Fuzzy Evaluation of SWOT Analysis

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***Abstract*— To develop a strategy for an organization it is important to understand the organization and its surrounding environment. Strength, Weakness, Opportunity, Threat (SWOT) analysis is a famous tool to perform this task precisely by showing the strength, weakness of the organization and the external factors, opportunities and threats that affect its success. SWOT analysis is commonly used by business; however, non-profit organizations also use SWOT analysis for decision-making and strategy evaluation. The limitation of SWOT analysis is that it does not give weight for the factors and there is no quantified result from the analysis. The methods introduced in this paper are Sugeno lambda measure and Choquet fuzzy integral. Sugeno lambda measure is used for aggregating the importance of characteristics and Choquet fuzzy integral is used for the overall analytical evaluation of strength, weakness, opportunity and threat of a specific organization. The methods discussed in this paper provide a way to quantitatively evaluate SWOT analysis of an organization, without having to worry about dependencies among characteristics. A case study has been conducted for a currency exchange office and the region of Pardubice, Czech Republic (CR) to explain the application of the proposed approach for profit and non- profit organizations.**

***Keywords*—** *Choquet fuzzy integral, Strategy evaluation, Sugeno fuzzy integral, Sugeno λ-measure, SWOT analysis, fuzzy membership function, Yager's ranking indices*

1. Introduction

Preparing a strategy for any organization should include a process to help identify and understand certain variables such as the purpose of the organization, its financial status, competitors, its environment and its future. Strategy evaluation is an essential process of strategy planning. Strategy evaluation process is ongoing as long as the organization exists. Generally the result of a strategy evaluation include answers to questions: Are the objectives of the enterprise appropriate?, Are the major plans and policies appropriate to achieve the objectives?, Do the results confirm that? and so on. It should be noted that strategy evaluation is used or should be used not only for profit organizations but also for non-profiting organizations. Different tools and methods are used to understand the aforementioned variables; this paper particularly focuses on SWOT analysis. The SWOT analysis is a preferable way to understand the position of an organization with respect to its environment [10]. In order to improve the success of an organization it is important to understand What the organization is doing right?, If what the organization is doing right is important?, What the organization is doing wrong?, What obstacles the organization faces? and What opportunities the organization should exploit?. SWOT analysis is a famous tool to shade light on these questions. Using SWOT analysis the strength, weakness, opportunity and threats of an organization could be explained.

The objective of this paper is to provide methods that quantitatively evaluate SWOT analysis of an organization. Sugeno lambda measure and Choquet fuzzy integral were used to numerically analyse characteristics and sub characteristics of SWOT analysis.

2. Literature review

As briefly mentioned in the introduction SWOT analysis is used for analysing an organization's strength, weakness, the opportunities at its disposal and the threats it is facing. These variables should be identified by experts since this is the corner stone of the whole analysis. After a selected group of experts choose SWOT sub characteristics and their priorities, the evaluation of how the organization is doing on these selected characteristics is collected based on the status of the organization. Finally, Sugeno lambda measure and Choquet fuzzy integral are used to analytically evaluate these variables.

2.1 SWOT analysis

SWOT analysis is used for identifying the importance of sub characteristics in order to choose the best strategy for an organization. However, this practice does not provide analytical means to evaluate importance of characteristics. Some authors have proposed methods to quantify results of a SWOT analysis: analytic network process to develop an evaluation method for SWOT analysis [23], application of a quantification SWOT analytical method

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[3], application of fuzzy analytic network process in SWOT analysis[16], [9].

Businesses perform SWOT analysis when entering a new market, to evaluate their strategy or while launching a new product. SWOT stands for Strength, Weakness, Opportunity, and Threat [10], [11]. Strength and weakness are most often viewed from the organization's point of view whereas opportunities and threats are considered as external environmental factors. Strength is what an organization has or what it can offer that others of its type do not. Weakness in opposite is what an organization does not have or does not offer others of its type do. Opportunities are advantages in the environment that an organization could use. Threats are situations in an organization's environment that could compromise the organization's success. The SWOT analysis can also be used for non-profit organizations, governmental units and for individuals for decision-making situation when a desired objective has been defined [1], [8], [15]. SWOT sub characteristics and their priorities are highly dependent on the type of organization [3], [10], [11], [23] the figure (Fig. 1) below shows the general description of SWOT characteristics in a hierarchical structure.

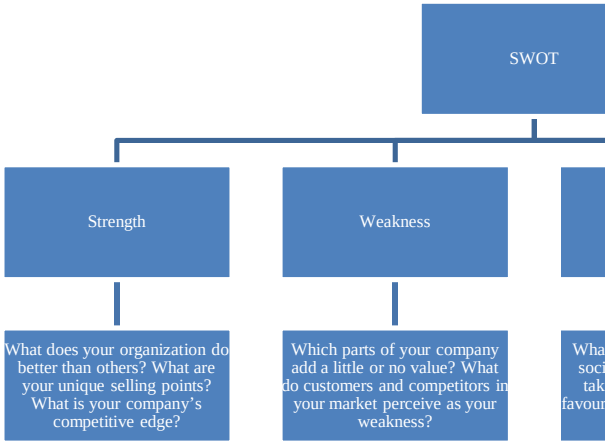

Figure 1 SWOT analysis and some questions its sub characteristics should address (Source: Process based on [10], [11])

What is proposed in this paper is fuzzy integral method, if Choquet fuzzy integral method is used there is no need to consider dependencies among SWOT sub characteristics and additional effect of each sub characteristic on the overall performance of a strategy is evaluated. This method is used for quantitatively evaluating an organization's strategy and its effectiveness, based on importance of characteristics and the productivity or profit of the organization.

Expert opinion should be used to identify importance of sub characteristics. The status of the organization can be used to find actual value that shows in which parts the organization is doing well and where the strategy should focus more in the future.

2.2 Fuzzy integrals

Fuzzy integrals are interesting tools to summarize all the pieces of information provided by a function in a single value; this value could be a sort of average of the function, in terms of the underlying fuzzy measure. Fuzzy integrals permit the aggregation of information under different assumptions on the independence of the information sources. In particular, to model situations in which sources are independent as well as in situations in which such independence cannot be assured. Many authors have used fuzzy integrals, among are: Measuring Software Product Quality with ISO Standards based on Fuzzy Logic Technique [22]. Authors in China have used fuzzy integrals for comprehensive framework for measuring the performance of an organization resource planning [21] and other researchers have used fuzzy integrals for handwritten signature verification [17] and many others [2], [19], [20].

Fuzzy integrals use the term fuzzy measure which does not require additivity. Fuzzy measure can be defined as:

Let X be a finite index set X = {1, ..., n}.

Definition 1: A fuzzy measure μ defined on X is a set function $\mu : P(X) \rightarrow [0,1]$ satisfying the following axioms [5][18]: $\mu(\varnothing) = 0$, $\mu(X) = 1$, and $A \subseteq B \Longrightarrow \mu(A) \leq \mu(B)$.

The P(X) indicates the power set of X, i.e. the set of all subsets of X.

A fuzzy measure on X needs 2^n coefficients to be defined, which are the values of μ for all the different subsets of X. Fuzzy integrals are integrals of a real

function with respect to a fuzzy measure, by analogy with Lebesgue integral which is defined with respect to an ordinary (i.e. additive) measure. There are several definitions of fuzzy integrals, among which the most representatives are those of Sugeno fuzzy integral [18] Choquet fuzzy integral [4].

Choquet fuzzy integral was chosen over Sugeno fuzzy integral for this paper since the Sugeno method is based on min and max, such integral calculation can only determine interval at which the measured values are possibly located, unlike Choquet fuzzy integral, which provides a unique solution.

Definition 2: Let μ be a fuzzy measure on X. The discrete Choquet fuzzy integral of a function f: X→IR+ with respect to μ is defined by

$$C_{\mu}(f(x_1), ..., f(x_n)) = \sum_{i=1}^{n} (f(x_1) - f(x_{i-1}))\mu(A_i) \quad (1)$$

Where i indicates that the indices have been permuted so that $f(0) \leq f(x_1) \leq \ldots \leq f(x_n) \leq f(1)$. Also $A_i = \{x_i, ..., x_n\}$, and $f(0) = 0$.

Definition 3: Let $\lambda \epsilon (-1, \infty)$ and let $X = \{x_1, x_2, \ldots, x_n\}$ be a finite set. If (X, P(X)) is a measurable space and if set function g_λ: P(X)→[0,1] satisfies the following conditions, then g_λ is denoted by a Sugeno λ measure and $g_\lambda(\varnothing)=0$, $g_\lambda(X)=1$; $A \cap B=\varnothing$, $A \cup B \neq X$ $g_\lambda(A \cap B)=g_\lambda(A)+g_\lambda(B)+ \lambda g_\lambda(A)g_\lambda(B)$ that

$$\lambda + 1 = \prod_{i=1}^{n} (1 + \lambda g_\lambda(x_i)), \ \lambda > -1 \quad (2)$$

where $g_\lambda(x_i)$ is fuzzy measure.

Definition 4: Let set function g: P(X)→[0,1] be a fuzzy measure on measurable space (X,P(X)), and h: X→[0,1] be a measurable function on X. If $h(x_1) \leq h(x_2) \leq \ldots \leq h(x_n)$, $A_i=\{x_i, x_{i+1}, \ldots., x_n\}$ then [4],[6]

$$E^{def} = \int h dg^{def} = h(x_1)g(A_1) + \sum_{i=2}^{n} (h(x_i) - h(x_{i-1}))g(A_i) \quad (3)$$

Where E^{def} denotes the overall function, $h(x_i)$ is viewed as the performance of sub characteristic x_i of the organization at a specific time. $g(A_i)$, express the grade of importance for the subset Ai. The fuzzy integral of $h(x_i)$ with respect to g denotes the overall evaluation.

3. Methodology

The limitations of SWOT analysis, i.e. not providing analytical analysis could be solved by using the fuzzy measure and fuzzy integral methods discussed in the above section. By using Eq. (3) discussed in section 2.2, the overall evaluation for each, Strength, Weakness, Opportunity and Threat is obtained. From these aggregated values, status of an organization with respect to its environment is determined. The organization can use the output for amending a strategy and/or for developing a new strategy based on the numbers obtained from the fuzzy aggregation. The method can also be used to compare different strategies.

The following are the main steps in evaluating strategy and its effectiveness:

1. Change the importance values to decimal values between 0 and 1
2. Change the performance values (weight) to decimal values between 0 and 1
3. Calculate for λ for each level
$$\lambda + 1 = (1 + \lambda g_\lambda(S1))(1 + \lambda g_\lambda(S2))(1 + \lambda g_\lambda(S3)), \ \lambda > -1 \quad (4)$$
4. Calculate the combined effect of sub characteristics using the formula
$$g_\lambda(A, B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B) \quad (5)$$
and so on until all sub characteristics at this level are analysed
5. Calculate evaluation value for higher level according to Eq. (3).

The result from this analysis is aggregated performance of the strength of the organization; the same procedures are used to determine Weakness, Opportunity and Threats. Based on the result we can evaluate existing strategy and decide whether to keep the strategy or propose a new one.

4. Discussion and Result

This paper describes how to use Sugeno lambda measure and Choquet fuzzy integral to analytically analyse characteristics and sub characteristics of the SWOT analysis. The importance of higher characteristics is evaluated based on sub characteristics. The hierarchical structure of SWOT analysis represents sub characteristics of the SWOT analysis for each characteristics and the success of a strategy is valuated based on the importance and weight of these sub characteristics. An evaluation of a strategy of an organization is highly subjective and uncertain; hence, it is appropriate to use fuzzy measure instead of traditional additive measures. Fuzzy integrals consider the worth of each sub characteristic and their performance as an input. It is considered that a perfect organization is strong, has overcome all its weaknesses, exploited all the possible opportunities and has no threats. Although that is impossible, an organization's strategy is expected to have a higher value for strength and opportunity and a lower value for weakness and threat.

The Sugeno λ-measure applied in this paper is one of fuzzy measures used widely, and has plenty applications

recently, including pattern recognition. SWOT sub characteristics for a specific organization could be selected and prioritized based on expert opinions or experience of the organization. After obtaining the individual importance and performance of the sub characteristics, fuzzy integrals are applied to find the overall performance of the characteristics (Strength, Weakness, Opportunity and Threats).

The main procedures applied in the proposed method for evaluating SWOT characteristics and their effectiveness for a currency exchange office and for analyzing the region of Pardubice, CR are discussed in the following sub sections.

4.1 Application of proposed method for foreign currency exchange office

There are many currency exchange offices in Prague some of these offices buy and sell foreign currencies for a small difference and they make their profit by buying and selling a large amount of foreign currencies per day while others make a better profit from each unit of currency they buy and sell and make significantly less amount of transaction. The currency exchange company, studied here, uses the second method and has more than five offices each making a small amount of transaction a day.

The data shown in the following table (Table 1) was gathered from one of these currency exchange offices. This data was used only as an empirical example to clarify the application of the discussed methods. The SWOT sub characteristics were selected and assigned importance and performance (weight) value by the staff of the company based on their experience in that office and in comparison of their other exchange offices located in Prague [7].

The sub characteristics are defined by the following way: S1 is Location of the exchange, S2 is Customer service and S3 is Promotion for Strength; W1 the exchange share the same main door with a mini market hence too many people come through the door , W2 is Reserved money in the exchange and W3 is Not a tourist center for Weakness; O1 is there are restaurants next to the exchange, O2 is No direct VAT and O3 is the number of hotels and hostels around the exchange for Opportunity; T1 is Changing to euro, T2 is automated teller machine (ATM) and T3 is there are two more exchange places for Threats. The following table contains the data after it was transformed in to [0,1] scale.

As shown in the table below (Table 1), strength of this company is the location, customer service and promotion. The importance of a location of an exchange office is evaluated to be 0.6 out of 1and the location of this particular exchange is very good since it is located on the building right next to a traffic light, 0.9 out of 1. They also have a good customer service, which they believe is 0.9 out of 1 and the importance of good customer service for the success of the exchange is evaluated to be 0.4. The importance of promotion is also 0.4 for exchange and they have a Very good promotion.

Table 1. Input data from experts and calculated λ

Characteristics	Importance	Weight	λ
S1	0.6	0.9	-0.69
S2	0.4	0.9	
S3	0.4	1	
W1	0.2	0.2	-0.46
W2	0.5	0.7	
W3	0.5	0.8	
O1	0.6	0.4	-0.97
O2	0.2	0.7	
O3	0.7	0.9	
T1	0.8	0.3	-0.92
T2	0.5	0.4	
T3	0.5	0.5	

It is important to note that this experiment was only done for one branch of the exchange company to explain the application of the method.

The step by step procedure to evaluate the SWOT analysis performed for the exchange office is shown below

1. λ was calculated for each level
   $\lambda+1=(1+\lambda g_\lambda(S1))(1+\lambda g_\lambda(S2))(1+\lambda g_\lambda(S3)),\ \lambda>-1$
   $\lambda+1=(1+0.6\lambda))(1+0.4\lambda)(1+0.4\lambda),\ \lambda>-1$
   for Strength (S)
2. The data was arranged according to $h(x_1)\le h(x_2)\le\ldots\le h(x_n)$
   $g_\lambda(S1,S3)=0.83, g_\lambda(S2,S3)=0.69$
   $g_\lambda(S1,S2,S3)=1$
3. Combined effect of sub characteristics was calculated using fuzzy measure

The same procedure is used for W, O and T

4. The aggregated value for each characteristics was calculated using Eq. (3)

The same procedure is used to find the values for the rest of the characters. The result of the evaluation is shown in the following table (Table 2):

Table 2. Evaluated value for strength, weakness, opportunity and threat

Strength	Weakness	Opportunity	Threat
0.94	0.25	0.54	0.44

Based on these results the company over all has good strength but they also have weakness they could improve their weakness more by reserving more money and they could change their offices to a more tourist center since the combined effect of these two sub characteristics is significant. The opportunity at their disposal is 0.54, these are the factors the company could not control, but in the future they could choose a place in an area where there are more hostels and restaurants in order to increase their success. Finally the threat is that they worry about the country changing the currency to Euro and that makes them cautious to invest more in the business and that many people are using credit cards, unfortunately they can not do anything about that.

4.2 Application of proposed method for analyzing Pardubice region

Pardubice region is among the smallest region of the CR, both of area or population, which is reflected in its economic performance, which moves among average, below average or mild zones in comparison with other regions. For example, the formation of the National Gross domestic product Pardubice region accounts for only 4%, which is the third lowest contribution in CR. On the gross value added (GVA) to the region's central role in industry, whose share in GVA in 2011 amounted to 36.9% (which is about 25% more than the national average). Many factors contribute to this result; processing and manufacture, followed by sub-sectors of the services sector (service sector contributes more than half the total mostly on the structure of GVA). Among the services are outstanding logistics services - transport, storage and communications followed by trade and repair of motor vehicles and products. The region has excellent export performance, contributing 7.7% to the total export of CR (4th place among the regions). Pardubice region has diversified and managed to keep a relatively strong industrial base. Regional innovation and research system of the region in the CR is on the average level [6], [13], [14].

The aggregated quantized SWOT analysis was calculated based on the evaluation of experts opinion and using Sugeno λ-measure Choquet fuzzy integral. The experts opinion is used to determine how strong is the region's strength, how weak is its weakness, how effective are the opportunities at the region's disposal and how well are they being exploited and how bad is the Threat the region is facing and how eminent it is.

The sub characteristics are defined by the following way: S1 is the industrial tradition and proportion of manufacturing industry in the creation of gross domestic product (GDP), S2 is Share of exports of medium and high-tech industries from the region, S3 is The share of innovative enterprises in the manufacturing industry, S4 is Activity of regional innovative companies in the use of public programs to support research and development (R&D) purpose and infrastructure, e.g. the TIP, Alpha and Prosperity program, and S5 is Simplification of administrative burden for recipients of public support for R & D (Public Procurement Act, etc.) for the Strength. For the Weakness: W1 is Level of gross fixed capital formation (ie. low investment activity entities in the region, and so on), W2 is Innovative infrastructure, W3 is Interest of key actors in R&D and regional and local political representation on the implementation of existing RIS and promote the knowledge economy, W4 is Barriers to the development of cooperation between the public and private sectors, W5 is Participation in 7^{th} framework program (FP7) in comparison to other regions but significantly below average in international comparison with EU-15.

For the Opportunity: O1 is Geographical location and transportation access, O2 is Process preparation of Structural Fund 2014+ that will lead to an open partnership and cooperation between different actors in R&D and regional and local authorities, O3 is The attractiveness of the region for foreign direct investment (FDI) in medium and high-tech manufacturing industries, O4 is Use of capacity of the research centers in other regions for innovative businesses, and O5 is New technologies in education and popularization of Science, Technology, Engineering and Mathematics. For the Threats: T1 is Continued disinterest in the issue of R&D in relation to strengthening the competitiveness of the region within the framework of regional and local authorities, T2 is Key manufacturing industries and spending during economic crisis, T3 is The aging population and the impact on the labor market, social network and educational system, T4 is the largest FDI investment in high-tech medium tech manufacturing industries and largest employers in this sector, and T5 is Positions of many companies (mostly small and medium enterprises) in the Global value chains. The data is shown in Table 3.

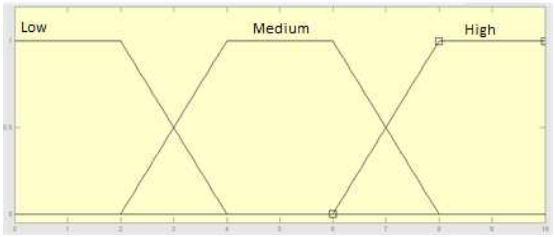

Figure 2. Trapezoidal membership function representing the linguistic values of performance variable

Importance is the importance of characteristics for the success of the region on the scale 0 to 1. The values for the current performance of the region on the listed characteristics were collected using linguistic variables. The linguistic variables from the weight column were presented using trapizoidal membership function shown in the figure above (Fig. 2); which were then transformed to crisp values using Yager's ranking indices [11]. The same membership functions were used for Weakness, Opportunity and Threat.

Table 3. Input data from experts and calculated λ

Characteristics	Importance	Weight	λ
S1	0.8	0.95	-0.989
S2	0.5	0.95	
S3	0.6	0.55	
S4	0.6	0.55	
S5	0.4	0.95	
W1	0.5	0.55	-0.946
W2	0.6	0.15	
W3	0.4	0.55	
W4	0.5	0.95	
W5	0.3	0.55	
O1	0.5	0.55	-0.963
O2	0.5	0.15	
O3	0.6	0.95	
O4	0.4	0.55	
O5	0.5	0.55	
T1	0.5	0.15	-0.933
T2	0.6	0.55	
T3	0.3	0.95	
T4	0.4	0.55	
T5	0.4	0.55	

Using the same steps as discussed in the previous case (currency exchange office) the overall performance of Strength, Weakness, Opportunity, and Threat was evaluated. The results are presented in the following table (Table 4)

Table 4. Evaluated value for strength, weakness, opportunity and threat

Strength	Weakness	Opportunity	Threat
0.93	0.72	0.77	0.64

Based on the result table above (Table 4) Strength of the of Pardubice region on the economic characteristics discussed in this section is 93% which, could be considered a success. The weakness of the region is 72% which is not good for the region, the opportunity the region is currently exploiting is 77% and the threat the region is facing is 64%. These results show that even though the region has a really good strength but all the opportunities are not being exploited and the weakness and the treats need to be eliminated, especially the ones with high importance in order to increase the success of the region.

5. Conclusion

Strategy evaluation is the most crucial part of strategic management life cycle; SWOT analysis is one of the tools used in strategy evaluation to understand an organization with respect to its internal and external environment. However, SWOT analysis does not provide a way to analytically analyse and evaluate a strategy. Although some multiple criteria decision methods have been used to analytically analyse the importance of SWOT sub characteristics for comparing different strategies, what is discussed in this paper is fuzzy integral methods, where considering dependencies is not an issue and the method can also be applied to evaluate an organization's strategy. The result from this method could be used as a report for stakeholders on how an organization is performing. By using fuzzy integral methods, organizations will be able to evaluate their current strategy and its effectiveness with respect to the status of the organization. That is to see how effective the strategy they are applying is, and what they should change in the future. The expected result, from the above method is a numerical value on how the current strategy is doing in driving the organization towards its goal, and which part of the strategy should the organization improve.

These methods can also be applied to compare strategies for bigger organizations, profit or non-profit. In that case, it is recommended to use the linguistic variables and fuzzy defuzification methods, discussed in this paper, to record the performance of selected variables, since it is difficult to exactly quantify performance of sub characteristics for big organizations.

Although applying fuzzy integral methods will provide a way to quantitatively evaluate a strategy, SWOT analysis is an expensive and time-consuming task and cannot be done as often, and does not guarantee success since some effects of a strategy may not be visible at a certain time. Using expert systems like reasoning systems to continuously monitor and record effects of a strategy is recommended for further work.

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