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MANAGER COMPETENCY ASSESSMENT MODEL IN THE CONDITIONS OF INDUSTRY 4.0

Henryk Dzwigol [1], Mariola Dzwigol-Barosz [2], Radoslaw Miskiewicz [3], Aleksy Kwilinski [4*]

[1,2,3]Silesian University of Technology, 26 Roosevelta Street, Zabrze, 41-800, Poland
[4]The London Academy of Science and Business, 3rd Floor, 120, Baker Street, London, W1U 6TU, England*

E-mail: [4] koaduep@gmail.com (Corresponding author)*

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Abstract. The approaches to modeling competencies have been explored in the article and a model of a strategically oriented approach to the development of management competencies of the company "Industry 4.0" has been built. An algorithmic "fuzzy logic" model to assess the input managers' competencies and obtain a final assessment as a parameter for achieving strategic goals has been formed. A methodology for using the "fuzzy logic" toolkit to assess managers' competencies in obtaining the pair impact assessment, which forms a new level of the comprehensive assessment of managers' work, has been developed.

Keywords: Industry 4.0, competencies; "fuzzy logic" model; input and output parameters of the model; strategically oriented approach; membership function

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JEL Classification: M21, O16

1. Introduction

The modern global economy exists in conditions of increasing competition, powerful economic crises, and the daily aging of technology and knowledge, therefore success is achieved by those companies in which the key factor among all resources is the human factor, especially management personnel (management). The post-industrial stage of the development of world society (Industry 4.0) contributes to changes in the existing traditional technologies of personnel management to more adaptive and organic, which, accordingly, requires the continuous development of managers at all levels of the hierarchy (Meissner et. al., 2017). Therefore, the development of a managerial competencies model in the knowledge economy is an important theoretical and practical task. The above circumstances testify to the need for a search of various mechanisms and models for the development of managerial personnel, the involvement of a fuzzy logic model, which determines the actual nature, scientific and practical interest of the topic of the article.

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2. Literature Survey

In modern companies operating in the conditions of Industry 4.0, managers' competency models play an important role in personnel policy. As noted by the scientists (Bucker and Poutsma (2010), Makedon et. al. (2019), Mathis & Jackson (2003), Zoni et. al. (2012), competencies are primarily used as an assessment tool, allowing company owners to evaluate work performance and "analyze, not only what management has achieved over the past period but also how it was done" (Schwab (2016), Tessier & Otley (2012). Moreover, management features leave an imprint on the requirements for the managers' competency profile. To maintain the competitiveness of activities in the market, the company needs to develop managerial personal with limited resources in a short period of time.

3. Methods

In the methodological field of our research, the following ideological and scientific-methodological directions are distinguished. 1) A scientific and methodological approach to a differentiation of types of managerial competencies, where the assessment of the effectiveness of introducing a competency model is assessed in the sense of: a) knowledge competencies, which are characterized by a practical or theoretical understanding of the nature of the managerial work; b) competencies of skills and abilities based on the ability of the manager to carry out managerial actions to carry out strategic tasks taking into account the interests of the company (Carnall (2007), Mabin, Forgeson and Green (2001); Bernardi, (2019); 2) Methodology of key competencies. In the framework of its use, three main types of competencies are distinguished: key, technical, and managerial: a) key competencies are knowledge, skills, and personality traits; b) technical competencies are inherent in professional areas/roles; c) management competencies (Ferreira & Otley (2009), Dzwigol et.al. (2018, 2019)). 3) Methodology for assessing managerial work on the basis of fuzzy logic, where the contact areas of qualitative assessment are distinguished: a) development level – the possession of the general theoretical and practical knowledge of the profession, the ability to solve complex problems, and the ability to work independently under minimal supervision; b) advantage level - knowledge of the trends of the profession, ongoing research, legislative framework used by the manager to develop its own strategies, standards, and processes, completely independent performance of the work (Afshari et. al. (2014), Chang et. al. (2000), Drobyazko et. al. (2019a,b), Rezk et al. (2019)).

4. Results

We propose to distinguish three approaches to the development of the company management competencies: 1) The resource approach considers management competence (knowledge, skills, abilities) as a source of the company's competitive advantage; 2) The purpose of the behavioral approach to the development of managers is to create the necessary conditions for the realization of their creative abilities, to build knowledge, and develop skills in the process of functioning of the company; 3) A strategic approach to management development is to ensure a sustainable competitive advantage of the company, by increasing the competitiveness of management and ensuring the guarantee of its professional growth and development for the long term. Based on the selected approaches, a strategically competent approach to the development of management competencies is offered, which contributes to: a) the achievement of competitive advantages for managers; b) planning and organizing the development of knowledge, skills, and abilities in accordance with the level of management and the corresponding company strategy (Dechow et. al. (2007), Draganidis, Mentzas (2006), Kwak et al. (2003); Tvaronavičienė (2018)). The level model of using the strategic competency-based approach in the company's management mechanism is presented in Figure 1.

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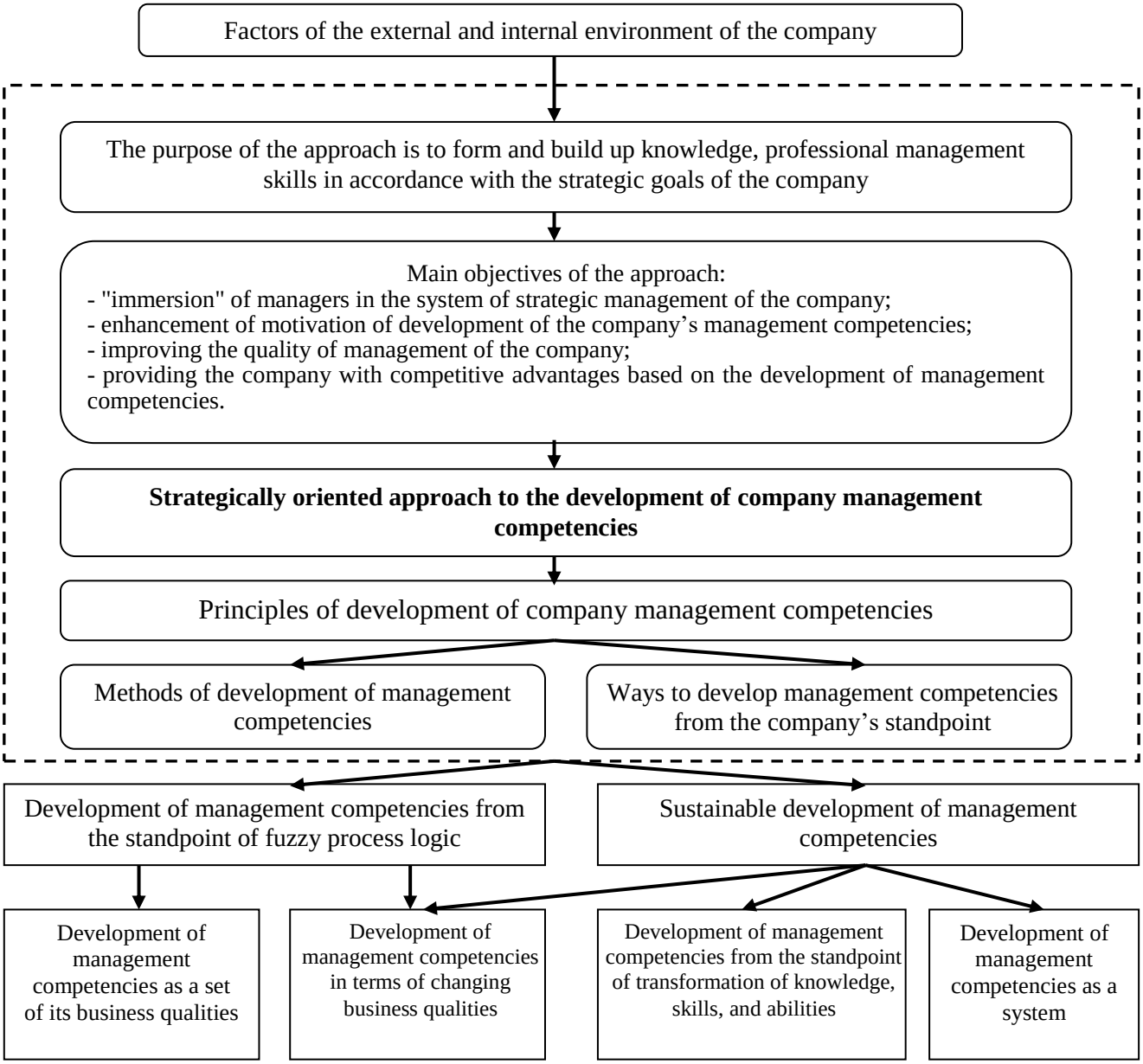

Figure 1. A level model of a strategically oriented approach to the development of company management competencies
Source: the authors

Speaking about the competency-based approach to the development of managers, the principles of choosing competencies and designing models should be highlighted. Competencies should be: comprehensive, cover the functional responsibilities of a particular position; discrete, characterize a separate type of activity, distinguishing it from others; focused, that is, clearly defined; understandable; congruent (compatible), forming within the framework of the organizational culture and strengthening it in accordance with the company's strategy; relevant, that is, updated in a timely manner, reflecting the current and future needs of the company (Lin (2010), Snell, Morris and Bohlander (2016), Vakola, Tsaousis & Nikolaou (2004), Dźwigoł-Barosz, Wolniak (2018)). The basic groups for assessing the competencies of managers who are most in demand on the part of Industry 4.0 companies are defied and presented in Table 1.

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Table 1. The basic model of competencies of company management in the conditions of Industry 4.0

Competency group	Description of competencies
X1. Experience and term of work	*Characteristics:* - special knowledge and skills acquired in the course of labor activity; - functional accuracy and experience; - management of personal learning and development; *Assessment options:* - 0-10 years; - 10-20 years; - more than 20 years.
X2. Education, cognitive and creativity potential	*Characteristics:* - basic education, second education, academic degree; - professionalism, entrepreneurial abilities; - effective time management. *Assessment options:* - Bachelor (basic education) - Master/MBA degree; - Doctor of Philosophy (PhD).
X3. Effective goal setting and development	*Characteristics:* - development of planning and goal setting skills; - organization of the activity process in accordance with the functions of management; - ability to make decisions; - ability to effectively delegate authority. *Assessment options:* - achievement of goals within six months; - achievement of goals within one year; - achievement of goals in more than a year.
X4. Communicative, leadership function and managerial orthobiosis	*Characteristics:* - communications and interpersonal and group communication skills; - ability to resist manipulation; - ability to respond constructively to criticism. - a healthy, reasonable lifestyle; - corporate culture of the organization of the work process, workloads, and leisure. *Assessment options:* - the number of direct communications up to 7 points; - the number of direct communications from 7 to 14 points; - the number of direct communications is more than 14 points.

Source: the authors

The basic model of managers' competencies can be for a company that operates under the conditions of Industry 4.0: the model of good practice, based on which the company and management will be able to increase their productivity and work efficiency; the standard, the goal of improving management, which will allow the company to clearly formulate requirements for managers; the template, in relation to which the company can evaluate the existing management, form programs for its development, and carry out improvements.

Possibilities of using "fuzzy logic" tools in company management

The presence of simultaneously different types of uncertainty in a complex multilevel hierarchical management system of a company makes it necessary to use the fuzzy sets theory for decision making, which allows adequately taking into account the existing types of uncertainty. Such an approach allows bringing together all available heterogeneous information: deterministic, statistical, linguistic, and interval regarding the formation and

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development of management competencies (Granlund & Mouritsen (2003)). With the most abstract approach to the system, the criterion for the functioning of such a management competency analysis system, in the language of the theory of fuzzy sets, can be represented in the form of maximizing the degree of admissibility and effectiveness of decisions made. Therefore, a subset of admissible and effective values of the parameter x is chosen as a subset (Zongmin et. al. (2017); Kwilinski (2018, 2019)). The subset of effective values of the parameter x is fuzzy for real systems since it cannot be said that only one value, for example $x^2 = 4$, is effective, and all other values of x are ineffective (Figure 2), i.e. $\mu_A(4)=1$, $\mu_A(x)=0$ для $x \neq 4$.

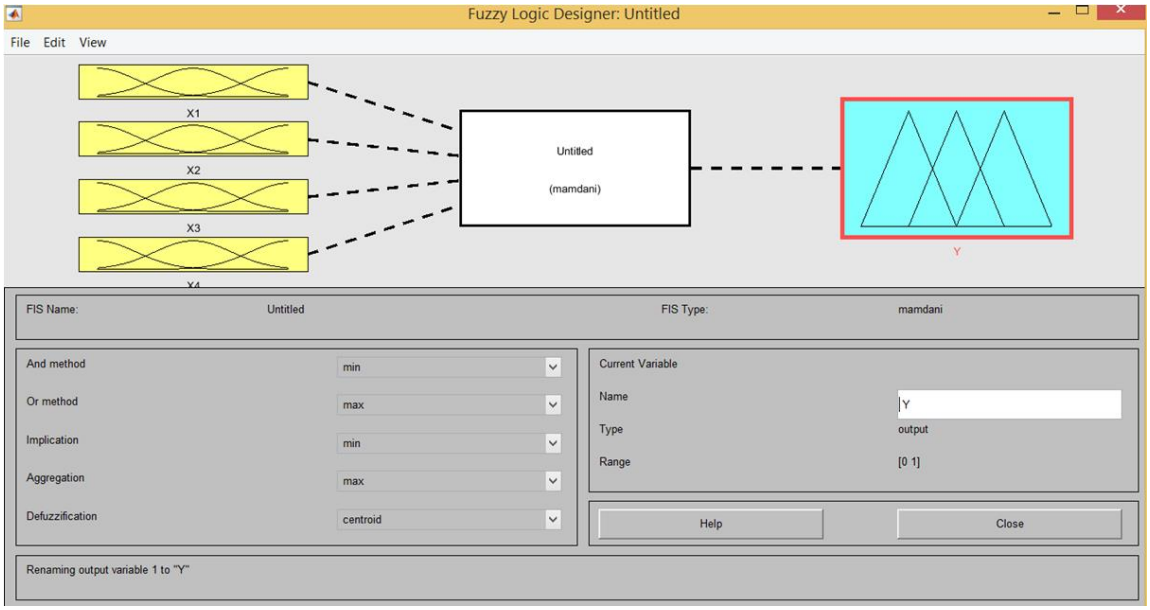

Figure 2. Algorithmic view of the "fuzzy logic" model

In reality, there is no such a boundary since an insignificant change in x leads only to a small change in $\mu_A(x)$, therefore, membership functions of the form are more consistent with reality. Thus, the use of an expression of the form "should be close to x^2", which is not a precisely formulated goal, can be modeled by a fuzzy subset with a membership function. A fuzzy goal means a goal that can be described as a fuzzy set in the corresponding space. Thus, the value X is a given set of alternatives. Then, the fuzzy goal, or simply the goal, G will be determined by a fixed fuzzy set G in X. In the usual approach, the preference function that is used in the process of determining competencies serves to establish linear ordering on the set of alternatives (Dursun, Karsak (2010) Jana et. al. (2017)). Obviously, the membership function $\mu_G(x)$ of the fuzzy goal performs the same task and can be obtained from the advantage function using normalization, which preserves the established linear ordering.

Similarly, a fuzzy constraint or simply a constraint C in the space X is defined as some fuzzy set in X. An important point here is that both the goal and the constraints are treated as fuzzy sets in the space of alternatives; this makes it possible not to distinguish between them when forming a solution. A solution is essentially the choice of one or more of the existing competencies. The decision-making problem in fuzzy conditions is interpreted as the complex effect of the fuzzy goal G and fuzzy restriction C on the choice of alternatives and it is characterized by the intersection $G \times C$, which forms a fuzzy set of alternatives for the choice of management competencies D, i.e. $D = G \times C$ (Gungor et. al. (2009)).

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The membership function for the set of solutions is defined by the relation:

$$\mu_D(x) = \mu_G(x) \wedge \mu_C(x) \tag{1}$$

In the more general case, if there are n goals and m constraints, then the resulting solution is determined by the intersection of all given goals and constraints, ie:

$$D = G_1 \cap ... \cap G_n \cap C_1 \cap ... \cap C_m \tag{2}$$

and accordingly,

$$\mu_D = \mu_{G1} \wedge ... \wedge \mu_{Gn} \wedge \mu_{C1} \wedge ... \wedge \mu_{Cm} \tag{3}$$

In the above definition, fuzzy goals and restrictions enter the expression for *D* in exactly the same way. Such a definition of a solution as a fuzzy set in the space of alternatives may seem somewhat artificial. In fact, it is quite natural, since a fuzzy solution can be considered as some kind of "instruction", the fuzziness of which is a consequence of the inaccurate formulation of goals set and restrictions in the ranking and allocation of competencies of company managers (Thompson & Martin (2010)).

In many cases, it is still reasonable to choose those alternatives that have the maximum degree of belonging to the set *D*. If there are several such elements, then they form the usual set, which is called the optimal solution, and each element of this set maximizes the solution (Varmazyar, Nouri (2014); Czyżewski et. al. (2019)). The more general case when the goals and restrictions are fuzzy sets in different spaces is of practical interest. Let's the mapping be from *X* to *Y*, with the variable *x* denoting the "input" effect and *y* the corresponding "output". Let's suppose that the purpose of competency choice is given as a fuzzy set *G* in *Y*, while a restriction is a fuzzy set *C* in the space *X*. Having a fuzzy set *G* in *Y*, one can find a fuzzy set *G* in *X*, which induces *G* in *Y*. Membership function $\bar{G}$ in *Y* is given by the equation:

$$\mu_{\bar{G}}(x) = \mu_G(f(x)) \tag{4}$$

After this solution, D can be expressed by the section of the sets *G* and *C*. Using the preliminary relation, one can write:

$$\mu_D(x) = \mu_G(f(x)) \wedge \mu_C(x) \tag{5}$$

Thus, the case when goals and restrictions in the question of choosing competencies are set as fuzzy sets in different spaces can be reduced to the case when they are set in the same space (Tzuu-Hseng et. al. (2008)). In addition, the basic concepts are the fuzzy concepts "growth of the level of competencies" and "decrease in the level of competencies", and the relationship between them is presented in the form of a compositional inference rule:

$$f\_U\_then\_E \tag{6}$$

where Ũ and Ẽ are fuzzy concepts that are judgments about the competence of the manager for consideration, respectively. The membership function corresponds to a fuzzy conditional operator *S*, where a fuzzy subset *U* is defined on the judgment area *X*, a fuzzy subset *E* in the area *Y*:

$$\mu_S(y,x) = \min\left[\mu_U(x), \mu_E(y)\right], x \in X; y \in Y \tag{7}$$

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The complex system of behavior is described by a set of fuzzy instructions using "or" operations:

$$f\_U_1\_then\_E_1\_or\_U_2\_then\_E_2 \tag{8}$$

with membership function:

$$\mu_S(y,x) = \max\left\{\min\left[\mu_{U1}(x), \mu_{E1}(y)\right]; \min\left[\mu_{U2}(x), \mu_{E2}(y)\right]\right\} \tag{9}$$

In this form, the strategy for choosing managers' competencies for a company operating in the conditions of Industry 4.0 may be an expression of a fuzzy operator. The basis for deciding on competencies $\tilde{E}$ with a known input $\tilde{U}$ and a given relation between fuzzy sets is the Zadeh's compositional rule:

$$\mu_E(y) = \max_x \min\left[\mu_U(x), \mu_S(y,x)\right] \tag{10}$$

When controlling a specific process, the input can also be point (clear) x_0. In this case, the compositional rule of output is simplified since the input x_0 can be interpreted as a fuzzy input $\tilde{U}$ with membership function $\mu_U(x)$, which is everywhere equal to zero, except for the measuring point x_0 where it is equal to unity:

$$\mu_E(y) = \mu_S(y, x_0) \tag{11}$$

To make a clear decision on the competencies of managers, it is necessary to choose a control y_0 that maximizes the resulting membership function:

$$\mu_E(y_0) = \max_y \max_x \min\left[\mu_U(x), \mu_S(y,x)\right] \tag{12}$$

Let's give a description of the principles of construction and operation of a fuzzy control model for the simplest process (one "input" - one "output"), in which each instruction *"i"* associates the fuzzy concept of assessment of the quality of competence *"p"* with the fuzzy concept of achievement of the strategic goals of the company *"q"* from their membership function:

$$\mu_i(p) \Rightarrow \gamma_i(q), i = \overline{1,n} \tag{13}$$

For the case (13), a clear value for the achievement of strategic goals q_o can be found using the following algorithm with an unchanged set of competencies "p_0":

1. For each instruction *"i"*, the degrees of assessment of the quality of competencies of managers are determined:

$$\mu_1(p_0), \mu_2(p_0) \ldots \mu_n(p_0) \tag{14}$$

2. Membership functions that define the fuzzy concept of achieving strategic goals for each instruction are found:

$$\beta_i(q) = \min\left[\mu_i(p_o), \gamma_i(q)\right], i = \overline{1,n} \tag{15}$$

and then the complete fuzzy concept of strategic goals:

$$\beta(q) = \max_i \min\left[\mu_i(p_o), \gamma_i(q)\right] \tag{16}$$

3. A clear control impact q_o is calculated, which ensures the maximum membership function $\beta(q)$:

$$\beta(q) = \max_q \max_i \min\left[\mu_i(p_o), \gamma_i(q)\right] \tag{17}$$

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The initial construction of membership functions can be performed using exponential functions with their subsequent adaptation according to the quality criterion for choosing managers' competencies using the fuzzy logic model used. For control, it is possible to build several types of models that differ in the type of information used: only deviations from a given value, deviations and the value of its first derivative, and the like are measured. A specific type of algorithm is selected for each case, based on an analysis of the various strategic goals that are put before the management.

5. Practice of applying the "fuzzy logic" technique to assess the competencies of managers in the conditions of Industry 4.0

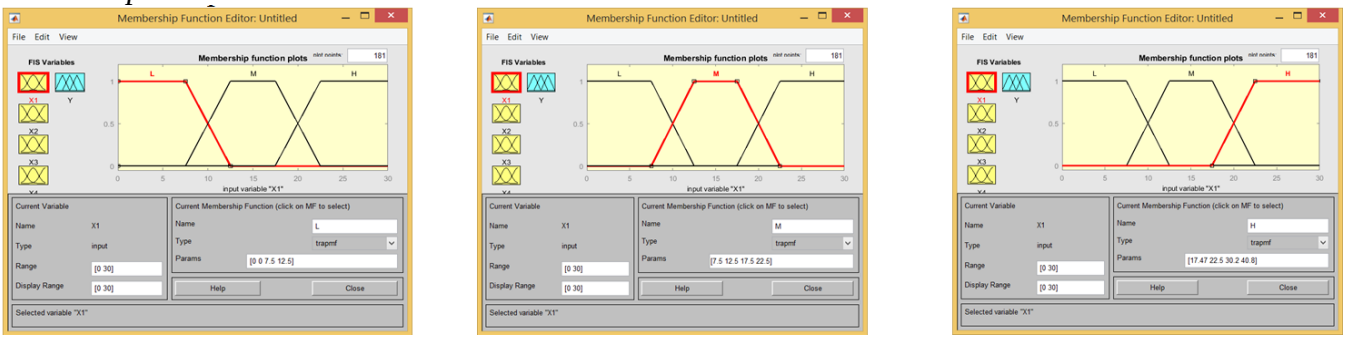
In general, the fuzzy logical inference mechanism should include four steps: 1) phasification (introduction of fuzziness); 2) fuzzy conclusion; 3) composition; 4) dephasification (bringing to clarity). Interpretation of the fuzzy model involves selecting and specifying the input and output variables of the corresponding fuzzy output system (Regina (2012), Shipley & Johnson (2009), Sutton, Watson (2013)). Managers' competencies will be assessed using the Fuzzy Interference System (FIS) framework, which is the basic concept of the MATLAB software package's Fuzzy Logic Toolbox module. Using the data in Table 1, a rule base for determining the output variable for assessing the managers' competencies is formulated. The model "*X*" is the competency designation/input variables, the output variable "Y" is "achievement of the strategic goals of the company".

Table 2. Fuzzy rule base for determining the input variable of competencies of managers

Input variables	Values of the terms of the input variables		
	Low level (L)	Middle level (M)	High level (H)
X1. Experience and term of work	0-10 years	10-20 years	More than 20 years
X2. Education, cognitive, and creative potential	Bachelor's Degree (Basic education)	Master / MBA degree	Doctor of Philosophy (PhD)
X3. Effective goal setting and development	achievement of goals for more than a year	achievement of goals within one year	achievement of goals in a period up to six months
X4. Communicative, leadership function and managerial orthobiosis	number of direct communications more than 14 points	number of direct communications from 7 to 14 points	number of direct communications up to 7 points

Appendix 1 provides assessments of the logical rules for assessing managers' competencies. A choice in favor of trapezoidal accessory functions was made. A demonstration of the "fuzzy logic" technique is presented in Figure 3.

For the input variable X1:



For the input variable X2:

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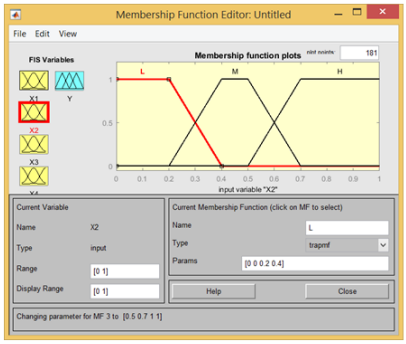
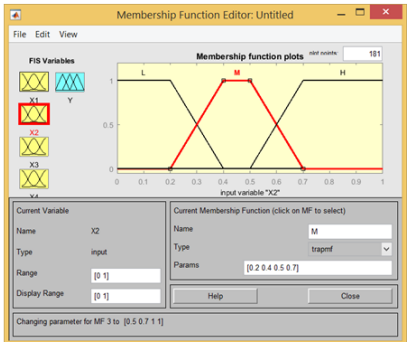
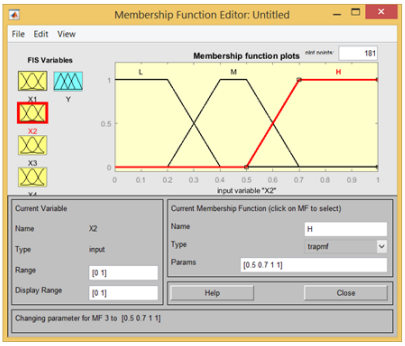
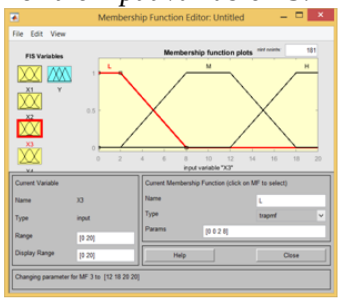
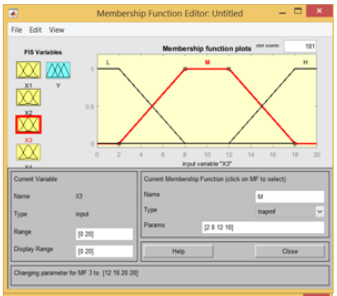


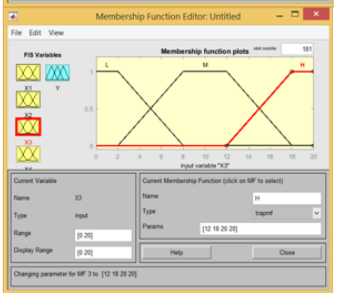




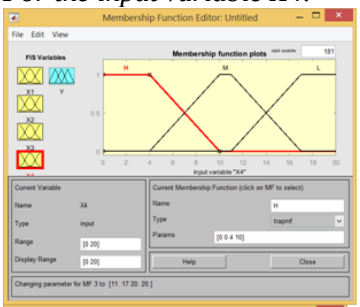
For the input variable X3:

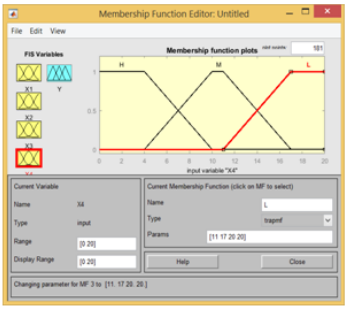


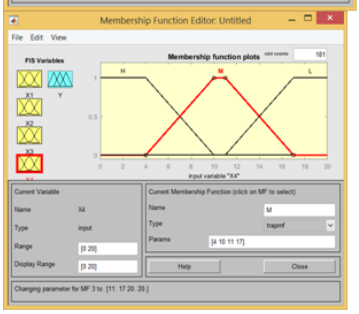




For the input variable X4:







For the output value Y:

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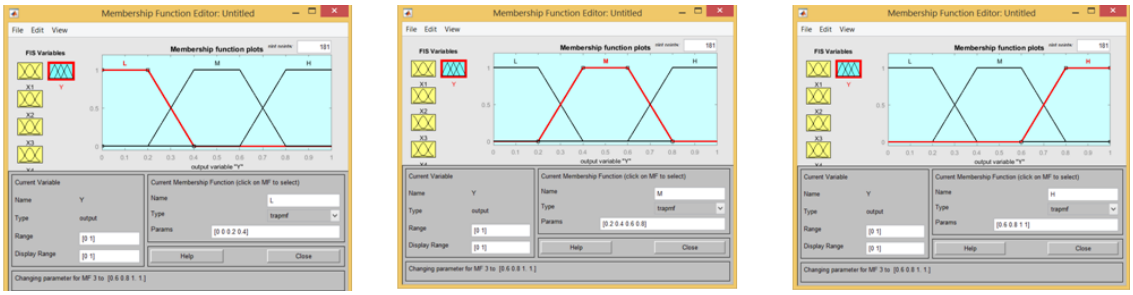

Figure 3. Membership function graphs for input linguistic variables (manager competencies) X1 - "experience and term of work", X2 - "education, cognitive and creative potential", X3 - "effective goal setting and development", X4 - "communicative, leadership function and managerial orthobiosis »

The constructed model of fuzzy inference allows setting values for the input variables *X1, X2, X3, X4* that correspond to the competencies from the table 2 and evaluate the parameter *Y* - "level of achievement of the strategic goals of the company". The "fuzzy logic" visualization is presented in Figure 4.

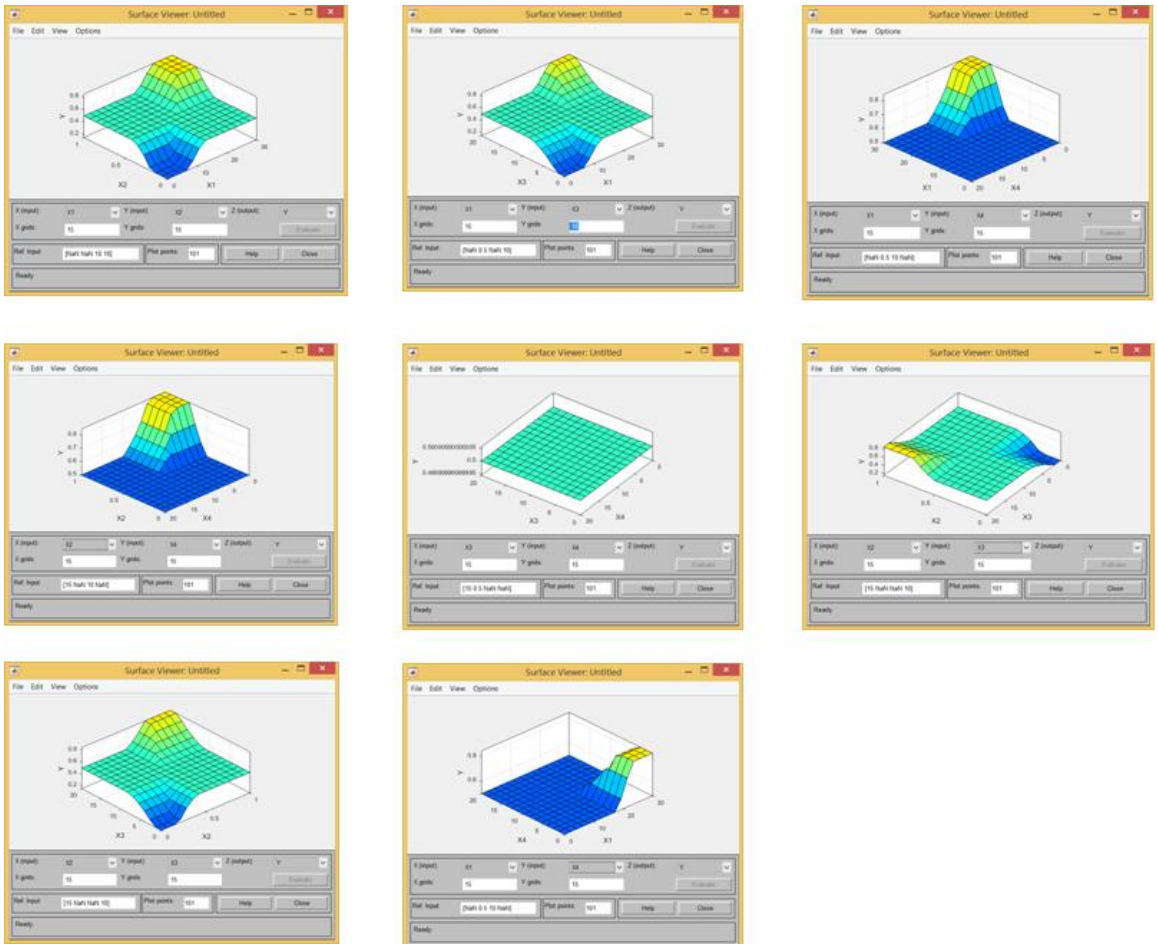

Figure 4. The surfaces of the fuzzy inference of the output value "the level of achievement of strategic goals of the company" from the input variables X1 - "experience and term of work", X2 - "education, cognitive and creative potential", X3 - "effective goal setting and development", X4 - "communicative, leadership function and managerial orthobiosis"

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Thus, the fuzzy set method allows determining the dependence of the risk level of corporate mergers and acquisitions on the probability of failure of transactions, exceeding transaction costs and exceeding the terms of the transaction. The response surface in Figure 2 is constructed taking into account logical rules, phasification of input variables, and dephasification of the output variable.

6. Discussion

Further research can be conducted into the study of complex paired combinations of managerial competencies at the level of organizations and companies. In the course of this, an analysis of the hierarchy of management, consideration of functional links between organizational units, familiarization with the charter, staffing schedule, and distribution of duties of managers of the company based on the competencies and challenges of Industry 4.0 will be developed. As well, the system of promotion of positions and managers of the company, the component of which is the competency assessment system, will be improved.

Improving the "fuzzy logic" assessment method will allow the company to obtain objective and comprehensive information about the potential of managers. Managers at different levels of management will feel more confident in their positions. Thus, the proposed assessment method will improve the quality and accuracy of the organizational decisions made.

Conclusions

In the course of the research, the author reflected the main methodological approaches and evaluation tools for determining the effectiveness of the company's management. During the research principles and basic approaches to forming of competences of managers have been studied. Based on the resource, behavioral, and strategic approaches in the development of competencies, a model of a strategic-oriented approach to the development of competencies of managers of Industry 4.0 has been built. A methodology for using the "fuzzy logic" toolkit to assess managers' competencies has been developed.

The surface fuzzy inference of the output value "level of achievement of strategic goals of the company" from the input variables "experience and term of work", "education, cognitive and creative potential", "effective goal setting and development", and “communicative, leadership function, and management orthobiosis” have been built in application software packages.

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Appendix 1. Linguistic rules for assessing the competencies of managers

№	X1	X2	X3	X4	Y
1.	L	L	L	L	L
2.	L	L	L	M	L
3.	L	L	L	H	L
4.	L	L	M	L	L
5.	L	L	M	M	L
6.	L	L	M	H	L
7.	L	L	H	L	L
8.	L	L	H	M	L
9.	L	L	H	H	L
10.	L	M	L	L	L
11.	L	M	L	M	L
12.	L	M	L	H	L
13.	L	M	M	L	M
14.	L	M	M	M	M
15.	L	M	M	H	M
16.	L	M	H	L	M
17.	L	M	H	M	M
18.	L	M	H	H	M
19.	L	H	L	L	L
20.	L	H	L	M	L
21.	L	H	L	H	L
22.	L	H	M	L	M
23.	L	H	M	M	M
24.	L	H	M	H	M
25.	L	H	H	L	M
26.	L	H	H	M	H
27.	L	H	H	H	H
28.	M	L	L	L	L
29.	M	L	L	M	L
30.	M	L	L	H	L
31.	M	L	M	L	M
32.	M	L	M	M	M
33.	M	L	M	H	M
34.	M	L	H	L	M
35.	M	L	H	M	M
36.	M	L	H	H	M
37.	M	M	L	L	M
38.	M	M	L	M	M
39.	M	M	L	H	M
40.	M	M	M	L	M
41.	M	M	M	M	M
42.	M	M	M	H	M
43.	M	M	H	L	M
44.	M	M	H	M	M
45.	M	M	H	H	M
46.	M	H	L	L	L
47.	M	H	L	M	M
48.	M	H	L	H	M
49.	M	H	M	L	M
50.	M	H	M	M	M
51.	M	H	M	H	H
52.	M	H	H	L	M
53.	M	H	H	M	H
54.	M	H	H	H	H
55.	H	L	L	L	L
56.	H	L	L	M	L
57.	H	L	L	H	L
58.	H	L	M	L	M
59.	H	L	M	M	M
60.	H	L	M	H	M
61.	H	L	H	L	M
62.	H	L	H	M	M
63.	H	L	H	H	H
64.	H	M	L	L	L
65.	H	M	L	M	M
66.	H	M	L	H	M
67.	H	M	M	L	M
68.	H	M	M	M	M
69.	H	M	M	H	H

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70.	H	M	H	L	M
71.	H	M	H	M	H
72.	H	M	H	H	H
73.	H	H	L	L	H
74.	H	H	L	M	H
75.	H	H	L	H	H
76.	H	H	M	L	H
77.	H	H	M	M	H
78.	H	H	M	H	H
79.	H	H	H	L	H
80.	H	H	H	M	H
81.	H	H	H	H	H

Henryk DZWIGOL, Ph.D., Habilitated Doctor in Economics, Faculty of Organization and Management, Silesian University of Technology
ORCID ID: orcid.org/0000-0002-2005-0078

Mariola DZWIGOL-BAROSZ, Ph.D., Habilitated Doctor in Economics, Faculty of Organization and Management, Silesian University of Technology
ORCID ID: orcid.org/0000-0002-5306-3836

Radosław MISKIEWICZ, Ph.D., Habilitated Doctor in Economics, Faculty of Organization and Management, Silesian University of Technology
ORCID ID: orcid.org/0000-0003-2370-4783

Aleksy KWILINSKI, Ph.D., Habilitated Doctor in Economics, The London Academy of Science and Business, London, England
ORCID ID: orcid.org/0000-0001-6318-4001