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WPROWADZENIE DO ROZMYTEJ METODY DELPHI

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Streszczenie: *Początek artykułu krótko charakteryzuje klasyczną metodę Delphi oraz logikę rozmytą. Następnie opisano rozmytą metodę Delphi oraz jej przykład.*

Słowa kluczowe: *rozmyta metoda Delphi, klasyczna metoda Delphi, logika rozmyta*

Introduction to the Fuzzy Delphi method

Abstarct: *Beginning of the article briefly characterizes the classic Delphi method and fuzzy logic. Then describes the Fuzzy Delphi method and an example of it.*

Keywords: *Fuzzy Delphi method, classical Delphi method, fuzzy logic*

1. INTRODUCTION

Long-term prediction in the economic field is currently popular. It affects the companies and enterprises that adapt their operation respectively to the results of long-term forecasting. Choosing the appropriate method of forecasting is an important issue. Due to the numerous advantages which it possesses the Delphi method is often used. It occurs in many varieties. The Fuzzy Delphi method deserves particular attention. In comparison to the classical Delphi method, Fuzzy Delphi method is faster, requires less iterations. It reflects the way a man thinks. Respondents do not give a single number in response to the question, but some characteristic values defining the membership function.

2. CLASSICAL DELPHI METHOD

The classical Delphi method [6] was developed in 1959 by Olaf Helmer, Norman Dalkey and Nicholas Rescher. Its aim is to forecast future events based on the knowledge of experts who answer questions included in the questionnaire in subsequent rounds. However, in each subsequent stage, each expert knows what are the mean values of answers to the questions in the previous step. Examination using this method ends up in this round, in which consensus is achieved. The steps in the classical Delphi method are shown in Figure 1.

The specificity of the Delphi method makes it relies on the independence and anonymity of the opinion. Besides, it is time consuming and requires the involvement of large numbers of people developing the questionnaire and responses. The problem is the lack of direct exchange of views between the experts in this method. Contrast, the

advantages include no need for the collection of experts in one place and time during the survey and the possibility of obtaining opinions from a large group of people.
Number of questions in the survey should not exceed the 25th. The content of the question should not affect the others.
A common practice is to send the sample survey to the experts. From the results of the trial survey is created the final version of survey.
When one of the experts can strongly deviate from the average answers to the questions, we asking him to explain it.
The Delphi method has many applications. In Poland, the most famous is the research the National Foresight Programme Poland 2020. With this test, you can find out the opinion of experts on the development of information technology and telecommunications in Poland and other fields. Forecasts are largely positive. Anticipated improved health status of citizens, increase employment and improve the environment. Not the best predictions related to the development of science.

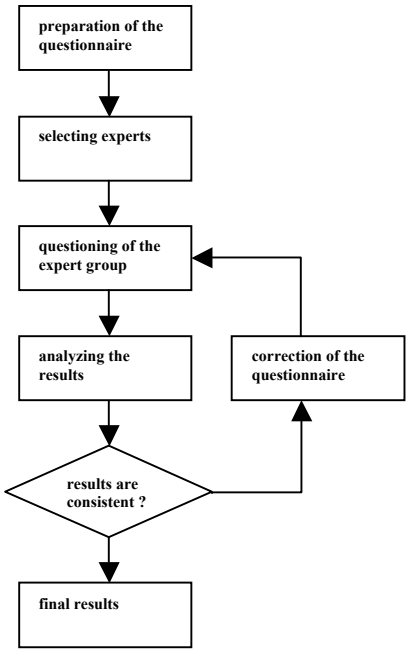

Figure 1. The steps in the classical Delphi Method.

3. FUZZY LOGIC

The creator of fuzzy logic is Lotfi Zadeh, who in 1965 published "Fuzzy sets". Fuzzy logic, unlike classical logic allows for the existence of intermediate values between 0 and 1. The sentences in this logic can be true in a certain degree of membership.

Important concepts related to this subject are the membership function and a fuzzy set [1].

Membership function μ_A of fuzzy set A in some space X performs the mapping:

$$\mu_A : X \rightarrow [0,1] \ \forall x \in X ,$$

While a fuzzy set A in some space X is the set:

$$A = \{(\mu_A^*(x), x)\} \ \forall x \in X ,$$

where:

$\mu_A^*(x)$ - degree of membership to fuzzy set of element x

The genesis of the creation of fuzzy logic was, among other things, the need to create mathematical notation that reflects the thinking of human. Experts often have difficulty with answering questions in the questionnaire, because they relate to the forecast. In such situations it is easier to use vague terms such as "slow" or "fast", rather than a more specifically laid down. Using a modified Delphi method it makes easier to carry out the survey.
In the figure below an example of fuzzy number “about 5”.

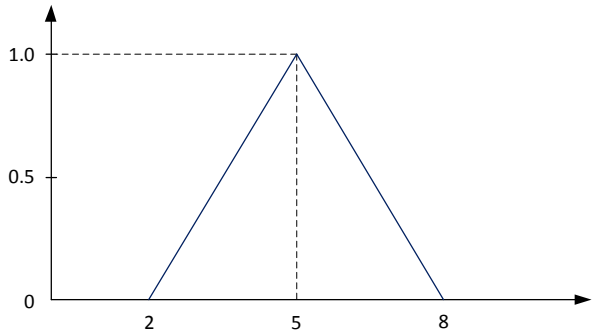

Figure 2. Example of fuzzy number “about 5”.

4. FUZZY DELPHI METHOD

Fuzzy Delphi method was proposed by Kaufmann and Gupta in 1988. In contrast to the classical Delphi method is more effective. It differs from classical Delphi method form responses, which provide experts who do not give a single number, but several, depending on what shape membership function adopts. For example, for the triangular membership function experts give 3 numbers that correspond to the minimum, most likely and maximum values to be adopted by the parameter predicted by the experts. In the case of membership function of the shape of Gaussian function, the experts give about 10 numbers. For the membership function of other shapes will be a different number. But the most popular is the triangular membership function [12].

Fuzzy Delphi method also consists of rounds. After answering questions by the experts responses are assessed. For this purpose, it is calculated the mean and standard deviation. For the triangular membership function is done by the following formulas. Triangular number in the Delphi method is defined as follows:

$$A_i = (a_1, a_M, a_2)$$

where:
a_1 – minimum value
a_M – most probable value
a_2 – maximum value

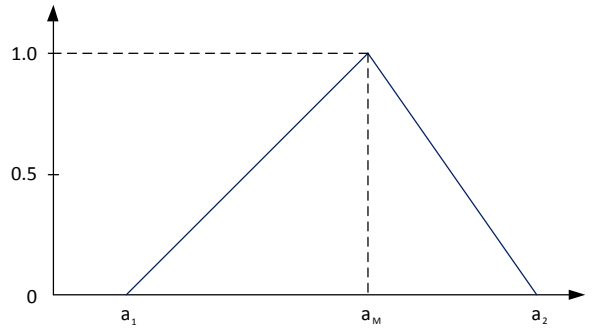

Figure 3. Example of triangular number in Fuzzy Delphi method.

While the average number A_i has the following form:

$$A_{avg} = (\sum_{i=1}^{n} a_1^i, \sum_{i=1}^{n} a_M^i \sum_{i=1}^{n} a_2^i)$$

where:
n – number of experts

The standard deviation is shown below:

$$A_{dev} = A_{avg} - A_i$$

Fuzzy Delphi method terminates when consensus is reached, ie. when the average A_{avg} be at a satisfactory level and its values in the current and last round are similar. If not, the experts will familiarize themselves with the values of standard deviation for each question, and another round of answers begins.

For example we have a question in the questionnaire: "When artificial intelligence will be introduced?" We have six experts, who gives responses, such as in the following table:

A_i	Earliest year	Most probable year	Latest year
A_1	a_1^1 = 2030	a_M^1 = 2052	a_2^1 = 2090
A_2	a_1^2 = 2025	a_M^2 = 2060	a_2^2 = 2100
A_3	a_1^3 = 2027	a_M^3 = 2045	a_2^3 = 2085
A_4	a_1^4 = 2030	a_M^4 = 2050	a_2^4 = 2075
A_5	a_1^5 = 2025	a_M^5 = 2045	a_2^5 = 2095
A_6	a_1^6 = 2027	a_M^6 = 2058	a_2^6 = 2085

Table 1. Answers of experts to the sample question.

We can count the average triangular number by calculating the average for each column. It can be represented as follows for our example:

$$A_{avg} = (2027, 2052, 2088)$$

We may call the number in parentheses as follows:

$$m_1 = 2027$$
$$m_m = 2052$$
$$m_2 = 2088$$

Then we could calculate the standard deviation for responses of each expert. Results are in the table below.

D_i	$m_1 - a_1^i$	$m_M - a_M^i$	$m_2 - a_2^i$
D_1	-3	0	-2
D_2	2	-8	-12
D_3	0	7	3
D_4	-3	2	13
D_5	2	7	-7
D_6	0	-6	3

Table 2. Example of standard deviation for responses of each expert.

Fuzzy Delphi method, unlike classical Delphi method usually requires a smaller number of rounds, which is characterized by lower costs and shorter duration.

5. CONCLUSION

It turns out that Fuzzy Delphi method has more advantages than the classical Delphi method. For example Kuei-Yang Wu list many of them in his article [11]. The combination of the Delphi method with fuzzy logic was a good idea – survey results in the study are more reliable then. The experts participating in the survey have a greater opportunity to comment. Additionally, it is more economical. While the classical Delphi method is characterized in that it is difficult to obtain a compact opinion. Receive the final results last longer in the classical Delphi method.

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