CWW Enhanced Fuzzy SWOT Evaluation for Risk Analysis and Decision Making under Uncertainty

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***Abstract*—The SWOT analysis is a method used worldwide to assist in the decision making in industrial, and business management, as well as in banking, military planning operations, and science. Without question, it is seen as an obligatory tool on both the governmental level, as well the personal. Until now, all data had to be collected from the experts and the decision makers in numerical form, and be presented in numerical form. In this paper, we aim to enrich the SWOT analysis using the 'Computing with Words' paradigm for expert knowledge extraction in a verbal form. By presenting data in this format, we allow experts to express their opinion alongside possible uncertainties. Moreover, enriched SWOT analysis results are extremely useful for the risk analysis and decision making.**

Keywords—SWOT analysis, computing with words, fuzzy, risk analysis, decision making, uncertainty

I. INTRODUCTION

There are many numerous methods for extracting knowledge from experts throughout the varying fields of academic and professional activity. If some information about one specific area is needed, it is not mandatory to have deep knowledge in that area. This is the case where field experts take a major role, and the method itself is only needed to save extracted information in a structured form. Generally, data extraction and the structuring process can be defined as:

Data → Information → Knowledge → Wisdom.

Data extraction is always performed in a certain form of dialogue. Experts from different fields often use different terminology to describe the same objects, just from different perspectives. The biggest challenge is to conduct a successful conversation with an expert so that the opinion would be expressed adequately. For this purpose, a widely used SWOT analysis method, enriched with the 'computing with words' paradigm, was used for a verbal knowledge expression and uncertainties evaluation. The results of such analysis can also be expressed in linguistic form, providing information for the risk management and decision making.

Chapter 2 contains a related work section, chapter 3 describes CWW enhanced SWOT analysis methodology, and chapter 4 describes risk management and decision making. In chapter 5, experimental simulation is presented, and chapter 6 concludes everything with remarks.

II. RELATED WORKS

SWOT analysis enhanced by the 'Computing with Words' methodology is described in [10]. This article mainly focuses on the use of analysis under uncertainties for experts' knowledge extraction, and the use of analysis results in risk management and decision making. The idea is that risk is not simply a loss multiplied by the probability, but that there are also positive risk options, described in [4]. The risk management part in this work is based on a composed risk formula, presented in [7], that links risk analysis inputs and SWOT analysis outputs.

III. CWW ENHANCED SWOT ANALYSIS

It is known that SWOT stands for strengths (ST), weaknesses (WK), opportunities (OP), and threats (TH) that surround any idea, plan, or project to be investigated and / or implemented. Opportunities and threats are usually defined as external issues of the project and signify possible positive and negative achievements once the project is realized. At the same time, strengths and weaknesses mean internal issues enable, and impede, the achievement of both the main goals and the development of projects. A quantitative interaction between OPs, THs, STs and WKs is usually expressed by a numerical SWOT matrix which shows the influence of STs and WKs on strengths and threats [10].

This article aims to find ways on how to use verbal qualitative evaluation in the process of delivering descriptions of data necessary for SWOT analysis. Attempting to perform necessary SWOT computations and deliver the obtained SWOT analysis results in a verbal form OPs, THs, STs and WKs were characterized by means of using words. It indicates that CWW (Computing with Words) methodology enriches SWOT methodology and creates a possibility for SWOT users and decision makers to communicate using words of common language. We propose and investigate new possibilities to apply and enrich SWOT analysis mechanisms, using elements of artificial intelligence, and the computing with words paradigm. This approach is novel due to the originality of the encoding of input words that describe the investigated situation in a new functional organization of the SWOT engines. Put simply, the method, decodes and aggregates numerical outputs into a verbal form. The main idea of CWW enhanced SWOT analysis is to take verbal descriptions as input, convert that data into numbers for internal computation using a 'fuzzy logic' engine, and translate the result to the user in a verbal form (as shown in Fig. 1).

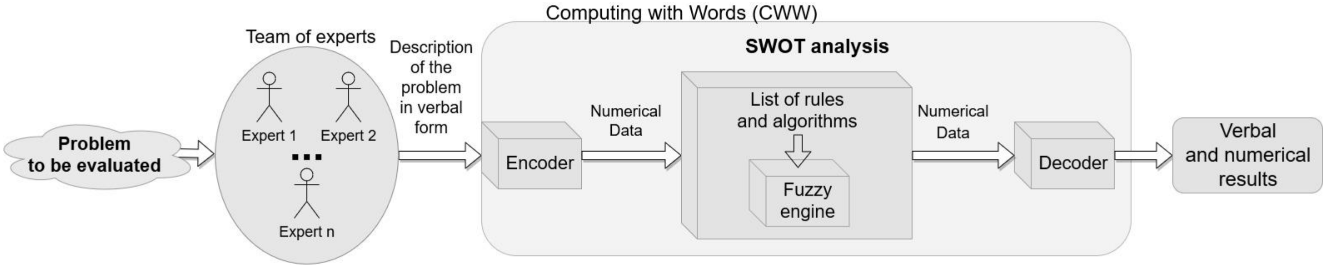


Fig. 1. Functional structure of SWOT+CWW methodology.

It is not necessary to have the knowledge on a specific domain – this is the role of experts. A certain number of experts can describe the situation and all the dynamics of the domain. The main focus is to collect required expert information for analysis and data storing. The most convenient way to describe a situation for any human being is to express it verbally instead of using numbers but some level of uncertainty arises from those words. Computational systems are based on a numerical data, so data encoding, and decoding, is needed. In line with the CWW paradigm, all inputs and outputs to the user (expert) are in a verbal form. All the internal SWOT analysis computations using CWW paradigm are performed using a black box principle. When an expert characterizes the information and dynamics for the domain, all this information and data is processed by a translated list of rules and algorithms. Rules and algorithms are determined by expert's described dynamics of the field and used to translate between numerical and verbal data using 'Fuzzification' and 'Defuzzification' with fixed membership functions (displayed in Fig. 2).

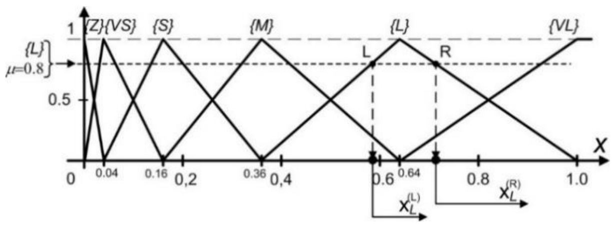


Fig. 2. Fixed CWW fuzzy membership functions.

The 'Fuzzy logic' engine calculates a numerical value of a given verbal term and a value of uncertainty by assigning a membership function. The number of different verbal terms describes input words as possibilities. But, according to "Miller's law" [6] (The Magical Number Seven, Plus or Minus Two), a human can differentiate approximately up to seven different verbal evaluations. This CWW enhanced SWOT analysis verbal data input and output dictionary are selected based on this law. It used six different terms:

- "Zero" ({Z}),
- "Very small" ({VS}),
- "Small" ({S}),
- "Medium" ({M}),
- "Large" ({L}),
- "Very large" ({VL}).

Each verbal term from the selected dictionary has its triangular form. The peak of each triangle on the X axis represents a numerical value for verbal terms in case of an absolute certainty. Left and right shoulders of the triangle represent uncertainty. In an example (Fig. 2), an expert expressed an opinion as "Large" with a degree of certainty (μ) as 0.8. Left shoulder of term "Large" ($X_L^{(L)}$) is the pessimistic value of uncertainty and the right shoulder ($X_L^{(R)}$) is optimistic.

When all data needed for SWOT analysis is submitted in that form, aggregated opportunity OP_{Σ} and TH_{Σ} values are calculated. Due to the data being translated in two ways (pessimistic and optimistic), there is a possibility for multiple perspectives of the results that can serve as a possible input data for risk analysis methodology.

IV. Risk Analysis and Decision Making

Risk is the level of uncertainty of action (results). Most of the methodologies interpret that risk directly depends on threats. In our approach we reference to Hillson [4] and state that risk is symbiosis of opportunities and threats. To implement this idea, we have associated risk components with SWOT analysis.

A. *Risk analysis*

In the context of a risk analysis, opportunities and threats can be associated with SWOT analysis components with opportunities and threats components; efforts and hesitancies also make an impact. Efforts can be expressed as investments in a risk analysis process, and hesitancies are the level of uncertainty. In our approach, risk can be described as:

$$\boldsymbol{R} = \mathbf{R}(\boldsymbol{EFF}\uparrow; \boldsymbol{OP}\downarrow; \boldsymbol{TH}\uparrow; \boldsymbol{HES}\uparrow) \quad (1)$$

The concept of risk combines:

- Activity (EFF/efforts/input/ ...);
- Potentially positive results (OP/ achievements/attainments/ ...);
- Potentially negative results (TH/ losses/defeats, …);
- Uncertainties (HES/hesitations/instabilities/options/probabilities/ ...).

OP and TH components of risk are strictly related to SWOT analysis outcomes ($\boldsymbol{OP_{\Sigma}}$ and $\boldsymbol{TH_{\Sigma}}$). Risk can be evaluated by combining it with an expert evaluation about required efforts (EFF) and (if needed) uncertainties (HES) evaluation. Risk evaluation can be estimated, and actions taken if necessary. Furthermore, verbal advices or visual representation of the results can be done.

B. *Decision making*

A decision is a commitment to a proposition, or a plan of an action based on the information and values associated with the possible outcomes. The process operates in a flexible timeframe that is free from the immediacy of evidence acquisition and the real time demands of the action itself. Thus, it involves deliberation, planning, and strategizing [8]. The study of decision making is a multidisciplinary field. It occurs in psychology, statistics, economics, finance, engineering (e.g., quality control), political science, philosophy, medicine, ethics, and jurisprudence. There are many conflicting criterions that need to be evaluated in making decisions in our daily or professional lives.

Research on a multi-criteria decision support developed two main groups of methods, i.e., American and European schools. Methods of the American school of decision support are based on a functional approach, more precisely the utility or value function. Researchers from the European school emphasize the fact that many methods do not consider the variability and uncertainty of expert judgments. However, the most common solution to this problem is to use granular mathematics, e.g., fuzzy sets theory or interval arithmetic [5].

V. EXPERIMENTAL SIMULATION

Generally, a lot of SWOT analysis tools were created, but they lack verbal operations. For this reason, a prototypical SWOT enhanced CWW analysis tool was created and used to test the effectiveness of the described methodology. Pilot testing was made on “Construction of a new hotel complex in a particular area” example from [11]. The example itself has already been analyzed in article and all SWOT analysis data is accessible for the use and the comparison of the results.

A. *Data input*

SWOT enhanced CWW tool data input is processed by one component at a time. There are two groups of identical data input:

1. Opportunities and Threats;
2. Strengths and Weaknesses.

The user must enter a title and a short acronym of every SWOT analysis component (row number is generated automatically if not specified). When the user submits OP or TH information, a degree of importance (impact) and value of truth (membership value) evaluations needs to be specified. Estimation itself is entered in a verbal form. The input of the opportunity is shown in Fig. 3.

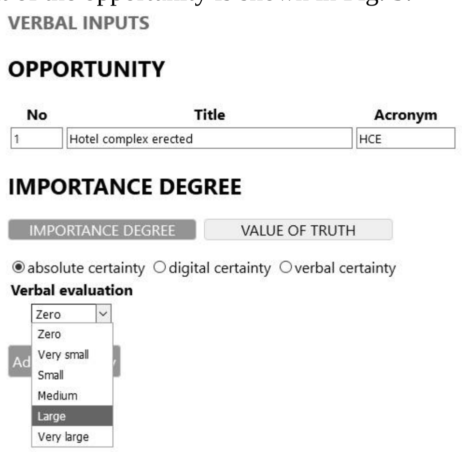


Fig. 3. Opportunity input.

The second step in data input procedure is ST and WK information as well as the data of influences. Information about strength or weakness is entered analogous to opportunities and threats. Procedure of the influence input is as follows: the user chooses ST or WK component from the existing list and then specifies the influenced component (OP or TH). Value of influence is entered in a verbal form. There are three ways to express certainty about the given evaluation:

1. Absolute certainty – used, when there is no doubt about given estimate;
2. Digital certainty – used, when there is some uncertainty which can be evaluated;
3. Verbal certainty – possibility to express both evaluation and a level of certainty about that evaluation in verbal form.

Strength input is shown in Fig. 4.

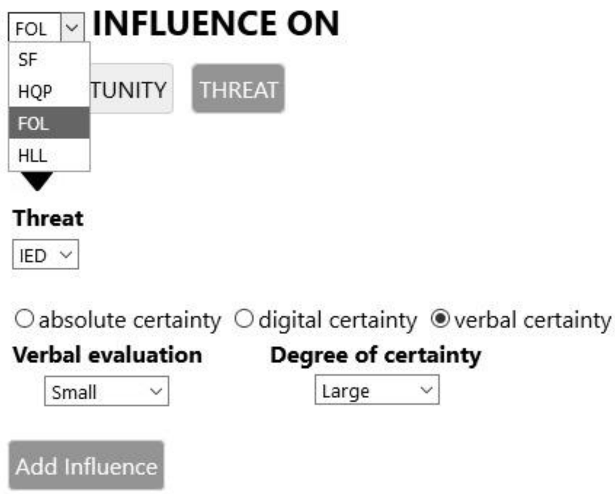


Fig. 4. Strength influence on threat.

B. *Testing situation*

Pilot testing was done using example from [11]. List of opportunities is shown in the TABLE I.

TABLE I. LIST OF OPPORTUNITIES

No.	Acronym	Name
1	HCE	Hotel complex erected
2	MID	Modern infrastructure developed
3	HPO	High profit obtained

List of threats is shown in the TABLE II.

TABLE II. LIST OF THREATS

No.	Acronym	Name
1	IED	Increased erosion of dunes
2	IPE	Increased pollution of environment

List of strengths is shown in the TABLE III.

TABLE III. LIST OF STRENGTHS

No.	Acronym	Name
1	SF	Significant financing
2	HQP	High quality of personnel
3	FOL	Flexibility of law
4	HLL	High level of lobbying

List of weaknesses is shown in the TABLE IV.

TABLE IV. LIST OF WEAKNESSES

No.	Acronym	Name
1	LOI	Lack of infrastructure
2	HLS	High level of storms
3	IPC	increasing protests of local community

All SWOT analysis components and evaluations are presented in a matrix. A SWOT evaluation matrix is shown in TABLE V.

TABLE V. SWOT EVALUATION MATRIX

	c	ρ	SF	HQP	FOL	HLL	LOI	HLS	IPC
HCE	L	S	L				M		
MID	L	S		S	M	M			M
HPO	M	M	L				M	M	
IED	L	S			S	L	S		M
IPE	L	S	M			M		M	

“Degrees of importance” (c), “Values of truth” (ρ) and influences are shown in verbal form (S – small, M- medium, L- large). Some of the words (Z - zero, VS - very small and VL - very large) did not occur in our model.

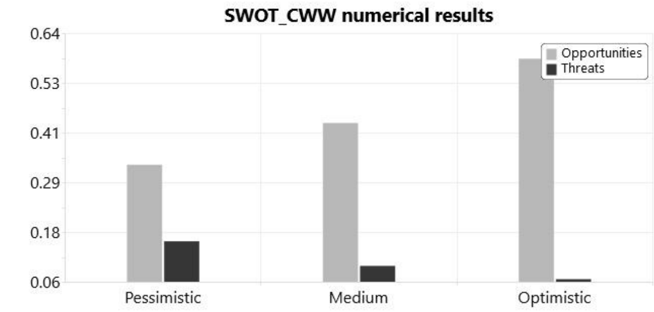
C. Experimental results

The final evaluation of summarized opportunities OP_{Σ} as well as threats TH_{Σ} is performed according to formulas (2) and (3):

$$OP_{\Sigma} = \sum_{o=1}^{O}\{c_o(\rho_o + \sum_{s=1}^{S} ST_{os} + \sum_{w=1}^{W} WK_{ow})\} \quad (2)$$

$$TH_{\Sigma} = \sum_{t=1}^{T}\{c_t(\rho_t + \sum_{s=1}^{S} ST_{ts} + \sum_{w=1}^{W} WK_{tw})\} \quad (3)$$

SWOT analysis results are shown in Fig. 5.



Verbal evaluation

Pessimistic	Opportunities: **VS:0.4, S:0.6**	Threats: **VS:0.67, S:0.33**
Medium	Opportunities: **VS:0.13, S:0.87**	Threats: **VS:0.91, S:0.09**
Optimistic	Opportunities: **S:0.83, M:0.17**	Threats: **Z:0.1, VS:0.9**

Fig. 5. Numerical and verbal results.

By given SWOT analysis evaluations, results are calculated and presented in three ways:

1. Optimistic – the best possible result of an overall Opportunities and Threats evaluation (Best opportunities size);
2. Pessimistic – the worst possible result of an overall Opportunities and Threats evaluation (Worst threats size);
3. Medium – the average result of overall Opportunities and Threats evaluation (Realistic view);

The tool shows numerical results in a graphical form and verbal results are shown at the bottom as the value and the certainty. Looking at the pessimistic perspective of this model, the resulting opportunities are estimated as very small (VS) with 0.4 certainty and as small (S) with 0.6 certainty. Meanwhile in the optimistic perspective common opportunities are estimated as small (S) with 0.83 certainty, and as medium (M) with 0.17 certainty. These results reflect the hotel complex building in Palanga Lithuania (example from article [11]).

VI. CONCLUDING REMARKS

This paper suggests the use of verbal descriptions for SWOT analysis data input. A new prototypical software tool based on Hillson’s ideology and methodology about enriching SWOT analysis with the CWW paradigm was created. Successful experiment simulation based on a created tool was made and simulation results were presented. Those results can serve as expert information for risk management and decision making.

Further research objective is to create a network of tools for more complex situation analysis with more than one SWOT analysis possibility. The main idea of SWOT enhanced CWW network is to use one SWOT analysis results as an influence on another connected SWOT analysis results.

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