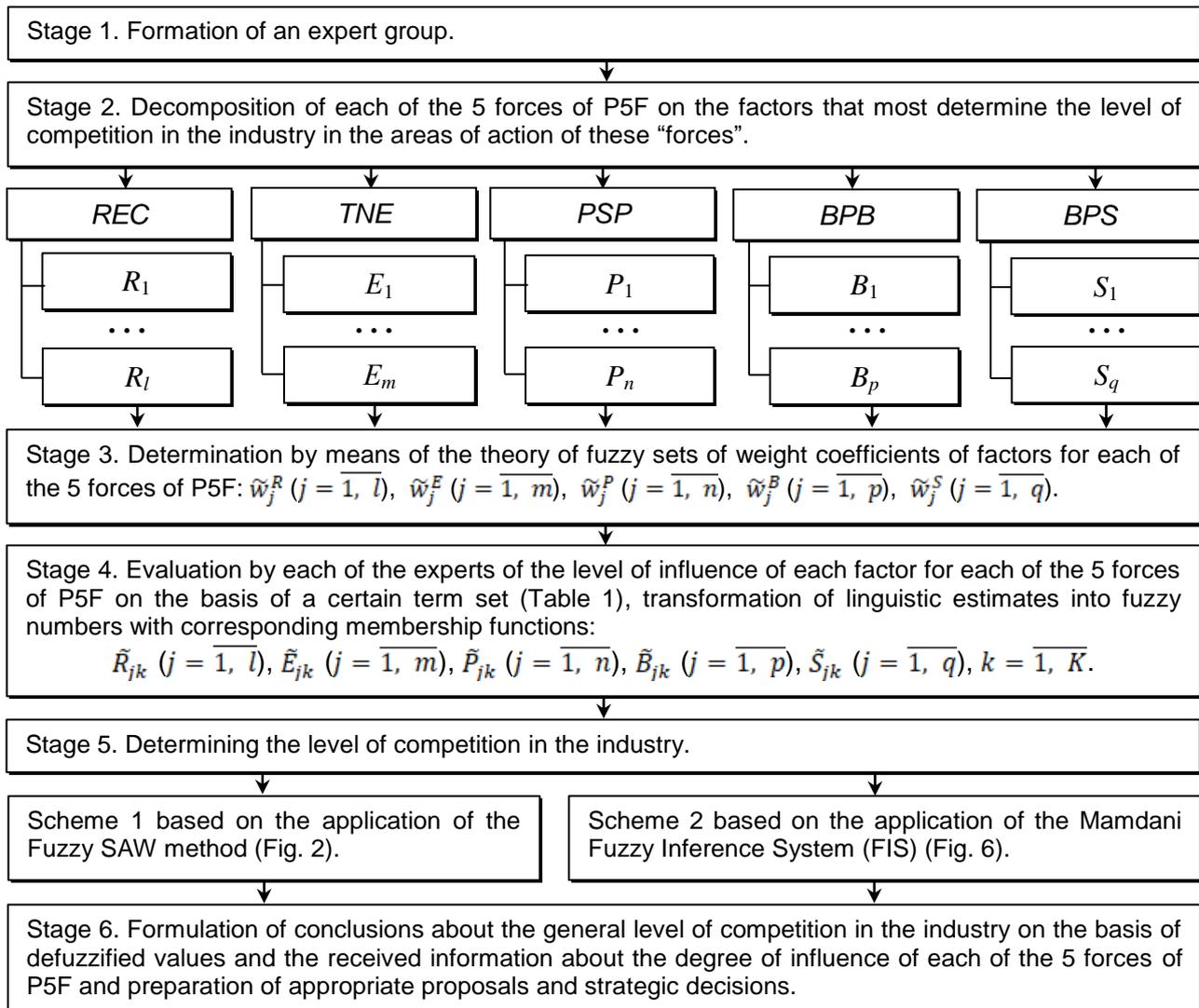
## Results

To take into account subjective, non-formalized, fuzzy input data, opinions and judgments of experts, a hybrid methodological approach developed by the authors is proposed (Fig. 1) based on the application of P5F, the theory of fuzzy sets.

Stage 1 involves the formation of an expert group of professionals who have the appropriate competence in the subject area. It is advisable to include both strategic analysts of the enterprise and external consultants-

practitioners with experience in analytical work and knowledge of the features, logical-causal relationships of the region.

At the 2nd stage, each of the 5 forces of P5F is decomposed into the factors that most determine the level of competition in the industry in the directions of action of these “forces”.



**Fig. 1.** Stages of applying P5F based on the theory of fuzzy sets. **Source:** Authors' own

In Fig. 1 from the opinions of Porter (1979), Brandenburger and Nalebuff (1996), Garashchenko and Kotsyuba (2013), the advances in the established competitive forces (CF) of P5F and the following factors:

- *REC* – Rivalry among Existing Competitors:  $R_1$  is the concentration of enterprises-operators of the industry;  $R_2$  is the product differentiation;  $R_3$  is the rate of market growth;  $R_4$  is the level of fixed costs;  $R_5$  is the exit barriers;
- *TNE* – Threat of New Entrants:  $E_1$  is the product differentiation;  $E_2$  is the level of expenses for the reorientation of the end consumer to the products of another enterprise;  $E_3$  is the average size of the initial investment costs;  $E_4$  is access to technologies and resources;  $E_5$  is access to product distribution channels;  $E_6$  is the legal barriers;  $E_7$  is the economies of scale;  $E_8$  is the effect of the experience curve;  $E_9$  is the possibility of technological progress (breakthrough);
- *PSP* – Pressure from Substitute Products:  $P_1$  is the number of real alternatives;  $P_2$  is profitability and aggressive business operators in the sectors producing substitute;  $P_3$  is the average market growth of substitutes;  $P_4$  is the prospects for technological development of industries that produce substitutes;  $P_5$  is the costs for end-users to reorient substitutes;
- *BPB* – Bargaining Power of Buyers:  $B_1$  is the number of end consumers of the industry's products;  $B_2$  is the concentration of direct buyers of the industry's products;  $B_3$  is the profitability of the activities of direct buyers of the industry's products;  $B_4$  is the elasticity of demand of end buyers of the industry's products;  $B_5$  is the number of substitute products for the industry's products;  $B_6$  is the level of expenses for the reorientation of the end consumer to the products of another enterprise;  $B_7$  is the degree of awareness of

end consumers about the products of the industry;  $B_8$  is the degree of influence of “influential persons”;  $B_9$  is the possibility of backward integration, that is, in the direction of the direct buyer – the industry;  $B_{10}$  is the possibility of forwarding integration, that is, in the direction of the industry – the buyer;  $B_{11}$  is the industry’s contribution to the quality and service of products is created by direct buyers;

- **BPS – Bargaining Power of Suppliers:**  $S_1$  is the concentration of industry supplying enterprises;  $S_2$  is the level of expenses for reorientation to other suppliers and/or differentiation of the resource;  $S_3$  is interchangeability of resources;  $S_4$  is the industry’s share in the profits of suppliers;  $S_5$  is the possibility of integration “forward”, that is, in the direction of suppliers – industry;  $S_6$  is the possibility of integration “back”, that is, in the direction: industry - suppliers;  $S_7$  is the share of costs for the products of suppliers in the total costs of the region;  $S_8$  is the contribution of suppliers to the quality and service of the product of the industry.

**Calculate the importance of the factors of each force P5F.**

At the 3rd stage, to determine the weight coefficients of each factor for each of the 5 forces of P5F using the theory of fuzzy sets, you can use the following procedure, which we will implement using such steps.

Step 1. Linguistic assessment by each of the experts of the importance of factors within each of the competitive forces of P5F. To do this, you can use a seven-level term-set (Table 1), where each of the defined terms is given by fuzzy numbers in a triangular form (TFN) on an interval [0,0; 6,0] with corresponding triangular membership functions. Note that the use in this work of the seven-level scale of linguistic assessment (Table 1), in our opinion, as quite informative and utilitarian, is due, firstly, to the weak ability of experts in subjective assessment to recognize no more than seven gradations of the studied characteristics (Saaty and Shang, 2011), and secondly, the need for their sufficient detailing. The choice of fuzzy numbers in triangular form is explained by the convenience of presentation, comprehensibility for experts and computational simplicity (Kaufmann and Gupta, 1988). Interval [0,0; 6,0] is also chosen for similar reasons and is determined by the triangular shape of fuzzy numbers, but can be easily transformed in to another one convenient for experts (Kaufmann and Gupta, 1988).

**Table 1.** Linguistic terms and fuzzy representations.

Linguistic terms	Designation	Triangular fuzzy number (TFN)
Extremely Low	EL	(0; 0; 1)
Very Low	VL	(0; 1; 2)
Low	L	(1; 2; 3)
Medium	M	(2; 3; 4)
High	H	(3; 4; 5)
Very High	VH	(4; 5; 6)
Extremely High	EH	(5; 6; 6)

**Source:** Authors’ own

The analytical representation of the membership function, for example, for a fuzzy number with a triangular  $\tilde{u} = (a; b; c)$  representation will look like this:

$$\mu_{\tilde{u}}(x) = \begin{cases} 0, & x < a; \\ (x - a)/(b - a), & x \in [a; b]; \\ (c - x)/(c - b), & x \in [b; c]; \\ 0, & x > c. \end{cases} \tag{1}$$

Note that for defuzzification of a fuzzy number in triangular form  $\tilde{u} = (a; b; c)$ , the method of CoA (Center of Area) is used (Van Leekwijck and Kerre, 1999):

$$def(\tilde{u}) = \frac{(c-a)+(b-a)}{3} + a \tag{2}$$

Thus, we obtain the following linguistic estimates of the importance of factors:  $lv_{jk}^R$  ( $j = 1, 2, \dots, l$ ),  $lv_{jk}^E$  ( $j = 1, 2, \dots, m$ );  $lv_{jk}^P$  ( $j = 1, 2, \dots, n$ ),  $lv_{jk}^B$  ( $j = 1, 2, \dots, p$ );  $lv_{jk}^S$  ( $j = 1, 2, \dots, q$ );  $k = 1, 2, \dots, K$ .

Step 2. Transformation of linguistic estimates of experts into fuzzy triangular numbers using the scale given in the table. 1:  $lv_{jk}^R \rightarrow \tilde{v}_{jk}^R = (\alpha_{jk}^R; \beta_{jk}^R; \gamma_{jk}^R)$ ;  $lv_{jk}^E \rightarrow \tilde{v}_{jk}^E = (\alpha_{jk}^E; \beta_{jk}^E; \gamma_{jk}^E)$ ;  $lv_{jk}^P \rightarrow \tilde{v}_{jk}^P = (\alpha_{jk}^P; \beta_{jk}^P; \gamma_{jk}^P)$ ;  $lv_{jk}^B \rightarrow \tilde{v}_{jk}^B = (\alpha_{jk}^B; \beta_{jk}^B; \gamma_{jk}^B)$ ;  $lv_{jk}^S \rightarrow \tilde{v}_{jk}^S = (\alpha_{jk}^S; \beta_{jk}^S; \gamma_{jk}^S)$ .

Step 3. Aggregation of fuzzy expert estimates by formulas (3) – (4):

$$\tilde{v}_j^R = \left( \bigoplus_{k=1}^K \tilde{v}_{jk}^R \right) / K = (\alpha_j^R; \beta_j^R; \gamma_j^R); \quad (3)$$

$$\tilde{v}_j^E = \left( \bigoplus_{k=1}^K \tilde{v}_{jk}^E \right) / K = (\alpha_j^E; \beta_j^E; \gamma_j^E); \quad (4)$$

in a similar way for  $\tilde{v}_j^P = (\alpha_j^P; \beta_j^P; \gamma_j^P)$ ;  $\tilde{v}_j^B = (\alpha_j^B; \beta_j^B; \gamma_j^B)$ ;  $\tilde{v}_j^S = (\alpha_j^S; \beta_j^S; \gamma_j^S)$ .

Step 4. Calculation using formula (2) defuzzified obtained values of weights:  $def(\tilde{v}_j^R)$ ,  $def(\tilde{v}_j^E)$ ,  $def(\tilde{v}_j^P)$ ,  $def(\tilde{v}_j^B)$ ,  $def(\tilde{v}_j^S)$ .

Step 5. Normalization of weights by formulas (5) – (6):

$$\tilde{w}_j^R = \frac{\tilde{v}_j^R}{\sum_{t=1}^l def(\tilde{v}_t^R)} = (w_{1j}^R; w_{2j}^R; w_{3j}^R); \quad (5)$$

$$\tilde{w}_j^E = \frac{\tilde{v}_j^E}{\sum_{t=1}^m def(\tilde{v}_t^E)} = (w_{1j}^E; w_{2j}^E; w_{3j}^E); \quad (6)$$

in a similar way for  $\tilde{w}_j^P = (w_{1j}^P; w_{2j}^P; w_{3j}^P)$ ;  $\tilde{w}_j^B = (w_{1j}^B; w_{2j}^B; w_{3j}^B)$ ;  $\tilde{w}_j^S = (w_{1j}^S; w_{2j}^S; w_{3j}^S)$ .

Stage 4. To assess the factors of each of the competitive forces, directly the competitive forces themselves and the level of competition in the industry, it is proposed to use the table 1 term set.

Thus, we get the following linguistic estimates of the importance of factors:  $L_{jk}^R$ , ( $j = 1, 2, \dots, l$ );  $L_{jk}^E$ , ( $j = 1, 2, \dots, m$ );  $L_{jk}^P$ , ( $j = 1, 2, \dots, n$ );  $L_{jk}^B$ , ( $j = 1, 2, \dots, p$ );  $L_{jk}^S$ , ( $j = 1, 2, \dots, q$ );  $k = 1, 2, \dots, K$ . Using the Table 1 we transform these estimates into fuzzy triangular numbers:  $L_{jk}^R \rightarrow \tilde{R}_{jk} = (x_{jk}^R; y_{jk}^R; z_{jk}^R)$ ;  $L_{jk}^E \rightarrow \tilde{E}_{jk} = (x_{jk}^E; y_{jk}^E; z_{jk}^E)$ ;  $L_{jk}^P \rightarrow \tilde{P}_{jk} = (x_{jk}^P; y_{jk}^P; z_{jk}^P)$ ;  $L_{jk}^B \rightarrow \tilde{B}_{jk} = (x_{jk}^B; y_{jk}^B; z_{jk}^B)$ ;  $L_{jk}^S \rightarrow \tilde{S}_{jk} = (x_{jk}^S; y_{jk}^S; z_{jk}^S)$ .

Stage 5. Next, we will use two calculation schemes with different approaches to assessing the impact of competitive forces on the level of industry competition, which can complement each other and provide the necessary information to formulate appropriate conclusions.

#### Calculation scheme 1 (based on Fuzzy SAW method).

Design scheme 1 is implemented according to the following algorithm (Fig. 2).

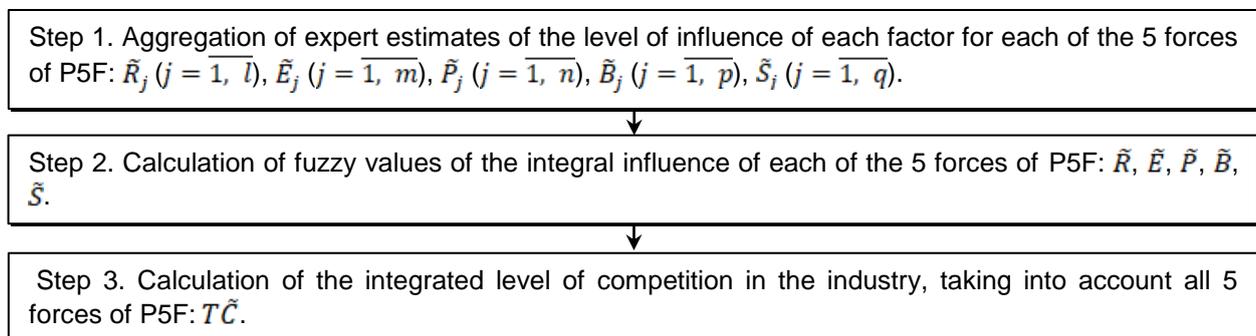


Fig. 2. Algorithm for applying the calculation scheme based on Fuzzy SAW method. Source: Authors' own.

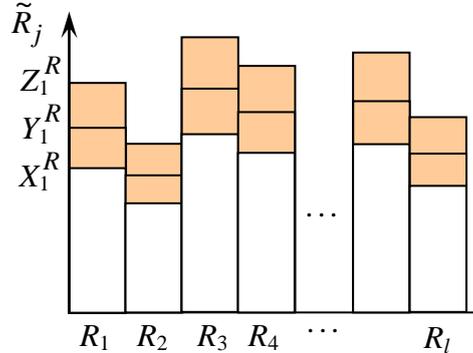
Step 1. Aggregation by formulas (7) – (8) of fuzzy expert estimates obtained at the stage 4:

$$\tilde{R}_j = \frac{1}{K} \bigoplus_{k=1}^K \tilde{R}_{jk} = \left( \frac{1}{K} \sum_{k=1}^K x_{jk}^R; \frac{1}{K} \sum_{k=1}^K y_{jk}^R; \frac{1}{K} \sum_{k=1}^K z_{jk}^R \right) = (X_j^R; Y_j^R; Z_j^R); \quad (7)$$

$$\tilde{E}_j = \frac{1}{K} \bigoplus_{k=1}^K \tilde{E}_{jk} = \left( \frac{1}{K} \sum_{k=1}^K x_j^E; \frac{1}{K} \sum_{k=1}^K y_j^E; \frac{1}{K} \sum_{k=1}^K z_j^E \right) = (X_j^E; Y_j^E; Z_j^E); \tag{8}$$

in a similar way for  $\tilde{P}_j = (X_j^P; Y_j^P; Z_j^P)$ ;  $\tilde{B}_j = (X_j^B; Y_j^B; Z_j^B)$ ;  $\tilde{S}_j = (X_j^S; Y_j^S; Z_j^S)$ .

You can use bar charts to illustrate the results (for example, for competitive force *REC* – Fig. 3).



**Fig. 3.** Graphic illustration of aggregated fuzzy expert estimates for competitive force REC. **Source:** Authors' own.

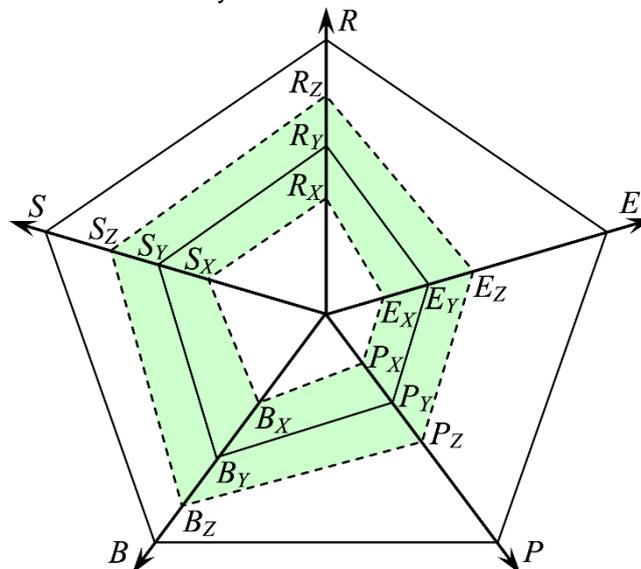
Step 2. Using the Fuzzy SAW method based on formulas (9) – (10), we determine the fuzzy values of the level of competition for each of the 5 forces of P5F:

$$\tilde{R} = \bigoplus_{j=1}^l \tilde{w}_j^R \otimes \tilde{R}_j = \left( \sum_{j=1}^l w_{1j}^R X_j^R; \sum_{j=1}^l w_{2j}^R Y_j^R; \sum_{j=1}^l w_{3j}^R Z_j^R \right) = (X^R; Y^R; Z^R); \tag{9}$$

$$\tilde{E} = \bigoplus_{j=1}^m \tilde{w}_j^E \otimes \tilde{E}_j = \left( \sum_{j=1}^m w_{1j}^E X_j^E; \sum_{j=1}^m w_{2j}^E Y_j^E; \sum_{j=1}^m w_{3j}^E Z_j^E \right) = (X^E; Y^E; Z^E); \tag{10}$$

in a similar way for  $\tilde{P} = (X^P; Y^P; Z^P)$ ;  $\tilde{B} = (X^B; Y^B; Z^B)$ ;  $\tilde{S} = (X^S; Y^S; Z^S)$ .

The obtained fuzzy weighted values of the integral influence of each of the 5 forces of P5F can be depicted on the diagram as a pentagon (Fig. 4), which allows us to conclude about the degree of influence of competitive forces on the state of competition in the industry.



**Fig. 4.** Diagram of the impact assessment on the level of competition in the industry based on the fuzzy model of M. Porter's model. **Source:** Authors' own.

We note that the results obtained (both in the form of fuzzy and defuzzified values (according to formula (2)) of the level of influence of competitive forces on competition in the industry can serve as a serious basis for the formation of strategic behavior of enterprises in the relevant markets in order to adequately respond to certain factors of forces of industry competition, to formulate competitive strategies.

Step3. To determine the level of integral impact, it is necessary to determine the weight coefficients of each of the

five forces. This can be done with a similar procedure as was done for the weights of factors of each of these forces (step 1 – step 5 in stage 3). As a result, we get the following values:  $\tilde{W}^R = (W_1^R; W_2^R; W_3^R)$ ,  $\tilde{W}^E = (W_1^E; W_2^E; W_3^E)$ ,  $\tilde{W}^P = (W_1^P; W_2^P; W_3^P)$ ,  $\tilde{W}^B = (W_1^B; W_2^B; W_3^B)$ ,  $\tilde{W}^S = (W_1^S; W_2^S; W_3^S)$ .

We introduce the following notation (Table 2):

**Table 2.** Weighing fuzzy values of competitive forces.

$R_X = W_1^R X^R$	$E_X = W_1^E X^E$	$P_X = W_1^P X^P$	$B_X = W_1^B X^B$	$S_X = W_1^S X^S$
$R_Y = W_2^R Y^R$	$E_Y = W_2^E Y^E$	$P_Y = W_2^P Y^P$	$B_Y = W_2^B Y^B$	$S_Y = W_2^S Y^S$
$R_Z = W_3^R Z^R$	$E_Z = W_3^E Z^E$	$P_Z = W_3^P Z^P$	$B_Z = W_3^B Z^B$	$S_Z = W_3^S Z^S$

Source: Authors' own

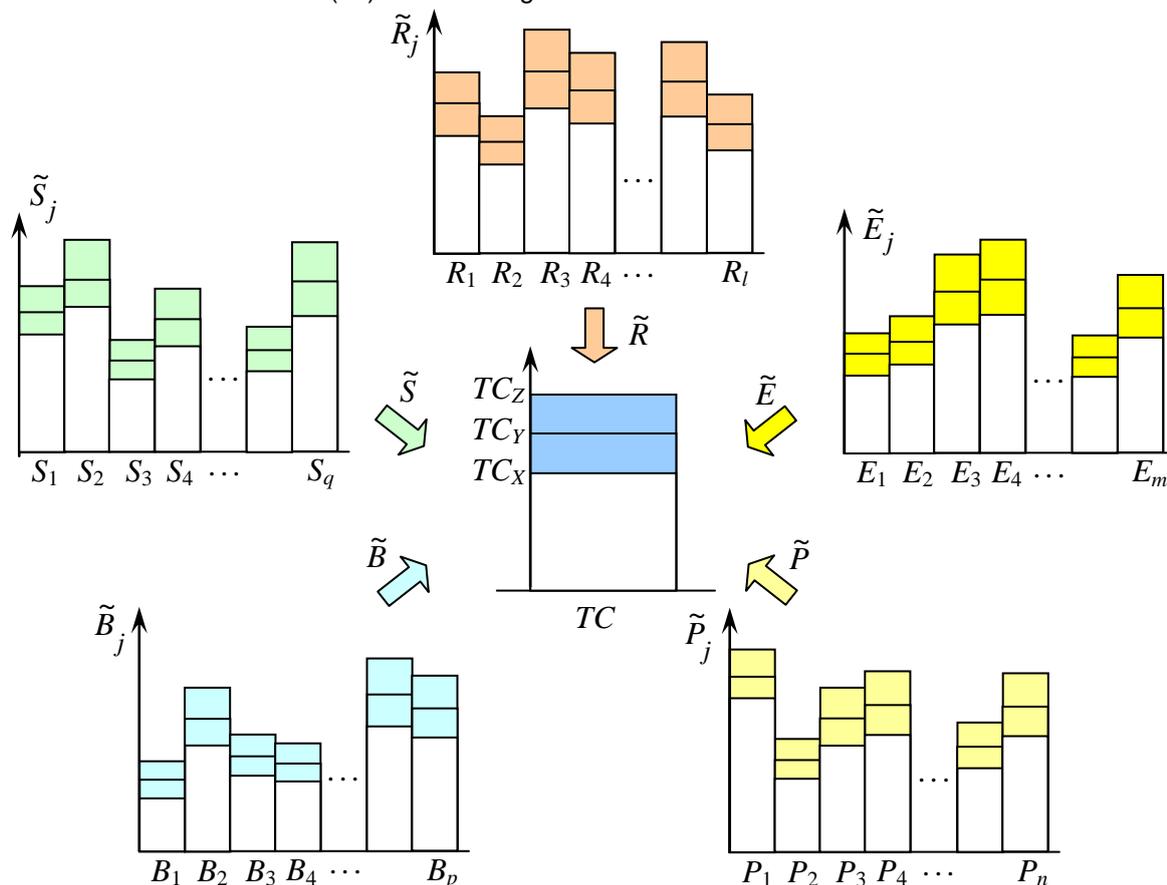
To determine the integral value of the level of competition, we use relation (11):

$$T\tilde{C} = \tilde{W}^R \otimes \tilde{R} \oplus \tilde{W}^E \otimes \tilde{E} \oplus \tilde{W}^P \otimes \tilde{P} \oplus \tilde{W}^B \otimes \tilde{B} \oplus \tilde{W}^S \otimes \tilde{S}. \tag{11}$$

So

$$\begin{aligned} T\tilde{C} &= (W_1^R X^R; W_2^R Y^R; W_3^R Z^R) \oplus (W_1^E X^E; W_2^E Y^E; W_3^E Z^E) \oplus (W_1^P X^P; W_2^P Y^P; W_3^P Z^P) \oplus \\ &\quad \oplus (W_1^B X^B; W_2^B Y^B; W_3^B Z^B) \oplus (W_1^S X^S; W_2^S Y^S; W_3^S Z^S) = \\ &= (R_X + E_X + P_X + B_X + S_X; R_Y + E_Y + P_Y + B_Y + S_Y; R_Z + E_Z + P_Z + B_Z + S_Z) = \\ &= (TC_X; TC_Y; TC_Z) \end{aligned} \tag{12}$$

Graphic illustration of the formula (12) shown in Fig. 5.



**Fig. 5.** Aggregation of fuzzy estimates. Source: Authors' own.

Defuzzify this value by formula (2). Thus, we obtain  $def(T\tilde{C})$ .

Note that the maximum defuzzified value of the level of competition (for all VH estimates) can be equal to  $5 \frac{2}{3}$ . To determine the integrated level of competition in the industry, you can also use the fuzzy value of area of the resulting pentagon by formula (13):

$$\begin{aligned} S\tilde{P} &= (R_X E_X + E_X P_X + P_X B_X + B_X S_X + S_X R_X; R_Y E_Y + E_Y P_Y + P_Y B_Y + B_Y S_Y + S_Y R_Y; \\ &R_Z E_Z + E_Z P_Z + P_Z B_Z + B_Z S_Z + S_Z R_Z) = (SP_X; SP_Y; SP_Z). \end{aligned} \tag{13}$$

Defuzzified value of area is found by formula (2). Obsessed  $def(S\tilde{P})$ .

Note that the maximum fuzzy value of the area at certain weights of 5 forces of P5F will be

$$\begin{aligned}
 \tilde{S}P^{\max} &= 6 \times (W^R W^E + W^E W^P + W^P W^B + W^B W^S + W^S W^R); \\
 &W^R W^E + W^E W^P + W^P W^B + W^B W^S + W^S W^R; \\
 W^R W^E + W^E W^P + W^P W^B + W^B W^S + W^S W^R &= (SP_X^{\max}; SP_Y^{\max}; SP_Z^{\max}), \quad (14)
 \end{aligned}$$

Let us denote its defuzzified value according to the CoA method by the formula (2):  $def(\tilde{S}P^{\max})$ . Then the ratio  $def(\tilde{S}P)/def(\tilde{S}P^{\max})$  can determine the integrated level of competition in the industry.

**Calculation scheme 2 (based on Mamdani FIS).**

To determine the level of industry competition to take into account the fuzzy assessments of experts, the Mamdani FIS can be used to the greatest extent – a fuzzy logical conclusion according to the Mamdani FIS (performed using Fuzzy Knowledge Bases – FKB), which are developed based on professional expert considerations). This scheme is implemented according to the following algorithm (Fig. 6). Note that this calculation scheme uses a superposition of two classic FIS Mamdani, which are used sequentially (the first to determine the level of competition in the industry for each of the P5F forces, the second to determine the integrated level of competition in the industry, taking into account all five forces). The choice of Mamdani FIS for our case is due to the nature of the data at the input and output of the inference system at each level of analysis.

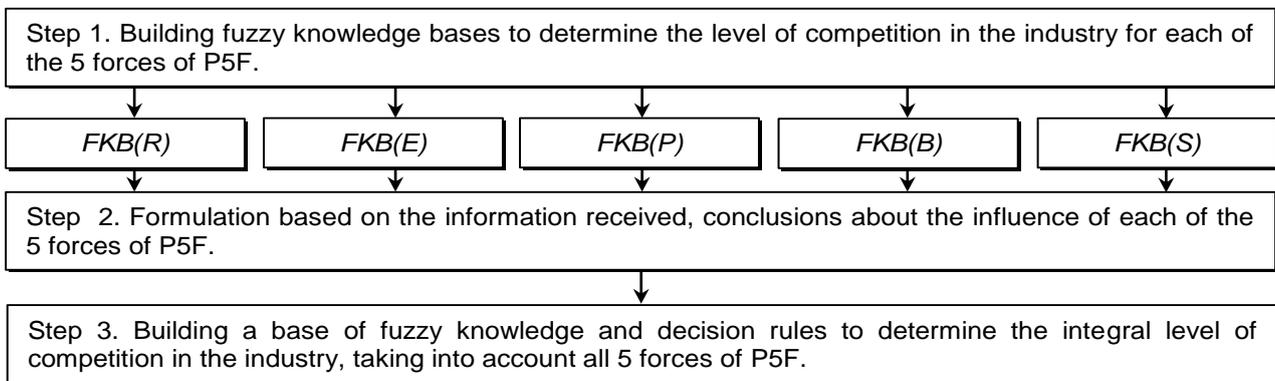


Fig. 6. Steps of applying the design model based on Mamdani FIS. Source: Authors' own.

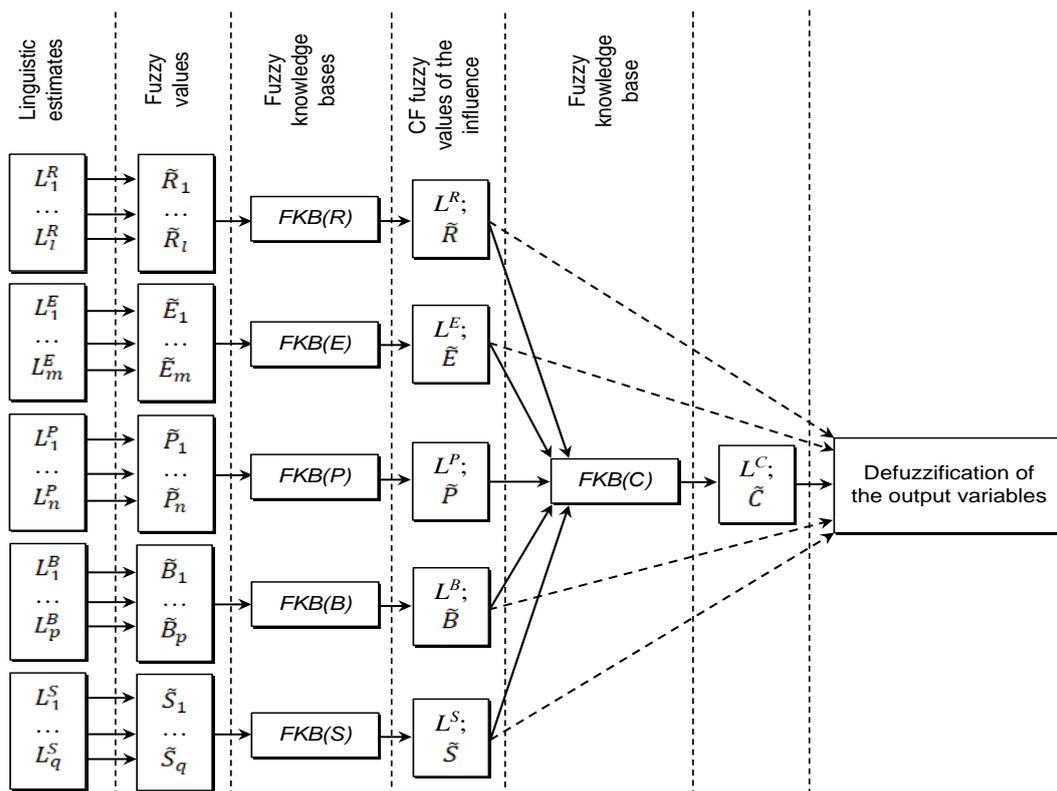


Fig. 7. The structure of the FIS. Source: Authors' own.

Step 1. The values of the input variables at the stage of determining the level of influence of competitive forces are (Fig. 7): for force *REC*:  $L_1^R, L_2^R, \dots, L_l^R$ ; for *TNE*:  $L_1^E, L_2^E, \dots, L_m^E$ ; for *PSP*:  $L_1^P, L_2^P, \dots, L_n^P$ ; for force *BPB*:  $L_1^B, L_2^B, \dots, L_p^B$ ; for force *BPS*:  $L_1^S, L_2^S, \dots, L_q^S$ . These values are transformed into fuzzy numbers with corresponding membership functions. Linguistic output variables are mentioned forces model Porter:  $L^R, L^E, L^P, L^B, L^S$  under their fuzzy. To obtain these output variables using logical operations (conjunction and disjunction), based on expert reasoning, it is possible to build fuzzy knowledge bases that are used to describe the influence of the identified factors of each of the competitive forces on the level of these forces.

Table 3 shows a fragment of the fuzzy knowledge base FKBREC to determine the level of competition in the industry by the competitive strength of REC.

**Table 3.** Fragment of the fuzzy knowledge base FKBREC to determine the level of competition in the industry by the competitive strength of REC.

№ rule	Linguistic meanings of input variables				Weights	The value of the original variable d	
	for $R_1: L_1^R$	for $R_2: L_2^R$	...	for $R_l: L_l^R$			
$r_{11}$	EL	EL	...	EL	$v_{11}^R$	$d_1^R$	EL
$r_{12}$	VL	EL	...	EL	$v_{12}^R$		
...	...	...	...	...	...		
$r_{1L_1}$	EL	EL	...	VL	$v_{1L_1}^R$	$d_2^R$	VL
$r_{21}$	VL	VL	...	VL	$v_{21}^R$		
$r_{22}$	EL	VL	...	VL	$v_{22}^R$		
...	...	...	...	...	...		
$r_{2L_2}$	VL	VL	...	L	$v_{2L_2}^R$		
...	...	...	...	...	...		
$r_{71}$	EH	H	...	EH	$v_{71}^R$	$d_7^R$	EH
$r_{72}$	H	EH	...	EH	$v_{72}^R$		
...	...	...	...	...	...		
$r_{7L_7}$	EH	EH	...	EH	$v_{7L_7}^R$		

**Source:** Authors' own

Similar fuzzy knowledge bases need to be built for other “competitive forces” of P5F. Note that the fuzzy knowledge base, for example, to determine the general level of influence of the competitive strength REC on the level of competition in the industry in a mathematical form, can be written using the production rules of fuzzy logic (Dubois and Prade, 1979) as:

$$V_{r=1}^{L_i} \left( \bigwedge_{i=1}^l R_i = d_{ji}^R \text{ with } v_{jr}^R \right) \rightarrow y^R = d_j^R \tag{15}$$

Accordingly, the decisive rule will be written as follows:

$$\begin{aligned} \mu^{d_j^R}(R_1, R_2, \dots, R_l) &= \left( v_{j1}^R \bigwedge_{q=1}^l \mu_q^{j1}(R_q) \right) \vee \left( v_{j2}^R \bigwedge_{q=1}^l \mu_q^{j2}(R_q) \right) \vee \dots \vee \left( v_{jL_j}^R \bigwedge_{q=1}^l \mu_q^{jL_j}(R_q) \right) = \\ &= V_{r=1}^{L_j} \left( v_{jr}^R \bigwedge_{q=1}^l \mu_q^{jr}(R_q) \right), \end{aligned} \tag{16}$$

where  $\bigwedge$  – fuzzy conjunction,  $\vee$  – fuzzy disjunction sign,  $\mu^{d_j^R}(R_1, R_2, \dots, R_l)$  – function of belonging of the vector of input variables to the value of the output variable  $d_j^R$ ;  $L_j$  – the number of combinations of variable values  $R_1, R_2, \dots, R_l$ , for which the original variable takes values  $d_j^R$ ;  $v_{jp}^R$  – weighting factor  $p$ -th combination ( $p = \overline{1, L_j}$ ) for the original variable  $d_j^R$ ;  $\mu_q^{jp}(R_q)$  – membership function of the input variable  $R_q$  to a fuzzy term  $d_q^{jp}$  ( $q = \overline{1, l}$ ).

Note that when constructing fuzzy knowledge bases to determine the level of competition in an industry by competitive forces, it is necessary to take into account the weight coefficients of their factors, since this affects the combinations of terms of input variables during conjunction.

Step 2. Given the importance of the impact on the level of competition in the industry of competitive forces of P5F, we can draw appropriate conclusions about the possible response of enterprises to these challenges.

Step 3. A similar procedure with the construction of a fuzzy knowledge base must be performed for the aggregation of competitive forces to determine the general level of competition in the industry.

Stage 6 involves the formulation of conclusions about the general level of competition in the industry and the preparation of appropriate proposals and strategic decisions, based on defuzzified values and the obtained information about the degree of influence of each of the 5 forces of P5F (Fig. 4, Fig. 5).

Note that for the practical application of the proposed algorithm (Fig. 1), the model was implemented as a framework in Excel, containing the following main blocks (Fig. 8).

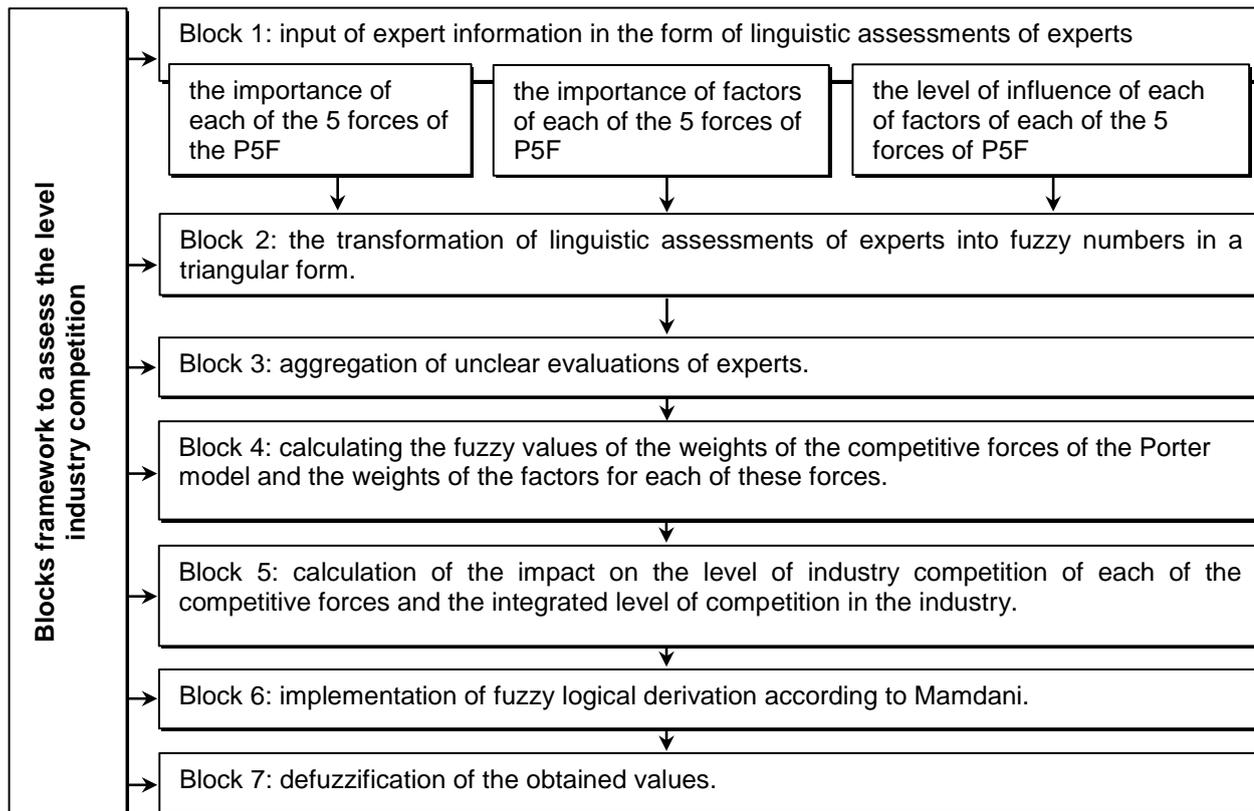


Fig. 8. The main blocks of a framework in Excel for analyzing the state of industry competition. **Source:** Authors' own.

## Discussion

Compared to the methods that use the tools of the theory of fuzzy sets (Mohammadi et al., 2011; Gavanelli et al., 2010; Gavanelli et al., 2011; Deng et al. 2015; Ulubelli, 2017; Garashchenko and Kotsyuba, 2013), this model is characterized by high flexibility, adaptability and the ability to customize by the specifics of the enterprise and industry. An important positive aspect of this model is also the possibility of verifying the obtained estimates of level of competition in the industry through the use of two calculation schemes: the main one – using the method of fuzzy additive weighting (FSAW), the auxiliary one – based on Mamdani FIS.

The use of P5F in the classical setting, according to the authors, can be improved using fuzzy modelling technologies. This is due to the nature of the information (linguistic, fuzzy, vague) that comes from experts when analyzing the factors of each of the forces that determine the competition in the industry. Further research on this topic the following areas can be distinguished: approbation of this methodology for enterprises of various industries by adapting the system of factors for each of the five forces of P5F to the characteristics of the industries under study; development and inclusion of a procedure for preliminary approval of expert opinions at the stages of assessing the importance of factors of each of the five forces of the P5F and linguistic assessments of experts on them; application of other fuzzy methods of multi-criteria analysis (in particular Fuzzy AHP) to assess the importance of the factors of each of the five forces of P5F and the development of procedures for reconciling the results obtained by the two calculation schemes; development of an expert system based on a logical-linguistic model and expert knowledge bases to determine the level of competition in the industry by using specialized applications that implement fuzzy modelling capabilities, for example, in Fuzzy Control Design Toolbox, fuzzy TECH, the Fuzzy Logic Toolbox package of the Matlab computing system, and the like; improving the methodological approach based on the application of scenario analysis to model the dynamics and change the influence of factors of each of P5F.

## Conclusion

The need to improve the existing tools of the strategic diagnosis of the environment, in particular, the analysis of the microenvironment of enterprises, due to the increasing complexity and turbulence processes that occur in most branches of national economies and the need for better integration of subjective, non-formalized, fuzzy input, opinions and expert judgments are involved in this study. Recently, a promising direction in strategic management for solving the problems of strategic analysis of an enterprise is the use of fuzzy set theory, which

expanded the capabilities of classical tools and demonstrated their effectiveness and flexibility. In this paper, we propose a hybrid approach to the strategic analysis of the state of competition in the industry based application model of five forces of Michael Porter, tools of logical-linguistic modelling tools and clearly set-theory. The authors have developed two complementary calculation schemes, the first of which is based on fuzzy multicriteria analysis using the Fuzzy SAW method, and the second on the construction of a logical-linguistic model with fuzzy expert knowledge bases and the use of fuzzy inference using the Mamdani FIS. For practical application of the proposed algorithm, the model is implemented as a framework in Excel and contains blocks in accordance with the developed algorithm. It is proposed to use column diagrams and a pentagon to illustrate the results obtained, reflecting the level of competition in the industry for each of the 5 forces of P5F, and allow calculating the fuzzy value of the integral level based on a weighted fuzzy assessment of the influence of each of these forces with subsequent defuzzification of this value. Note that, according to the authors, the developed methodological approach more efficient in structural analysis of the industry, in competitive analysis, in the strategic planning of enterprises as a basis for the development and implementation of effective competitive strategies.

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