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Competencies assessment using fuzzy logic

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Abstract:
Research Question (RQ): Competencies evaluation is complex. The question is how to evaluate a competency which was assessed with 360° feedback, in one result using fuzzy logic tools so the result represents an actual competency development in an individual.
Purpose: The purpose and goal of the study is to determine a possible process of competency evaluation that would enable creating a single competency assessment using fuzzy logic methods.
Method: The theoretical part examines the current state and terminology of competencies and fuzzy logic. The empirical part consists of a quantitative research study. Data from the survey questionnaire was used for model testing.
Results: An example of an »Initiative« competency evaluation model is created and tested in the research study. Testing confirmed that evaluation using fuzzy logic is efficient.
Organization: The study directly affects the development of the HR function in organizations. It enables an easier and more oriented competency evaluation.
Society: The study enables easier orientation in competencies development that can improve the social order as well as social responsibility and the environment indirectly.
Originality: The study presents a new competency evaluation model using fuzzy logic.
Limitations/Future Research: The study is restricted to one competency and certain assessors. Further research could explore the model with several assessors of the same rank.

Keywords: competency, competencies, assessment, evaluation, fuzzy logic.

1 Introduction

Competencies have been a modern form of systematic approach to understanding skills, knowledge and personal traits for some time now, but competency measurements, assessments and evaluations are still relatively poorly developed. There are many reasons for this. The focus of the study is on the mechanistic approach to competency evaluation with a direct influence on assessment results. Our presumption is that fuzzy logic methods that are close to handling immeasurable variables present an efficient approach to competency evaluation.

The aim of the article is to illustrate how to effectively evaluate competencies using fuzzy logic methods.

The study is important as it presents the current situation and forms new basis for further detailed research in competency evaluation that affect employee management in organizations.

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2 Theoretical framework

2.1 Competencies

The term 'competencies' is used in many scientific disciplines. There are many published theories that deal specifically with competencies and, as a result, there is not only one theoretical definition and classification but several understandings and definitions of the term.

In the study, one's competencies translate as activation, use and connectedness of skills, competences, motives, self-image and values that enable an individual to successfully perform roles, tasks and solve problems in an organization and society, in complex and unpredictable situations. A competency is not just the ability to use (practical) knowledge (Bramming & Holt Larsen, 2000, p. 68) or specific knowledge: knowledge on the use of knowledge (Svetlik & Pavlin, 2004, p. 203; Colarič Jakše & Ambrož, 2015, p. 233) - it is more than that. It is a whole of the ability (competences, knowledge and motivation) of self-image and values that one can and will successfully use in the context and environment of a given situation. When a whole of abilities, self-image and values of an individual is placed in a social and physical environment in which an individual has a certain role or task, then an individual is competent or incompetent. Adopted standards of the environment and requirements of a given situation (social and relational conditionality) are crucial in determining one's competency. It depends on the environment whether one's performance in a certain environment and context is accepted as competent. Competency gives one a chance to adapt to the environment with one's behavior. Several authors (Blank, 2001, pp. 28-29; Burgoyne & Stuart, 1976, p. 23; Sanghi, 2007, p. 16; Spencer & Spencer, 1993, p. 11; Yukl, 2010; p. 18) believe that many competencies can be acquired and developed. For that reason, exploring and managing competencies is important for all organizations as it directly affects the culture and success of an organization.

The importance of competencies is emphasized in the ISO 9000 international family standards (CEN, 2015) and all models of national and transnational performance excellence awards: EFQM, Deming prize, Malcolm Baldrige Award and others (Conti, 2007).

The term »competencies« has various interpretations (Jevšček & Gorenc, 2015, pp. 58-60). In contemporary social science, the term was founded by David McClelland (McClelland, 1973) who studied approaches to testing of individuals and proved that one's success is not dependent on one's intelligence but on one's competencies which are expressed in one's behavior. McClelland did not specifically define the term in his study, however, he did make a distinction between »traditional competencies«: reading, writing, arithmetic and the likes, and »other competencies« that include what are commonly known as personality traits: communication, patience, goal-setting, etc.

McClelland's studies have become a successful business model. In 20 years of research and practice, McClelland's successors Lyle and Signe Spencer (Spencer & Spencer, 1993, p. 20) have gathered data from 286 competency profiles, which included 760 types of behavior and 360 of which were used to form 21 competencies to account for 80 – 98 % types of behaviors recorded in the competency models. They elaborately described these 21 competencies and set criteria and scales for their identification and evaluation. This study deals specifically with the »Initiative« competency.

2.2 Competency assessment

The term "competencies" is widely discussed, explained and used. The same goes for evaluation of competencies which does not have a coherent theory impute. Undoubtedly, competency evaluation is a very hot topic in management of competencies. It raises a pragmatic question, namely how to successfully and effectively approach evaluation of different competencies in practice.

When it comes to competency development assessment, there is no general or reference method and scale, nor a single unit of measurement for competency development. There are several different approaches and scales but they are all specific to areas, organizations or time frames.

Lyle and Signe Spencer (Spencer & Spencer, 1993, p. 8) linked their model with focus interviews that were carried out by professionals. For this reason, this method is expensive and time consuming.

360° feedback is a widespread approach to competency development assessment that reduces high assessment relativity of assessors. According to this method, one's competencies are assessed from different points of view. One's competencies are assessed by assessors in different relations to the assessee. Usually, the assessors are: immediate superior, close co-workers, subordinates, sometimes buyers, suppliers and other interested clients. Also, the assessee performs a self-assessment (Gruban, 2005, p. 22; Hattie & Timperley, 2007, p. 102).

Hensel, Meijers, Van der Leeden and Kessels (2010, pp. 2813–2830) studied how the number of assessors influences the reliability of the assessment. They came to a conclusion that the higher the number of assessors, the highest the reliability of assessment.

This type of assessment improves the objectivity of assessment and decreases assessment errors as an assessment by one person only is incomplete or biased (Gruban, 2005, p. 23).

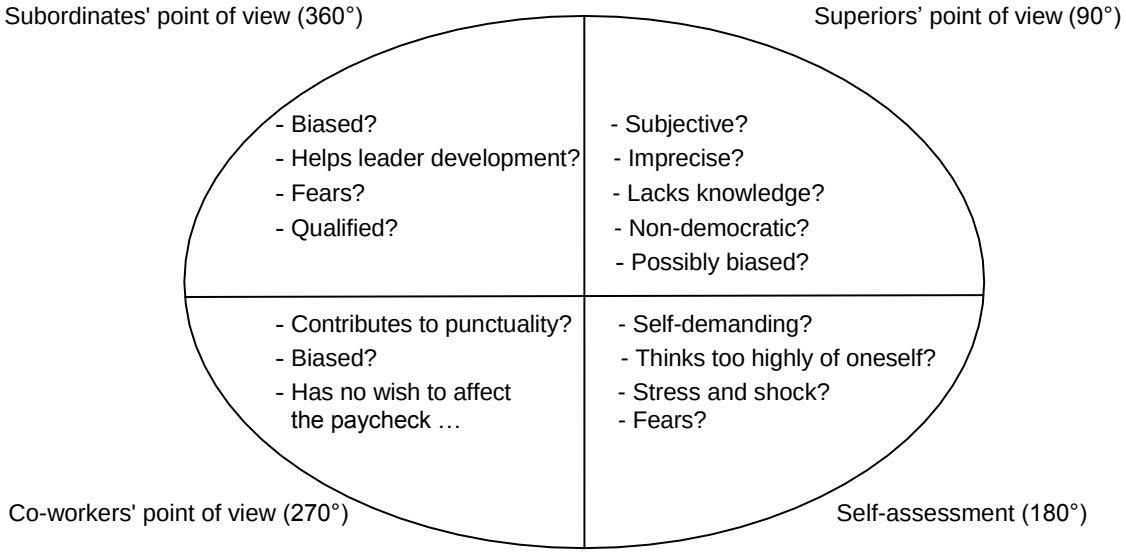

Figure 1. 360° feedback. Adapted from *Sebe razkrivamo skozi druge - metode povratne informacije 360°* (p. 23) from B. Gruban, 2005, Human resource management magazine, 3(10), pp. 22–27.

The 360° feedback does not specify a more detailed methodology for creating a synthetic competency assessment of the assessee as the implementation of the method largely depends on the manner of structuring, description and evaluation of competencies. For the purpose of this study, a model for creating a synthetic competency assessment using fuzzy logic was formed.

2.3 Fuzzy logic

Fuzzy logic is an innovative concept that enables systematic phenomena descriptions and modelling by using everyday linguistic expressions. The concept is fundamentally simple but it represents a radical intervention in mathematical theory. By using fuzzy logic, expressions such as »easy«, »high«, »average«, »above-average« and the likes, are connected in mathematical models that enable computer data processing and evaluation (Inform, 2001, p. 114; MathWorks, 2014, pp. 1-4). The concept was introduced by L. Zadeh, professor at University of California, Berkeley in 1965 (Zadeh, 1965, pp. 338-353).

Fuzzy logic is based on fuzzy sets. A fuzzy set is a set of elements with different grades of membership. A grade of membership is determined with a membership function. A fuzzy set differs from a crisp set. Namely elements of a fuzzy set have a grade of membership on the interval [0,1] which is presented with a membership function (Ross, 2010, p. 15). The idea of a fuzzy set logic is to blur the sharp boundaries between sets and allow in-between grades of membership. This way, individual elements can partially belong to two sets at the same time. A membership function is indicative of the grade of membership to a set (Figure 2).

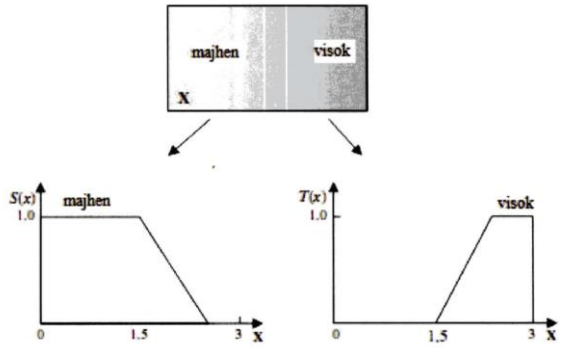

Figure 2. A fuzzy set with two membership functions. Adapted from *Fuzzy Systems Engineering: Toward Human Centric Computing* (p. 33) from W. Pedrycz, 2007, John Wiley & Sons Inc.

Taking this into account, membership functions with a set of real numbers as the definition area can be expressed in various ways. A triangular-shaped membership function (also lambda function) is the simplest model with which to describe a grade of membership with only three parameters.

$$A(x,a,m,b) = \begin{cases} 0\,, & pri\ x \le a \\ \dfrac{x-a}{m-a}, & pri\ x \in [a,m) \\ \dfrac{b-x}{b-m}, & pri\ x \in [m,b] \\ 0\,, & pri\ x \ge b \end{cases}$$

where the a, m, b parameters define the coordinates of vertices on the x-axis (Figure 3).

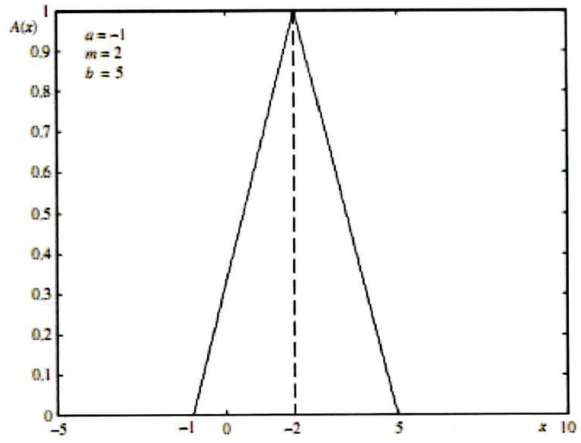

Figure 3. Triangular-shaped membership function. Adapted from *Fuzzy Systems Engineering: Toward Human Centric Computing* (p. 43) from W. Pedrycz, 2007, John Wiley & Sons Inc.

A triangular-shaped membership function can be transformed to S and Z membership functions. With S-shaped membership functions, parameter b is outside the function's definition area, whereas with Z-shaped membership functions, parameter a is outside the definition area (Figure 4).

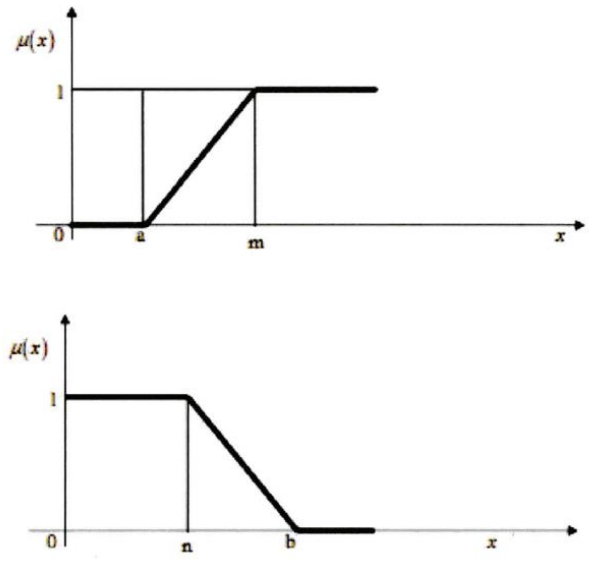

Figure 4. S- and Z-shaped membership functions. Adapted from *Mehka logika in mehke množice* (p. 68) from J. Usenik, 2008, Fakulteta za logistiko.

Models functioning with the help of fuzzy logic consist of three steps:

1. Fuzzification – numeric input data is converted to linguistic variables (fuzzy values) based on experience and expertise,
2. Fuzzy inference – output variables are assigned respective fuzzy output values based on basic fuzzy rules (algorithm),
3. Defuzzification – crisp numeric output values are produced from integration of fuzzy output values.

2.4 Competencies and fuzzy logic

Research studies have been published on the connections between competencies and fuzzy logic, as the notion of competency is close to the approaches of fuzzy logic.

In their study, Houé, Grabot and Tchuente (2011, pp. 651-656) studied competency assessment for implementation of individual process activities and alerted to the shortcomings of the most frequently used numeric assessment. The focus was on competency management in terms of knowledge, skills and abilities. They theoretically presented a possible formation of membership functions for several competencies and assessment analysis process. They noted that the use of fuzzy logic in competency assessment is a great example of the method's use and that with the use of fuzzy logic more credible results are expected when assessing the differences between the required and expected competencies than with usual assessment methods.

Pépiot, Cheikhrouhou, Fürbringer and Glardon (2008, pp. 353-363) took a wider approach, namely they included social competencies and treatment of group competencies on the level of organization. They suggested a generalized two-level assessment approach: on the first level various indicators of a competency are assessed according to several criteria, whereas on

the second level the global indicator ACI (Aggregated Competence Indicator) of a competency is assessed and it is dependent on the type of assessment on the first level.

Macwan and Srinivas (2013, pp. 324-329) studied the use of competency evaluation model using fuzzy logic in computer-based assessment. They selected ten behavioral competencies and assigned them membership functions. For each employee, a total competency value was calculated and, in accordance to the set rules, ranked it as high, neutral or unsatisfactory. In their following research, they confirmed that the fuzzy logic approach enables creating solid assessments even based on less reliable and accurate data.

Yu-Chen and Tien-Chin (2007, pp. 7-12) conducted a short study on applying fuzzy logic to competency assessment for middle managers. They determined nine linguistic descriptions of competencies and assigned them triangular fuzzy numbers. Based on survey questionnaires, they gathered linguistic assessment on eight selected competencies in four selected candidates. They calculated their values and used them as a criterion for candidates' suitability. The results confirmed that this approach is suitable and simple.

The nature of competencies is close to the approaches of fuzzy logic. Fatima and Abdul Suleman (Suleman & Suleman, 2012, pp. 323–339) agree but they emphasize the importance of determining membership functions in such analyses.

Moradi, Maleki and Pilehrod (2015, pp. 1864-1870) studied the possible use of fuzzy logic in analysis of leadership competencies and selection of top leaders. They presented a four-candidate selection based on seven competency criteria. The study resulted in a relatively efficient manner of comparative competency analysis.

Mittal, Goel and Mohindru (2013, pp. 89-97) used fuzzy logic for candidate selection in large Indian pharmaceutical companies, whereas García, Benjamin and Perez (2014, pp. 41-52) analyzed the influence of fuzzy logic in training effectivity assessments.

The use of an expert system based on fuzzy logic for 360° feedback was studied by Lasserre et al. (2014, pp. 1-18). System testing in a production company in Mexico confirmed the advantages of using fuzzy logic in this field.

2.5 Research question

The article studies how to use fuzzy logic to evaluate a competency assessed with 360° feedback to get an overall result, namely an assessment of an actual competency development in a certain individual.

3 Method

The basic 360° feedback was used and then transferred into a model's structure with elements of fuzzy logic. The model was created with FuzzyTech 5.5.

The empiric research study data model consists of the following steps:

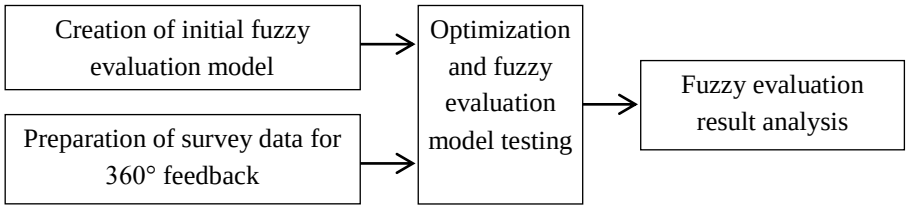

Figure 5. Research data model.

As an example of a competency assessment, the »Initiative« competency was selected from a list of competencies in Lyle and Signe Spencer's model (Spencer & Spencer, 1993, p. 20). The selected »Initiative« competency has a precisely determined assessment scale in Lyle and Signe Spencer's model (Spencer & Spencer, 1993, p. 32). For the sake of clarity, a simplified four-level competency scale for competency development assessment in relation to time dimension was used. The scale is shown in Table 1:

Table 1. Assessment scale of the »Initiative« competency

Weight O	**Description of competency development***
2	Addresses Current Opportunities or Problems
3	Is Decisive in a Crisis
5	Anticipates and prepares for a specific opportunity or problem
8	Anticipates situations years ahead and acts to create opportunities or avoid problems

Note. * - competency development graduates with description of one's behavior

Weight (O) assigned to each description of competency development is not linear and cannot be treated as interval variables, which is why basic statistics is not used in the evaluation. However, weight (O) is a useful aid to determine input membership functions in value fuzzification. Four membership functions were selected based on weight (O) in the assessment scale, as shown in Table 2:

Table 2. Description of input membership functions of the »Initiative« competency

Weight O	**Short description of membership function**
2	Current
3	Decisive
5	Anticipate
8	Create

Membership functions were created based on weight (O) values, as shown in Figure 6:

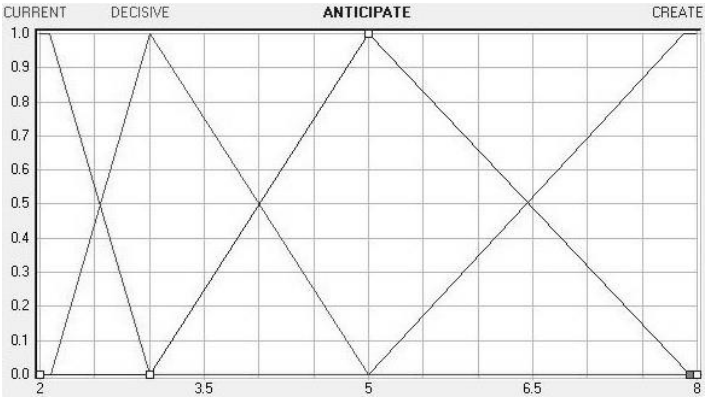

Figure 6. Membership functions of input variables.

Output variables functioning as the result of the assessment must be included in the model. Fundamentally, a crisp value is expected. The value functions as an assessment of the actual development of the »Initiative« competency assessed in an individual. This value is presented in the »INITIATIVE« output variable on a scale from 0 to 100 which can be understood as percentage. The score 0 denotes complete absence of the competency, whereas 100 presents the highest possible development stage of a competency.

The 360° feedback was then converted to the basic evaluation fuzzy logic model, as shown in Figure 7. A simple example with four persons involved in the assessment is used: the assessee (SELF), a superior (BOSS), a co-worker (COWORKER) and a subordinate (SUBORDINATE). Due to assessment methodology, all four assessors have identical input variable membership functions (see Figure 6). Assessments were implemented in accordance with the same assessment scale (Table 1). Each assessment enters the assessment model with its fuzzy value that is created based on input membership functions.

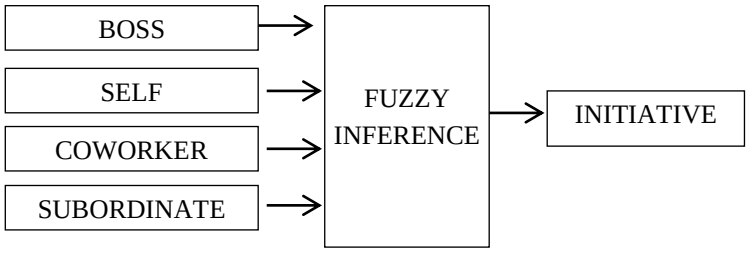

Figure 7. The basic model of assessment evaluation using fuzzy logic.

The central part of evaluation is fuzzy inference, where output variables are assigned respective fuzzy output values based on fuzzy rules. The rules of fuzzy inference must be determined for all possible examples of evaluation, otherwise the system proposes unsuitable output variables. Each possible example of evaluation are be assigned exactly one value of output variables. The model consists of 4 input evaluations, each of which has up to 4 values, namely 256 different examples of evaluation are possible. Hence, 256 rules of fuzzy inference

are needed. An example of a fuzzy inference rule that determines the result of the »INITIATIVE« variable when all four input variables equal the »CURRENT« value, is as follows:

IF BOSS = CURRENT AND COWORKER = CURRENT AND SELF = CURRENT AND SUBORDINATE = CURRENT THEN INITIATIVE = POOR

The final evaluation stage is defuzzication, where an output crisp numeric value is formed from integration of fuzzy output values. Fuzzification is performed via membership functions for output variables. The output variable »INITIATIVE« was assigned four membership functions with the following graduation on the scale: POOR – ACCEPTABLE – GOOD – EXCELLENT. The membership functions are shown in Figure 8:

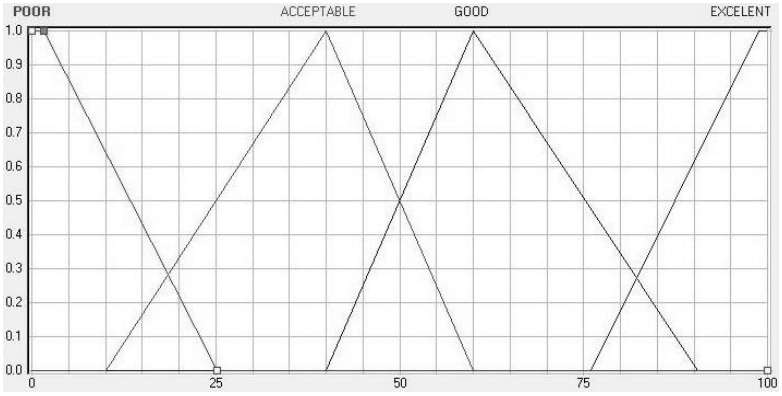

Figure 8. Membership functions of the »INITIATIVE« output variable.

For initial optimization and model testing, an Excel table was created including all possible entries, 256 altogether. The table was exported in a »comma separated values« (CSV) file that FuzzyTech directly reads and automatically performs fuzzy evaluation of the entries in accordance with the model.

A need for another output variable arose during model testing and optimization. There are cases when assessments of two (or more) assessors differ vastly. For example, the assessee sees oneself as very initiative, but the assessee's superior thinks he/she is non-initiative. It is possible to determine a rule of fuzzy inference in the model to create an output assessment value of the »Initiative« competency, but then the output value is questionable. In such a case, it is better for the assessment model to alert us to the inconsistency of assessments, and appropriate processes for coordination take place (for example, a conversation between the assesse and the superior). For this reason, another output variable »MEDIATE« was added to the model. It has only two values: when differences in assessments are acceptable, the value equals 0, but when the assessments differ too widely, the value is »MEDIATE«, as a warning that coordination is in order.

Only two membership functions were created for the »MEDIATE« output variable. Their graduation is steep, namely *assessments are okay, no coordination is needed (OK)* or

assessments differ too much, coordination is needed (MEDIATE). Figure 9 presents both membership functions:

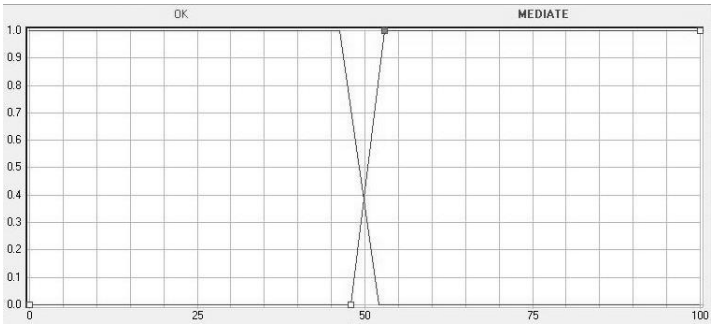

Figure 9. Membership functions of the »MEDIATE« output variable.

Another optimized evaluation model using fuzzy logic was created with the additional output variable, as seen in Figure 10:

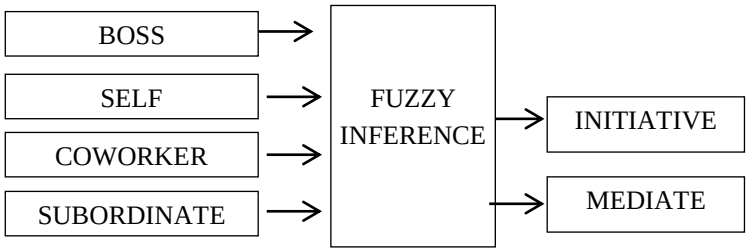

Figure 10. Optimized assessment evaluation model using fuzzy logic.

The optimized model was used on data gathered from 360° employee feedback in a large company. The survey questionnaire was created electronically and it consisted of several parts. In this study, only the »Initiative« competency was used from the survey questionnaire. In the survey questionnaire, a scale was given with descriptions of behaviors in connection with competency development, from the lowest to the highest competency development and a respective assessment score that equals weight (0) in Table 1. 350 participants completed the survey questionnaire, which adds up to around 3500 assessments.

The answers were first edited in Excel to make them suitable for model testing. All assessments that were not completed by exactly one superior, co-worker, subordinate and the assessee were excluded. Only 52 assessments were eligible. They were edited and extracted in a »comma separated values« (CSV) file. FuzzyTech directly reads the file and automatically performs fuzzy evaluation of scores.

4 Results and discussion

4.1 Result calculation

Results were calculated with the »Batch« command that reads the input file and assigns output variables to all input variables values in accordance with the fuzzy evaluation model.

Then it extracts the data in a tabular form to an output file. The results are listed from the lowest to the highest value of the »INITIATIVE« output variable in the range from 0 to 100.

Table 3. Input and output of the »INITIATIVE« and »MEDIATE« variables.

Nº	BOSS	COWORKER	SELF	SUBORDINATE	**INITIATIVE**	**MEDIATE**
1	2	5	8	5	**0**	**100**
2	3	5	5	2	**33**	**0**
3	3	5	5	3	**33**	**0**
4	3	5	3	3	**33**	**0**
5	5	5	3	3	**33**	**0**
6	5	5	3	3	**33**	**0**
7	3	5	3	3	**33**	**0**
8	5	5	3	5	**49**	**0**
9	5	3	5	3	**49**	**0**
10	5	3	5	3	**49**	**0**
11	5	5	3	5	**49**	**0**
12	3	5	5	5	**49**	**0**
13	5	3	5	3	**49**	**0**
14	5	3	5	5	**49**	**0**
15	5	3	5	5	**49**	**0**
16	5	5	5	3	**49**	**0**
17	5	3	5	5	**49**	**0**
18	5	2	5	5	**49**	**0**
19	5	5	5	3	**49**	**0**
20	5	3	5	5	**49**	**0**
21	5	5	5	3	**49**	**0**
22	5	3	5	5	**49**	**0**
23	5	3	5	5	**49**	**0**
24	5	5	5	3	**49**	**0**
25	5	8	5	3	**49**	**0**
26	5	5	5	3	**49**	**0**
27	5	5	5	8	**50**	**0**
28	5	5	5	5	**50**	**0**
29	5	8	5	5	**50**	**0**
30	5	5	5	5	**50**	**0**
31	5	5	5	5	**50**	**0**
32	5	8	5	5	**50**	**0**
33	5	5	5	5	**50**	**0**
34	5	8	5	5	**50**	**0**
35	5	5	5	5	**50**	**0**
36	5	8	5	5	**50**	**0**
37	5	8	5	5	**50**	**0**
38	5	8	5	5	**50**	**0**
39	5	8	5	5	**50**	**0**
40	5	8	5	5	**50**	**0**
41	5	8	5	5	**50**	**0**
42	5	5	5	5	**50**	**0**
43	5	5	5	5	**50**	**0**
44	5	8	5	5	**50**	**0**
45	5	8	5	5	**50**	**0**
46	5	8	5	5	**50**	**0**
47	8	5	5	5	**66**	**0**
48	5	8	5	8	**66**	**0**
49	8	8	5	5	**66**	**0**
50	5	8	5	8	**66**	**0**
51	8	8	5	3	**66**	**0**
52	5	8	8	5	**66**	**0**

In 360° feedback, the values of input variables are also listed on the left side, whereas the results of output variables are in both right columns of Tabele 3. The results are listed from the lowest to the highest value of the »INITIATIVE« output variable.

4.2 Result analysis

The results of general testing clearly display the performance of fuzzy inference for all possible combinations of input variables. The »INITIATIVE« value of the first 32 lines equals 0 due to the gap between the superior's and assessee's assessments. The value of the »MEDIATE« variable equals 100, namely the assessments should be coordinated and the coordinated values should be entered. Then the evaluation process should be repeated. The values of the »INITIATIVE« output variable gradually grow which is a result of a relatively rough structure of output variable membership functions. The results show that assessments of individual assessors have different influences on the final result. For example, a superior's assessment affects the result more than self-assessment. The results also show that the model is relatively strict, as the highest possible competency development assessment score 100 is awarded only to an assessee that receives the highest assessment score from all assessors. To receive an assessment score 88, there are only three possibilities – an assessment score 8 from the superior and 5 from one of the other assessors.

The results of 360° feedback in Table 3 show that assessors have a tendency to give middle assessment values. All assessment results were joined into three groups, where 75% of the results equal 49/50 and only 11% of results equal 33 and 66. There were no distinct extremes, neither low nor high. There was only one case where the assessment of a superior and self-assessment differed to such an extent that the model suggested coordination of scores: the »INITIATIVE« value of the first line equals 0 due to the gap between the superior's and assessee's assessments and the value of the »MEDIATE« variable equals 100.

5 Conclusion

Results of the study confirm the effectiveness of the fuzzy evaluation model. The experimental evaluation of competencies that was carried out provides important information on how the methodology and formation of the evaluation model affect the assessment results. Such concrete information is new to the field and can be directly used in further research in the field of competencies. In the field of human resources in organizations, the results can be used in employee selection, career development and education guidance. The study also helps and guides the community at large to the development of competencies that can indirectly improve the social order, social responsibility and the environment.

The study was restricted to one competency, a simplified competency scale and a very basic assessment group. Further research is sensible with reviewing the study's results with other competencies and 360° feedback in expanded assessment groups that would involve more co-workers, subordinates or other interested parties.

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Ocenjevanje kompetenc z mehko logiko

Povzetek:

Raziskovalno vprašanje (RV): Ocenjevanje kompetenc je zapleteno. Vprašanje je, kako kompetenco, ki je bila ocenjevana z metodo 360 stopinjskega ocenjevanja, z orodji mehke logike ovrednotiti v enotni skupni rezultat, kot oceno dejanske razvitosti te kompetence pri obravnavanem posamezniku.
Namen: Namen in cilj raziskovanja je določitev možnega postopka vrednotenja kompetenc, ki bi omogočal oblikovanje enotne ocene kompetence z uporabo metod mehke logike.
Metoda: Teoretični del zajema pregled stanja in izrazoslovja na področju kompetenc in mehke logike. Empirični del temelji na kvantitativni raziskavi. Za testiranje modela so uporabljen podatki iz anketnega vprašalnika.
Rezultati: V raziskavi je oblikovan in testiran primer modela vrednotenja kompetence »Iniciativnost«. Testiranje je potrdilo, da je postopek vrednotenja z uporabo mehke logike učinkovit.
Organizacija: Raziskava ima neposreden vpliv na razvoj kadrovske funkcije v praksi organizacij. Omogoča lažje in bolj usmerjeno vrednotenje kompetenc.
Družba: Raziskava omogoča lažje usmerjanje v razvoj kompetenc, ki lahko izboljšajo urejenost družbe, posredno tudi socialno odgovornost in okolje.
Originalnost: Raziskava izvirno podaja model vrednotenja kompetence z uporabo mehke logike.
Omejitve/nadaljnje raziskovanje: Raziskava je omejena na primer ene kompetence in posameznih ocenjevalcev. Zanimivo bi bilo raziskati model v primeru več istovrstnih ocenjevalcev.

Ključne besede: kompetentnost, kompetence, ocenjevanje, vrednotenje, mehka logika.