Application of Fuzzy Index
to Qualitative and Quantitative Evaluation
of the Quality Level of Working Conditions

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Abstract. Quality assessment can be performed with natural language (in descriptive form) or with numbers (in quantitative form). Such approach enables consideration of all the aspects and characteristics beyond quantification, difficult or impossible to assess with numbers, hence requiring linguistic representation. Application of fuzzy index to work conditions quality assessment provides objective identification of hazards and their influence on work conditions quality.

Keywords: quality of work conditions, quality characteristics, quality level.

1   Introduction

Man is a subject to every process of work and according to that human-centric paradigm he is the most important, the most active and decisive factor of production [1], [2], [5]. Thus considering man and his decisive role in manufacturing processes enterprises should strive for guaranteeing proper and safe work conditions that enable development of employees and performing their jobs in efficient and effective way [1], [3]. More complex analysis of the problem leads to the conclusion that safety and human-factor are just some of the factors influencing quality of work conditions [2]. Quality of work conditions is a complex term and it should reflect how many attributes connected with work influence satisfaction on health, professional life and supports increase of culture and morality of human environment in a company.

2   Quality of Work Conditions

Characteristics of quality of work conditions are not only limited to human-centric and hygienic aspects of work but also include some other areas of company's functioning [2]. They refer, for example, to reaction to changes, available resources, applied methods of assessment and improvement of work conditions, safety culture, managers' commitment and risk of managerial decisions taken, which are mostly caused by lack of knowledge about objectives, poorly determined goals, not noticing

influences of the environment, incompetent or inadequate information or wrong advisers and experts [6]. Characteristics determining quality of work conditions are presented in the table 1.

Table 1. Selected characteristics of quality of work conditions

Reaction to changes:
A1 – how fast an organization can react to law changes
A2 – how fast an organization can react to work conditions changes
A3 – how fast an organization can react to a problem
Managers' commitment
E1 – clear strategy towards quality of work conditions improvement
E2 – planning actions improving quality of work conditions in manufacturing processes
E3 – setting goals (strategic, tactical and operational)
Risk of managerial decisions
F1 - managerial decisions have regard to improving the quality of working conditions
F2 - style of leadership decisions takes into account risk understood as a result of employees

The characteristics presented are partial results of research conducted in Polish manufacturing companies [5]. The level of meeting requirements defined by each characteristics will contribute to the total level of quality of work conditions. Quality assessment will hence include qualitative approach (descriptive, linguistics) and quantitative approach determinable in numeric form.

3   Qualitative and Quantitative Evaluation of the Quality Level of Working Conditions

3.1   The Fuzzy Index of Work Conditions Quality Level

The fuzzy index of work conditions quality level(FI_{WQCL})is based on linguistic variables and linguistic values, turned into triangular fuzzy numbers.

Fuzzy numbers derived from assessment procedure are aggregated into fuzzy weighted average with max-min paired eliminated method. The result, which is certainly the fuzzy number is then turned back into linguistic value, which makes its analysis clear and simple. Turning back procedure is based on the Euclidean distance method. Fuzzy weighted average, identifying fuzzy index of work conditions quality level (FI_{WQCL})is calculated with the following formula:

$$\text{FI}_{\text{WCQL}} = \frac{\sum_{j=1}^{n} W_i R_i}{\sum_{i=1}^{n} W_i} \tag{1}$$

where:
R_i - fuzzy rating i, W_i – fuzzy weighting i, **i** – index of a characteristics, **n** – number of the characteristics.

The membership function can be defined as follows [4]:

$$f_Y(y) = \text{sup.min} \{f_{Wi}(wi), f_{Ri}(ri)\}, i = 1..n \ \ I \ \ y = \frac{\sum_{j=1}^{n} W_i R_i}{\sum_{i=1}^{n} W_i} \tag{2}$$

where:
for each i=1,2..n f_{wi} i f_{Ri} are the membership functions of fuzzy number W_i i R_i respectively.

The membership function fy can be calculated with using an appropriate procedure [4] according to max-min paired eliminated method.

The calculated Fuzzy Index of Work Conditions Quality Level is a fuzzy number, which defines the level of work conditions quality. Hence the result of running the procedure is a fuzzy number, the next step should be translating it into an appropriate linguistic term.

To translate the index presented (FI_{WCQL}) Euclidean distance method is applied which consist of calculating the Euclidean distance from the given fuzzy number (which is the FI_{WCQL} calculated) to each of the fuzzy numbers representing the natural language expression set. Thanks to calculating the Euclidean distance it is possible to interpret the value obtained in the max-min paired eliminated method.

3.2   Application of the Fuzzy Index of Work Conditions Quality Level (A Case Study)

Evaluation of characteristics (examples of which were introduced in the table 1) is performed by a team of independent experts representing various fields. The level of meeting requirements defined with pre-determined criteria is qualitatively assessed with seven-level-scale including the following levels: **E** – excellent, **VG** – very good, **G** – good, **F** – fairly, **P** – poor, **VP** – very poor, **W** – worst. Determination of the index is based on transformation of linguistic parameters given by experts into fuzzy numbers according to the scheme: **E** in fuzzy number is (0.8, 1.0, 1.0), **VG** is (0.6, 0.8, 1.0), **G** is (0.5, 0.65, 0.8), **F** is (0.3, 0.5, 0.7), **P** is (0.2, 0.35, 0.5), **VP** is (0, 0.2, 0.4), **W** is (0, 0, 0.2).

Each of the predefined characteristics i also defined with an importance rate representing its influence on achieving a given level of quality of work conditions. The pre-mentioned importance rates were also assessed with the seven-level-scale and translated into fuzzy numbers (given in brackets): **TNI -** totally not important (0, 0, 0.2), **NI -** not important (0, 0.2, 0.4), **LI -** less important (0.2, 0.35, 0.5), FI - fairly important (0.3, 0.5, 0.7), **I –** important (0.5, 0.65, 0.8), **VI -** very important (0.6, 0.8, 1.0), **MI -** the most important (0.8, 1.0, 1.0). The example of assessment of predefined characteristics with linguistic variables is introduced in the table 2.

Table 2. Example of assessment of quality of work conditions derived by experts

ATRIBUTES Reaction to changes	LEVEL	WEIGHT
A1 – how fast an organization can react to law changes	G	I
	G	I
	F	VI
	G	VI
	G	VI
A2 – how fast an organization can react to work conditions changes	P	LI
	BN	NI
	F	I
	F	I
	G	LI
A3 – how fast an organization can react to a problem	F	VI
	F	NI
	G	I
	G	I
	F	VI

After linguistic analysis weighted level of quality of conditions of work FI_{WCQL} is calculated as a fuzzy number identifying quality level of work conditions.

For better interpretation of the research results the obtained number should be transformed into qualitative, linguistic assessment. Natural language scale for definition of work conditions quality level in an enterprise is defined as follows:

- **Level A$^+$ -** The highest work conditions quality level, all the attributes are performed perfectly **– it is (1, 0.9, 0.8) in fuzzy numbers scale;**
- **Level A -** Very high work conditions quality level, though there are some characteristics that can be improved – **it is (0.9, 0.8, 0.7);**
- **Level A$^-$ -** Very high quality of work conditions level, though there are some characteristics that need to be improved **– it is (0.8, 0.7, 0.6);**
- **Level B$^+$-** The company has numerous attributes of work conditions quality but their level is fairly low **– it is (0.7, 0.6, 0.5);**
- **Level B** - The average level, the company has some attributes of work conditions quality but most of them need to be improved **– it is (0.6, 0.5, 0.4);**
- **Level B$^-$-** The company has some attributes of work conditions quality but all of them need to be improved – **it is (0.5, 0.4, 0.3);**
- **Level C$^+$-** Low quality level, the company has some attributes of work conditions quality but their level is very low and numerous changes need to be implemented **- it is (0.4, 0.3, 0.2);**
- **Level C -** Very low quality level, there are no attributes of work conditions quality but there possibilities of their implementation **– it is (0.3, 0.2, 0.1);**
- **Level C$^-$-** The lowest level. There are no attributes of work conditions quality and the company is not willing to implement them **– it is (0.2, 0.1, 0);**

As a result of calculation procedure [6] the following results were obtained and illustrated with triangular fuzzy numbers as presented in the figure 1.
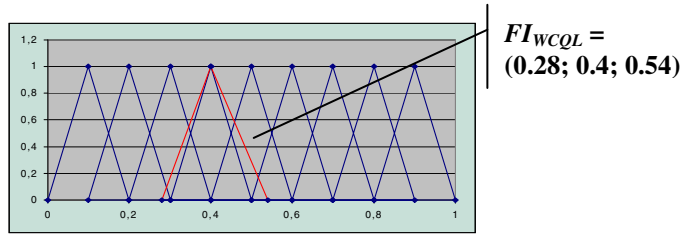
Fig. 1. Work conditions level assessment

Hence, the analysis led to the following conclusions: work conditions quality level in the company analysed can be defined as B- which means that the company has some attributes of work conditions quality but all of them need to be improved.

4   Conclusions

The attributes of quality are described with linguistic terms which makes fuzzy logic indispensable in quality measuring. Definition of the level of attributes of work conditions quality and consequently assessment of the quality level in the company allows to analyze the solutions applied in the work conditions quality area, as well as to make conclusions and improvement on the most requiring areas, analyze the influence of work conditions on the management quality, and analyze the influence of work conditions on the employees efficiency.

Companies can benefit from implementation of quality assessment performed as a calculation of the index presented as it provides them with detailed and holistic information in the same time. The components analysis indicates areas of necessary improvements, while the value of the index shows general level of quality. The index' structure enables repetitive analysis and results comparison, and experts team employed to assess the work system guarantees high standard of evaluation.

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