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ORGANIZATIONS' SUSTAINABLE DEVELOPMENT ASSESSMENT BY FUZZY LOGIC

Summary

The paper presents a method of organizations' sustainability assessment with the use of fuzzy logic. economic, environmental, and social components are fundamental to the model. Each of the inputs is treated individually, and the application of fuzzy logic helps provide an overall measure. The proposed model can be used to evaluate an organization's sustainable development level, and to compare organizations in a specific sector.

Purpose: The paper presents a method of organizations' sustainability assessment with the use of fuzzy logic. The proposed model enables evaluation of an individual organization's sustainable development level, but also comparisons between organizations in a specific sector.

Design/ methodology/ approach: In the paper a multistage fuzzy reasoning model is presented to assess an organization's sustainability. The model is based on 3 fundamental components: economic, environmental and social. Each of the inputs is treated individually and then combined with the aid of fuzzy logic to provide an overall measure.

Findings: The verification of method shows that it can be easy applied. The main advantages of the method used here are intuitive understandability of the process of reasoning and result interpretation, objectivity. Flexibility of the method allows for a change of the number of indicators, the use of selected indicators, the use of indicators expressed in different units of measurement, as well as introducing weights to their assessment.

Originality/ value: According to our knowledge similar method doesn't exist. Simoultaneously, well-developed system of macroeconomic evaluation cannot be easily applied to the goals of companies, majority of the proposed methods to assess sustainable development is inadequate to evaluate of organizations. The proposed method is essentially important for the practice of management of organizations. It enables evaluation of an individual organization's sustainable development level, but also comparisons between

organizations in a specific sector. The results it provides may become a reference for repair plans, ecological programs and in the process of strategic decision-making.

Key words: Sustainable development, fuzzy logic

Introduction

According to the concept of sustainable development, a company is sustainable if its practices contribute positively to the welfare of a society and have as small an environmental impact as possible. The assessment of a degree of sustainable development is the key condition of management in this area allowing for the creation of a sustainable development program for a company as well as evaluation of a company in this respect. A high value for the overall sustainability means that companies understand their social role and accept the principles of transparency and accountability. Some measures or, at least, indicators of sustainability exist, but their effectiveness cannot be assessed. A well developed system of macroeconomic evaluation cannot be easily applied to the goals of companies. On the other hand, company-oriented evaluation systems are either qualitative or do not allow for direct comparisons. With the Rio +10 summit in Johannesburg in the summer 2002, a preliminary evaluation of the achievements of business in moving towards a more sustainable development path seemed to be both necessary and appropriate. At the same time, the majority of the proposed methods of assessing sustainable development is inadequate to evaluate that level objectively.

The paper presents a multistage fuzzy reasoning model to assess an organization's sustainability. The model comprises 3 fundamental components: economic, environmental, and social. Each of the inputs is treated individually and the application of fuzzy logic helps provide an overall measure. The following two basic features justify the use of fuzzy logic reasoning: (a) fuzzy logic has the capacity to deal with complex and polymorphous concepts, which are not amenable to a straight forward quantification and contain ambiguities. In addition, reasoning with such ambiguous concepts may not be clear and obvious, but rather fuzzy; (b) fuzzy logic provides mathematical tools to handle ambiguous concepts and reasoning. For these reasons, the use of the natural language and linguistic values based on the fuzzy logic method seems more suitable to assess sustainability.

The authors do not intend to propose a new set of indicators to assess sustainability-related performance of an organization, but merely suggest a different mechanism to use the indicators already described in literature. The proposed model can be used to evaluate an organization's sustainable development level, and to compare organizations in a specific sector.

The structure of this paper is as follows. Sections 2 and 3 outline the theoretical background behind the concept of sustainability at the macro- and micro-economic levels, and the problems of corporate sustainability assessment; the next part discusses the possibility to apply fuzzy logic to evaluate sustainable development. The paper focuses mainly on the method for assessing sustainability performance in organizations. In the last part provides verification of the method proposed.

Defining Sustainability

Although the essence of the concept of sustainable development is clear enough, the exact interpretation and definition of sustainable development have caused heated discussions. Difficulties related to its definition show that sustainable development is a complex and multidimensional issue, combining efficiency, equity and intergenerational equity based on economic, social, and environmental aspects. This paper adopts the definition included in the Brundtland Report, which seems to capture the idea of sustainable development best. The study postulates that sustainable development is the kind of development that satisfies the current needs without endangering the future generations to satisfy their own. This definition is the most frequently cited one and seems to be more exhaustive than others (Ciegis, 2010). Five years after the publication of the Brundtland Report the United Nations Conference for Environment and Development globally accepted the vision of sustainable development. As a general concept, sustainable development encompasses three fundamental interrelated and complementary approaches: economic, environmental, and social. Economic sustainability is fundamental to financial success. In the long run, for instance, an organization simply cannot survive if its expenditure exceeds the income it generates. Social sustainability embodies the humanitarian context and relates to issues of poverty, income inequality, disease, education, and access to clean water. Environmental sustainability refers to the impact on the quality and quantity of natural resources, and improved management of pollution and emissions (Townsend, 2008).

Sustainability development is interpreted from the point of view of three characteristics: balance, durability, and self-support. Those characteristics are strongly correlated with each other and, in turn, refer to three aspects:

- structural – refers to the necessity of maintaining correct proportions of the development structure, of balancing the need to develop and the need to protect the environment,

- temporal (the quality of durability),
- creating resources and stimuli for further development (the quality of self-support; Borys, 1997).

Corporate Sustainability

The WCED definition as well as the influences from the strategy and management literature have led to a variety of definitions of organization-related sustainability. These definitions vary as to the degree to which they classify corporate sustainability as either ecological concern (Shrivastava, 1995) or as social responsibility of an organization (Carroll, 1999). They also broaden the concept of corporate sustainability to integrate corporate economic activities with organizational concern about environment (van Marrewijk, 2003). This study assumes that corporate sustainability can be defined as adopting business strategies and activities that meet the needs of the enterprises and its stakeholders today while protecting, sustaining, and enhancing the human and natural resources needed in future. Sustainability development enriches the older CSR concepts by providing a broader normative anchor and a guiding agenda (van Marrewijk, 2006).

The study also includes the concept of eco-efficiency – a win-win situation created by integrating economy and ecology through the efficient use of natural resources (Kleine, 2009). Thus, corporate sustainability entails incorporation of the objectives of sustainable development, i.e. social equity, economic efficiency and environmental performance into company's operational practices. Sustainability assumes abandoning a narrow version of the classical economic theory and developing corporate strategies which include goals that go beyond just maximizing shareholders' interests (Lopez, Garcia, Rodriquez, 2007). Attention is directed to the demands of a wider group of stakeholders, since the firm's success depends on stakeholders' satisfaction (Buchholz, Rosenthal, 2005). The relationships between organizations, society and environment are complex and characterized by the dialectic between the responsibility of an organization to maximize returns to its shareholders and benefits to a broader range of stakeholders, including the environment. By embedding sustainability across organization functions, one can address some of the negative impacts of economic growth. The principal problem in this context is how to translate the general principles of sustainable development into business practice. From a pragmatic point of view, corporate sustainability should start with the three dimensions rather than with the traditional ethical categories such as justice (Kleine, 2009). The shift towards to sustainability can be understood in business as an issue-driven heuristic multi-criteria approach (Schaltegger, 2005). For example, economic capital consists of financial capital, tangible capital, and intangible capital. Ecological capital includes the subtypes of natural resources and services provided by the ecosystem. Social capital refers to security, social cohesion, and human rights. Given the scope of the notion of capital itself, implementing sustainability development into business practices requires a system approach whereby corporate sustainability is not considered as a mere “add on”, but is systematically integrated into all business activities. It is necessary to include environmental and social aspects in the company’s reporting procedures or to measure sustainability performance and to evaluate progress in that area. If sustainability is an appropriate philosophy for addressing social and environmental issues, we need some method or a set of measurements to monitor the steps taken with a view to reaching this goal. Such metrics will allow all stakeholders to effectively evaluate progress towards sustainable development (Hussey, Kirsop, Meissen, 2001).

Assessing Corporate Sustainability

The techniques to measure social impact have continuously been developed for the last 25 years, i.e. since the concept of this form of accounting has come into existence (Aras, 2008). However, the opportunity to discuss that businesses, through their actions, affect their external environment and that they should take this environment into account often exceeded the opportunity to make practical suggestions for measuring such an impact. At the same time, alongside the technical implementation of social and environmental accounting, a philosophical basis for such an assessment was developing. Nowadays, many companies recognize and monitor sustainability performance using indicators that provide information on how the company contributes to sustainable growth. The development of sustainability performance measurement is driven by interests of various regulatory data requirements, demands from various pressure group for detailed information, the internal environment-related decisions and the requirements of financial institutions (Kinderyte, 2008).

Measuring corporate sustainability grew out of environmental accounting and environmental reporting. A prerequisite to understanding sustainable development is the construction of green accounts and sustainability indicators. Referring to the mainstays of the concept, the assessment of sustainable development covers performance in the environmental, social and economic areas. The environmental results can be defined by means of a company’s physical performance with regard to environmental aspects. An environmental aspect is defined here as an element of an organization’s activities and/or products that interact with the environment. Economic results refer to short-term profitability operationalized in terms of the generally accepted financial performance indicators. With regard to social performance, the measurement debate focuses on the human rights, health and safety at work, and diversity of workers.

Numerous sustainability indicators have been suggested so far. For example, the Center for Waste Reduction Technologies of AIChE (2004) and the Institution of Chemical Engineers (IChemE, 2002) published a set of their indicators. Veleva and Ellenbecker (2001) discussed the indicators of sustainability production, suggesting a methodology of core and supplemental indicators for measuring progress of companies towards sustainable development. Figge and Hahn (2002) proposed an integrated measure of sustainability based on a monetary assessment of how much the change of social and environmental performance of a company between two periods has contributed to making the national economy more sustainable. Azapagic (2004) developed a framework for sustainability indicators for performance assessment of mining and minerals industry, which is compatible with the general indicators proposed by GRI. Krajnc and Glavic (2003) collected and developed a standardized set of sustainability indicators for companies. The above-mentioned frameworks suggest using numerous sustainability indicators, which are generally measured in largely diverse units. While it is important to assess sustainability with several indicators, it may sometimes be difficult to make business decisions and comparisons among companies based on a large number of performance measurements (Krajnc, Glavic, 2005). In recent years international research has focused on the development of composite indices mostly for cross-national comparisons of economic, societal, environmental and sustainable progress of nations. Despite the indicators already developed, no efficient method for integrated sustainability assessment at the company level is available. In addition, Veleva, Ellenbecker indicate that (Veleva, Ellenbecker, 2001):

- the development of the majority of indicator frameworks is still underway. Such indicators continue to be the subject of discussions, tests and refinement;
- use of materials and environmental protection are best covered in all review frameworks. Social issues, workers and products receive least attention in existing indicator frameworks;
- most indicator frameworks attempt to address key global issues, yet these are typically environmental;
- most frameworks attempt to address economic performance, but they invariably use traditional economic indicators that cannot possibly adequately measure sustainability.

Preliminary Principles of the Method

The following method, basing on the previous studies, assumes that sustainable development covers ecological, economic, and social areas. Therefore:

$$SD = a\ Econ + b\ Ecol + c\ Soc$$

where:

SD – sustainable development level of an organization,
Econ – result for the economic sphere,
Ecol – result for the ecological sphere,
Soc – result for the social sphere,
a, b, and c – coefficients

The a, b, c values represent relative significance of each sphere in the assessment of the overall SD level. The equal weight of these coefficients was assumed, which follows from the very essence of sustainable development. Thus, in further considerations, the values of these coefficients were left out.

The three basic areas are determined by several components (indicators), whose number, depending on the method of assessment or the method of SD reporting, varies from a few to a few dozen. Following the rules and guidelines of GRI, the present paper adopts the indicators proposed in this method. During the procedure, all basic indicators pass through a filter that normalizes their values [0, 1]. The normalized value is:

a) $y = \frac{x-min}{a-min}$, min≤x≤a

b) $y = 1$, a≤y≤b

c) $y = \frac{max-x}{max-b}$, b≤x≤max

A graphic representation is below (Figure 1).

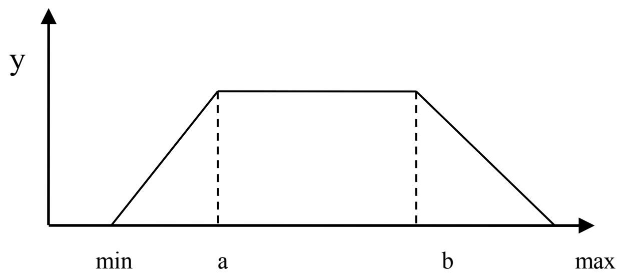

Fig. 1. Normalization of the basic indicator x

The graphic values for the normalization process are presented in Table 1.

Table 1.

Indicator	Min or b	Max or a	Interpretation
Ecological sphere			
Dust pollution emissions	Average for a sector [kg/t]	Value obtained by a company burdensome to the environment or the	x≤b→ SD=1 x>max→SD=0

		worst value obtained by a company from this region [kg/t]	
Gas pollution emissions	Average for a sector [kg/t]	Value obtained by a company burdensome to the environment or the worst value obtained by a company from this region [kg/t]	x≤b→ SD=1 x>max→SD=0
Total energy consumption	Average for a sector [MWh/t]	Value obtained by a company burdensome to the environment or the worst value obtained by a company from this region [MWh/t]	x≤b→ SD=1 x>max→SD=0
Number of protected species exposed to risk by a company's activity	0	Non-limited	x=0→ SD=1 x>0→SD=0
Total water consumption	Average for a sector [m^3/t]	Value obtained by a company burdensome to the environment or the worst value obtained by a company from this region [m^3/t]	x≤b→ SD=1 x>max→SD=0
Total amount of discharged sewage	Average for a sector [m^3/t]	Value obtained by a company burdensome to the environment or the worst value obtained by a company from this region [m^3/t]	x≤b→ SD=1 x>max→SD=0
Produced waste	Average for a sector [kg/t]	Value obtained by a company burdensome to the environment or the worst value obtained by a company from this region [kg/t]	x≤b→ SD=1 x>max→SD=0
Percentage of waste recycled	50%	90%	x≤50%→ SD=0 x>90%→SD=1
Expenditure on fixed assets related to environmental protection	Average for a sector [thousand PLN/company]	Average for industry + 20% [thousand PLN/company]	x≤min→ SD=0 x>a→SD=1
Number of environmental fines	0	Non-limited	x=0→ SD=1 x>0→SD=0
Economic sphere			
Sales revenue	Average for a sector [million PLN/company]	Average for industry + 20% [million PLN/company]	x<min→ SD=0 x≥a→SD=1
State financial support	0	1.8% of added value in a sector[1] for a company	x≥max→SD=0
Total liabilities	0	Average for industry [million]	x=0 and x>max → SD=0
Fixed investment	Average for a sector [million PLN/company]	Average for industry + 20% [million	x<min→ SD=0 x≥a→SD=1

[1] M.Warbiński, Pomoc państwa dla przedsiębiorstw w ramach UE [State support for enterprizes in EU], http://www.rcie.lodz.pl/info/dokumenty/03_przewodnik/16_msp/bp11.pdf

		PLN/company]	
Investment	Average for a sector [million PLN/company]	Average for industry + 20% [million PLN/company]	x<min→ SD=0 x≥a→SD=1
Taxes	0%	35%	x=0% and x≥35% →SD=0 x ϵ (0, 35) → SD = 1
Social sphere			
Employees' gross monthly salary	Average salary in a sector [PLN]	Maximum gross salary in a sector [PLN]	x≤min→SD=0 x≥max→SD=0
Number of days of an employee's absence from work	0	Average for a sector	x=0 → SD=1 x≥max→ SD= 0
Occupational accidents	0%	Average for a sector	x≥max → SD = 0 x=0 → SD = 1
Proportion of employees-trade union members	0%	15% of all employees	x=0 →SD=0 x>max →SD=0
Number of women employed in management positions	10%	50%	x<10%→ SD=0 x>50%→SD =0
Contribution to the development of local communities	0.1% of average sales revenue for a company [in million]	0.26% of average sales revenue for a company [in million]	x<min and x>max → SD=0

The values obtained for individual spheres are the sum of the normalized values of indicators and respective weight coefficients. For example, the calculations for the ecological sphere are as follows:

Ecol = a1 dusts + a2 gases +a3 water consumption + a4 sewage + a5 electric energy +a6 number of endangered species + a7 waste + a8 recycling + a9 environmental protection expenditure + a10 number of fines

$$Ecol = a1 \cdot D + a2 \cdot G + a3 \cdot W + a4 \cdot S + a5 \cdot E + a6 \cdot N + a7 \cdot Ws + a8 \cdot R + a9 \cdot P + a10 \cdot F$$

where:

D – dust pollution emission, G – gas pollution emission, E – total energy consumption, W – total water consumption, S – sewage, N – number of endangered species, Ws – total waste, R – recycling, P – environmental protection expenditure, F – number of fines.

Weights associated with coefficients a_1, a_2, …, a_n, may differ depending on the sector or on the significance of a given component to the company. They are determined by the Delphi method, AHP, and ranking lists. The authors assume that the sum of the coefficients a_1– a_n amounts to 1, while their values are equal (for example, for the ecological sphere they are: a=1/10=0.1). The values for the economic, ecological and social spheres, calculated in this way, successively undergo fuzzification.

Fuzzy Reasoning

The method described above allows for the estimation of the overall value for each of the three spheres of an organization's activity (economic, social, and environmental). Their influence on the overall sustainability assessment can be described with "if… then…" rules. For example: "if economy is strong and social development is medium, and environmental development is medium, then sustainable development is average". In order to use such rules to assess the overall final sustainability value, a method should be developed to transform numerical values into linguistic evaluation, to perform the process of reasoning, and to transform the conclusion into a specific numerical value of a sustainability indicator. The advantage of such a solution would be its intuitiveness and the clarity of rules, while the disadvantage would consist in the complexity of translation between quantitative and qualitative values. One of the most interesting tools employed for such tasks is fuzzy logic. Fuzzy logic stems from the fuzzy set theory developed by L. Zadeh (Zadeh,1965; Zadeh,1973; Zadeh,1975). This theory is based on the assumption that the membership of elements in a set may be partial, i.e. an element either belongs or does not belong to a set, but it may also belong to a set to a certain degree. The degree of membership is usually defined as μ and it is a number from the interval <0;1> (where 0 indicates that an element does not belong to a set, while 1 indicates that an element belongs to a set). Fuzzy sets are excellent tools to represent the so-called linguistic variables or concepts without clearly defined boundaries. Therefore, they may be useful to represent the evaluation of a company's activity and its overall sustainability assessment. The fuzzy set theory became the basis for fuzzy logic and for the operations corresponding to, among others, the sum operation (called s-norms), the product operation (called t-norms), or implication known from classical logic and set theory. Also, the inference rules, among others the *modus ponens* rule, were adapted to the principles of fuzzy logic.

The process of fuzzy reasoning used in this paper includes several stages:

1. determination of linguistic variables, their values (states) and membership functions;
2. determination of rules;
3. fuzzification or transforming numerical values of individual indicators into fuzzy values of linguistic variables;
4. inference:
    1. calculation of the degree of premise fulfillment in individual rules,
    2. calculation of the degree of rule fulfillment (implication operators),
    3. calculation of the conclusion membership function (in inferences involving several rules, the max-min rule is used);

5. defuzzification or transforming fuzzy values of the linguistic variables used to evaluate sustainability into specific numerical values of sustainability indicators.

The first step in the implementation of fuzzy reasoning is the determination of decision variables and of their values as well as the establishment of the inference rules. Since three initial indicators are necessary to assess sustainability, there will be three linguistic variables to describe them. Each of them has three values: strong, medium, and weak. The membership functions for each of these values are trapezoid functions (Fig. 2).

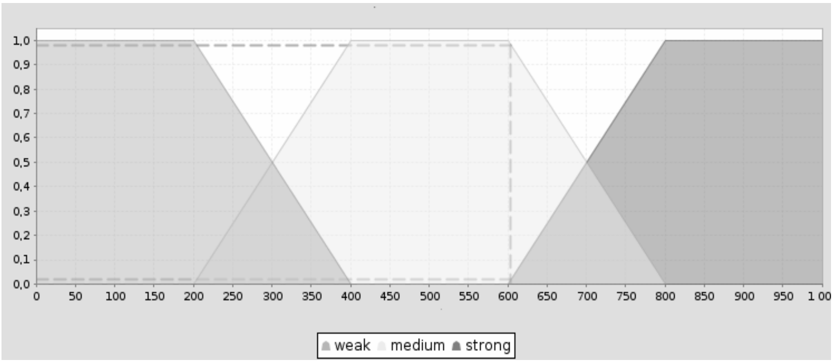

Fig. 2. Membership functions of fuzzy values of the linguistic variable of 'economic development'

As all the three indicators are normalized, the shape of the membership functions for individual values (states) is the same for all the linguistic variables.

The values of the linguistic assessment of sustainable development were divided into five categories (very bad, bad, medium, good, and very good). After defuzzification the result is given as an abstract value of the indicator form the interval <1-100> (Fig. 3).

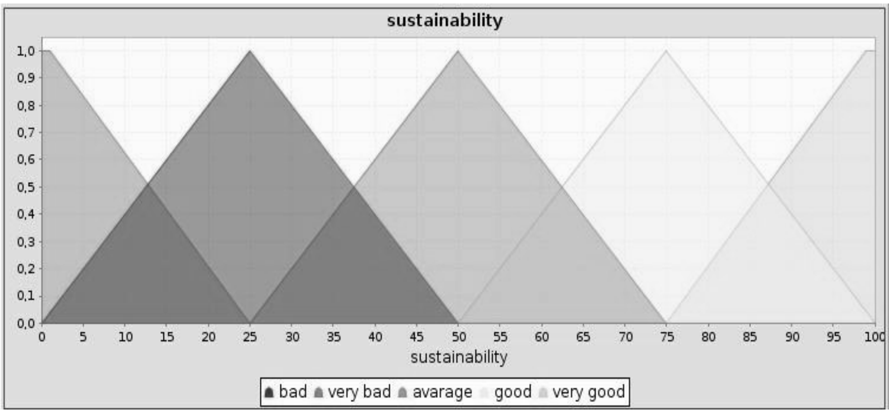

Fig. 3. Membership functions of fuzzy values of the linguistic variable of 'sustainability'

The rules in the list below (Table 2) represent the influence of individual indicators on the overall assessment of sustainability. Abbreviations: S – strong, M – medium, W – weak, VB – very bad, B – bad, A – average, G – good, VG – very good).

Table 2.

Environment	Social	Economic	Sustainability
S	S	S	VG
S	S	M	G
S	S	W	A
S	M	S	G
S	W	S	A
S	M	M	A
S	M	W	B
S	W	W	VB
S	W	M	B
M	S	S	VG
M	M	S	A
M	M	W	B
M	M	M	A
M	S	M	G
M	S	W	A
M	W	S	B
M	W	M	B
M	S	W	A
M	W	W	VB
W	S	S	G
W	M	S	A
W	W	S	B
W	M	M	B
W	M	W	B
W	W	M	B
W	W	W	VB
W	S	M	A
W	S	W	B

Fuzzification consists in the transformation of crisp values of indicators into fuzzy values of linguistic variables. For instance, if the value of economic development is E=0.25, then economic development is weak, E=weak, with the membership coefficient $\mu_{E=weak}$=0.75, and E=medium, with the membership coefficient $\mu_{E=medium}$=0.25 (see Fig. 1). Other indicators are transformed into fuzzy linguistic values in the same way.

Since the logical product (conjunction 'and') and implication were used in the rules, it is necessary to determine the functions to represent them. In the proposed method, the 'and' functor is expressed as the logical product of three fuzzy sets defined on three different universa. The simplest and most frequently used formula is applied here:

$\mu_{X1 \cap X2 \cap X3}(a_1,a_2,a_3) = \min[\mu_{X1}(a_1),\mu_{X2}(a_2),\mu_{X3}(a_3)]$

where:

X1- is the linguistic value expressing the level of economic development assessment;

X2- is the linguistic value expressing the level of environmental development assessment;

X3- is the linguistic value expressing the level of social development assessment;

a_1,a_2,a_3 – are the values of the assessment of economic, environmental and social development;

$\mu_{X1}(a_1)$ – is the degree of membership of the value a_1 to the set X1;

$\mu_{X1 \cap X2 \cap X3}(a_1,a_2,a_3)$ are the degrees of membership of the values a_1,a_2 i a_3 to the set that is the logical product of the sets X1, X2 and X3.

The implication used was the Mamdani fuzzy implication (Zimmerman, 2001):

$\mu_{X \rightarrow W}(x,y) = \min[\mu_X(x),\mu_W(y)]$

The degree of membership of the aggregate conclusion for several rules is determined with the max-min rule:

$\mu_{sust}(y) = \max_i [\min(\mu_{Xi}(x), \mu_{Wi}(y))]$

where:

$\mu_{sust}(y)$ – is the degree of membership of the final conclusion,

$\mu_{Xi}(x)$ – is the degree of membership of i rule requirements,

$\mu_{Wi}(y)$ – is the degree of membership of i rule conclusion.

Generally, the reasoning is based on the classical mechanism described, among others, in Lachwa, 2001 and in Zimmerman, 2001. A similar application and almost identical mechanism of reasoning was used in Liu, 2007. Defuzzification or the transformation of a fuzzy conclusion into a determined value of the sustainability indicator, was performed with the Center of Gravity function.

Verification of the Method

The proposed method was verified by applying it to a company operating in the paper industry. The assessed organization is located in central EU. The company produces cellulose pulp, paper, and cardboard. Its main source of emissions is the sodium boiler, although the company meets the nominal BAT requirements for an integrated manufacturer. The company's production in 2010 reached 8,927 tons, which does not significantly differ from the average production of an organization in this industry. The assessment of sustainable development level was performed based on the data from 2010. We obtained statistical data on the results from the paper industry and from the so-called companies burdensome to the environment. Table 3 lists the numerical values of individual indicators.

Table 3. Limit values and results obtained by the company

Indicator	Min	Max	Value obtained by the company	Normalized value
Ecological sphere				
Dust pollution emissions	0.36	1.39	0.4	0.96
Gas pollution emissions	0.49	0.58	0.55	0.33
Total energy consumption	0.61	1.2	1.1	0.16
Number of protected species exposed to risk by the company's activity	0		0	1
Total water consumption	18.1	59.9	33	0.64
Total amount of discharged sewage	16.1	52.2	47	0.14
Produced waste	23	60	42	0.48
Percentage of waste recycled	50	90	65	0.37
Expenditure on fixed assets related to environmental protection	35.1	42.1	22	0
Number of environmental fines	0		0	1
Economic sphere				
Sales revenue	28.1	33.7	28.2	0.017
State financial support		No data		
Total liabilities	0	10.6	8.8	1
Fixed investment		No data		
Investment	2.8	3.3	3.0	0.4
Taxes	0	19	19	1
Social sphere				
Employees' gross monthly salary	2782.93	4652.7	2900	1
Number of days of an employee's absence from work		No data		
Occupational accidents	0	1.7	1	0.41
Proportion of employees-trade union members	0	15	4	0.6
Number of women employed in management positions	10	50	16	0.15
Contribution to the development of local communities	0.028	0.073	0.01	0

On the basis of the above data, the following evaluation of the spheres was obtained:

- ecological 0.508,
- economic 0.604, and
- social 0.432.

The next stage of the method is fuzzification of the numerical indicators of the assessment of the companies' different spheres, their transformation into fuzzy values of linguistic variables.

The economic sphere was assessed as medium with the membership coefficient at μ=0.98, and as strong with the membership coefficient at μ=0.02 (Figure 4).

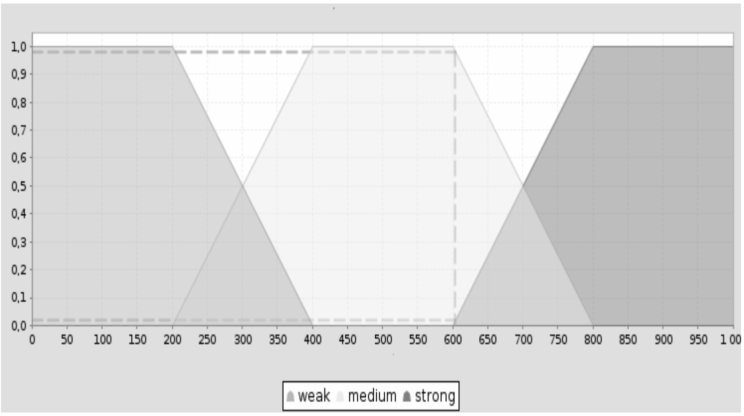

Fig. 4. Fuzzification of the economic sphere assessment indicator of the analyzed company

Social sphere is medium standing at μ=1.0 (Fig. 5).

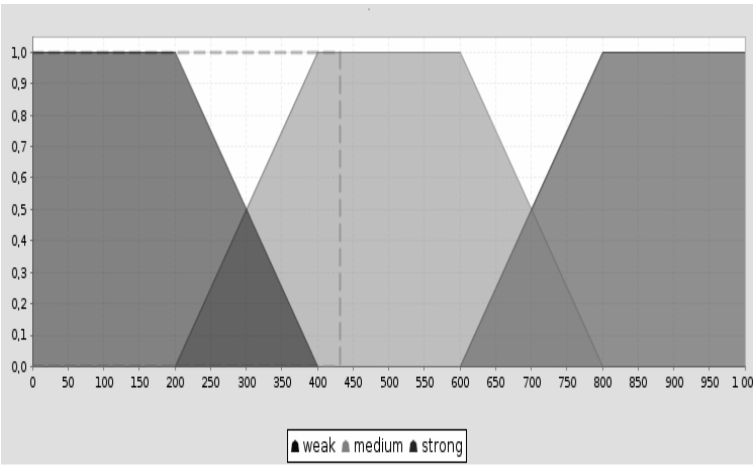

Fig. 5. Fuzzification of the social sphere assessment indicator of the analyzed company

Ecological sphere was assessed as medium standing at μ=1.0 (Fig. 6).

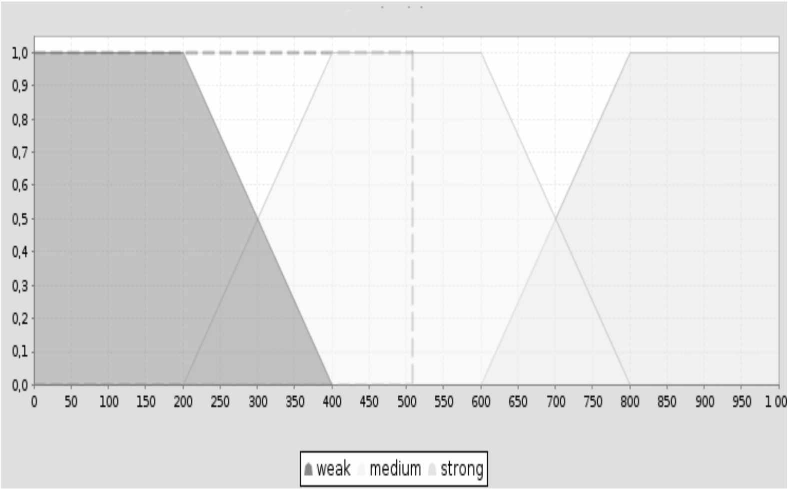

Fig. 6. Fuzzification of the ecological sphere assessment indicator of the analyzed company

In the reasoning process we applied the following two rules:

1. If the assessment of the economic sphere is medium, the assessment of the social sphere is medium, and the assessment of the ecological sphere is medium, then the overall sustainability assessment is average.
2. If the assessment of the economic sphere is strong, the assessment of the social sphere is medium, and the assessment of the ecological sphere is medium, then the overall sustainability assessment is average.

The conclusion of both rules is the average assessment of sustainability, and therefore the result of reasoning is a fuzzy set based on the membership function of the value 'average' of the linguistic variable 'sustainability'; it has the following form (Fig. 7).

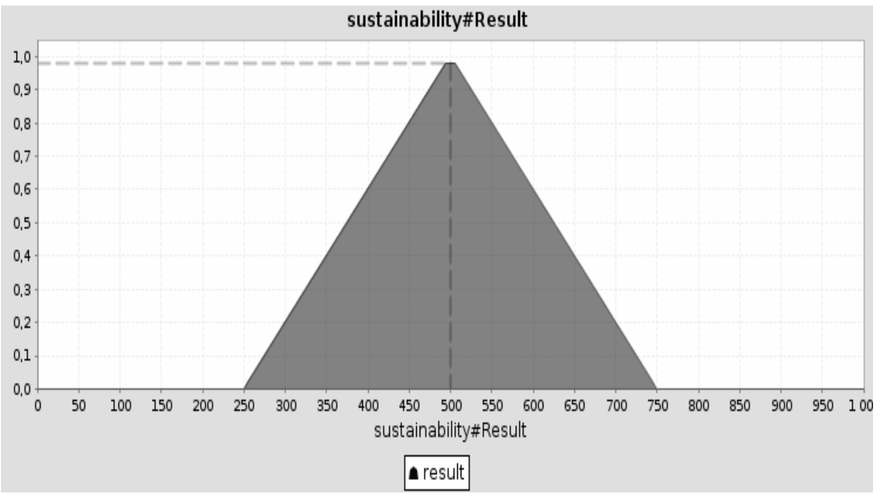

Fig. 7. The reasoning result

The next step is defuzzification, transformation of the initial fuzzy set into the specific numerical value. To achieve this, the Center of Gravity function was used. The final sustainability value after defuzzification and normalization to the interval <0;1> is 0.50.

Conclusion

Fuzzy logic provides a useful framework for assessing and managing organizational sustainability. Relative to the non-stochastic method, it 1) accounts for errors in measuring indicators or weights, and 2) addresses uncertainty regarding the relationship between the attributes and levels of sustainability. The application of fuzzy sets and reasoning to sustainability assessment makes it possible to apply simple and intuitively understandable "if… then…" rules in processing a number of indicators operating on various universa simultaneously obtaining a specific numerical sustainability assessment at the output. The main advantages of the method used here are intuitive understandability of the process of reasoning and result interpretation, objectivity and high customizability. For example, to change the influence of individual indicators on the overall evaluation, it is sufficient to slightly change the membership functions of the respective linguistic variables without changing the very mechanism of reasoning.

Flexibility of the method allows for a change of the number of indicators, the use of selected indicators, the use of indicators expressed in different units of measurement, as well as introducing weights to their assessment (although in the "original" version of the method, weights were not included). Unfortunately, those advantages are achieved at the cost of high complexity of calculations related to fuzzification, reasoning and defuzzification of the value of indicators. An important feature is the non-linear influence of the changes in the values of individual indicators on the overall sustainability assessment. Generally, the sensitivity of the overall sustainability assessment to changes in initial values of indicators is strongly dependent on the number of states of linguistic variables and on the shape of their membership function.

The proposed method is essentially important for the practice of management of organizations. It may be used to assess the level of sustainable development of an organization only on the basis of its economic, ecological, and social results. It does not require in-depth knowledge of causal relationships within sectors or on the market. The results it provides may become a reference for repair plans, ecological programs, and in the process of strategic decision-making. At the same time, due to the annual updating of the limit values, the results reflect dynamic changes occurring in the company and in the industry in which it operates. Contrary to other methods, our proposal makes use of the parameters external for an organization as the limit values. As a result, the method has a high level of objectivity. Therefore, it may be used to compare organizations.

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