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Fuzzy logic approach to SWOT analysis for economics tasks and example of its computer realization

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Abstract: *The article discusses the widely used classic method of analysis, forecasting and decision-making in the various economic problems, called SWOT analysis. As known, it is a qualitative comparison of multicriteria degree of Strength, Weakness, Opportunity, Threat for different kinds of risks, forecasting the development in the markets, status and prospects of development of enterprises, regions and economic sectors, territorials etc. It can also be successfully applied to the evaluation and analysis of different project management tasks - investment, innovation, marketing, development, design and bring products to market and so on. However, in practical competitive market and economic conditions, there are various uncertainties, ambiguities, vagueness. Its making usage of SWOT analysis in the classical sense not enough reasonable and ineffective. In this case, the authors propose to use fuzzy logic approach and the theory of fuzzy sets for a more adequate representation and post-treatment assessments in the SWOT analysis. In particular, has been short showed the mathematical formulation of respective task and the main approaches to its solution. Also are given examples of suitable computer calculations in specialized software Fuzicalc for processing and operations with fuzzy input data. Finally, are presented considerations for interpretation of the results.*

Key-words: *fuzzy SWOT analysis, qualitative methods, economic uncertainly, fuzzy modelling, linguistic assessments, risks forecasting*

1. Introduction

The In solving the a wide range of economic problems by researchers, especially in the early stages, usually used a standard set of well-known and proven methods of analysis, forecasting and decision-making. Among them, in particular, it is worth mentioning statistical methods, simulation tools and other types of modelling,

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various models and tools for qualitative analysis. Among the latter occupies a serious place the so-called SWOT analysis.

Classic SWOT-analysis (Strength, Weakness, Opportunity, Threats) is one of the simplest practical methods that is widely used for the analysis of different kinds of risks, forecasting the development of the situation in the markets, the status and prospects of development of enterprises, regions and economic sectors, territorial entities, etc. In particular, it can be successfully used to assess and analyse all sorts of project management tasks (investment, innovation, development, design and market launch of products, marketing, etc.). In fact it is a qualitative method based on the comparison, "weighing" of opposite qualities, opportunities, threats of the project (Caprarescu et al 2013, Deriy 2013, Chis and Belenesi 2014).

2. Formulation of goals and theoretical foundations of its solution

As well known, the traditional scheme of the SWOT analysis practically simply fixes the presence of weak or strong points of the project, as well as its opportunities and threats. Practically overlooked is the degree of feasibility, for example, project's opportunities and threats or the severity of the strengths or weaknesses. But an analysis of these, obviously, fuzzy indicators would allow to get a deeper appreciation for even such a simple technique, which is a SWOT analysis (Nistor 2009, Goranczewski and Puciato 2010, Nagara et al 2015, Xunpeng 2016).

Recently a number of publications describing the use SWOT analysis with elements of fuzzy production (Hamidreza and Fazlollahtabar 2012, Celik and Kandakoglu 2012, Ebonzo and Liu 2013). However, there exists a need to bring the total theoretical justification for the formulation of the problem in a generalized form. Further, it becomes topical the issue of specific calculations with fuzzy numbers, functions and variables for the practical implementation of the proposed approaches. In our view, in this case it is necessary to take advantage of special, relevant computer tools and applied computing programs.

Let assume that there are four sets of estimates:

$ST = \{st_i : i = 1,\dots, I\}$, representing the strengths of the project;

$W = \{w_j : j = 1,\dots, J\}$, weaknesses of the project;

$Opp = \{opp_k : k = 1,\dots K\}$, possibilities of the project;

$Th = \{th_q : q = 1,\dots,Q\}$, threats of the project.

Degree of expressiveness of the strengths and weaknesses of the project in our case appears to linguistic assessments, for example: experience of the personnel (sufficient, big, very big); the uncertainty of the sources of financing (not very big) etc. Implementation of the opportunities and threats may also have linguistic evaluation, such as: access to the other markets (reasonably likely); the occurrence of a strong competitor (highly likely). Accordingly, for each of the four sets can be constructed of the set of linguistic evaluations:

$$L_{st} = \left\{ l_{st_i,\, k_i} : k = 1,...K, i = 1,...I \right\},$$

$$L_{W} = \left\{ l_{w_j,\, q_j} ; q_j = 1,...Q, j = 1,...j \right\},$$

$$L_{Opp} = \left\{ l_{opp_k,\, m_k} : m_k = 1,...,M_k, k = 1,...,K \right\},$$

$$L_{Th} = \left\{ l_{th_q,\, n_q} : n_q = 1,...N_q, q = 1,...,Q \right\}.$$

And for the corresponding fuzzy sets:

$$M_{ST} = \left\{ \mu_{st_i,\, k_i}(z), z \in [0,1] \right\},$$

$$M_{W} = \left\{ \mu_{w_j,\, q_j}(z), z \in [0,1] \right\},$$

$$M_{Opp} = \left\{ \mu_{opp_k,\, m_k}(z), z \in [0,1] \right\},$$

$$M_{Th} = \left\{ \mu_{th_q,\, n_q}(z), z \in [0,1] \right\}.$$

For each set of estimates can be constructed (in a certain way) the convolution evaluations, which will do possible to conduct a final evaluation of projects. As is obvious, there are several variants of convolutions, the choice of which depends on the character of the tasks and the position of the decision makers. Therefore, we can consider, for example, two extreme possible positions of the decision makers: optimistic (there are no problems) and pessimistic (everything is lost).

The first position is expressed in the fact that the convolution of criteria represented through merge operation for corresponding fuzzy sets. The second position corresponds to the convolution of criteria, which is represented by the intersection operation for corresponding fuzzy sets, or the operation of its multiplication. In this case at SWOT-analysis in fuzzy statement can and should be reviewed the following combinations.

First variant: for the strengths and opportunities of the project the level of estimates is right relative to the average. And in their relationship decision makers adheres to the generally optimistic position. At the same time, weaknesses and threats assessment are located to the left relative to the average level. At that the decision maker tuned pessimistically regarding the possibility of their implementation. This is the most favorable case for the subsequent analysis.

Second variant: as before, for the strengths and opportunities of the project the level of estimates is right relative to the average. However this time the decision-maker tuned pessimistic with respect to this situation. As previously, weaknesses and threats assessment are located to the left relative to the average level. But in this case the decision maker assumes that this situation has high chances for implementation. Such a variant require some additional analysis.

Third variant: estimates for the strengths and opportunities of the project, as well as weaknesses and threats are distributed throughout the domain of the basic subsets of the corresponding linguistic estimates. The decision-maker may adhere to different positions. In the given case it is necessary to make analysis according to the full scheme.

Let suppose that on some project to its strengths sides have been expressed by experts or built by other reliable way such linguistic evaluations and defines corresponding membership functions:

$$L_{ST} = \left\{ l_{st_1,k_1}, \dots l_{st_I,K_I} \right\}$$

$$M_{ST} = \left\{ \mu_{st_1,k_1}(z), \dots, \mu_{st_I,K_I}(z) \right\}, z \in [0,1],$$

$$L_W = \left\{ l_{W_1,q_1}, \dots, l_{W_J,q_J} \right\},$$

$$M_W = \left\{ \mu_{W_1,q_1}(z), \dots, \mu_{W_J,q_J}(z) \right\}, z \in [0,1]$$

$$L_{Opp} = \left\{ l_{opp_1,m_1}, \dots, l_{opp_k,M_K} \right\},$$

$$M_{Opp} = \left\{ \mu_{opp_1,m_1}(z), \dots, \mu_{opp_k,M_K}(z) \right\}, z \in [0,1]$$

$$L_{TH} = \left\{ l_{th_1,n_1}, \dots, l_{th_Q,N_Q} \right\},$$

$$M_{TH} = \left\{ \mu_{th_1,n_1}(z), \dots, \mu_{th_Q,N_Q}(z) \right\}, z \in [0,1].$$

In order to assess the project in terms of its riskiness is necessary to build the convolutions given fuzzy sets. Then it is necessary to compare them, for example, using the standard methods of comparison of fuzzy sets.

As noted above, convolutions may be obtained from the optimistic or pessimist position. For the optimistic assessment convolution on the basis of combining operations is the most natural, for example:

$$M'_{ST} = \bigcup_{i=1}^{I} \mu_{st_i,k_i}(z) = MAX \left\{ \mu_{st_i,k_i}(z) \right\}.$$

Somewhat more complicated is the case with pessimistic estimates. The convolution which provides them, is based on the operation of intersection. It is known that the intersection can be determined as follows:

$$\mu_{A \cap B}(z) = \min\{\mu_A(z), \mu_b(z)\},$$
$$\mu_{A \cap B}(z) = \mu_A(z)\mu_B(z).$$

However, the calculation of the minimum may lead to empty intersection. At the same time, the use of cylindrical extensions for calculating a minimum due to the high computational complexity.

3. Graphical illustration of proposed approach

The corresponding graphical illustrations explaining the proposed approach are presented in the following figures. They are obtained by calculations (operations on the initial membership functions) which were carried out in specialized software for operations with fuzzy numbers and variables FuziCalc. In case of obtaining empty set as a result of the operation of intersection can be combined evaluations for groups that provide non-empty intersection. Then, using a merge operation, we can get fuzzy set of estimates for corresponding aspect of the project (Figure 1).

The position of extreme pessimism (worse than ever) we can imagine if the intersection operation will be determined through a multiplication operation:

$$\mu_{A \cap B}(z) = \mu_A(z)\mu_B(z).$$

Obtained and presented result (Figure 2) clearly confirms this position. The resulting score is clearly shifted toward lower values. As already noted, an optimistic estimate is based on a merge operation (Figure 3):

$$\mu_{A \cup B}(z) = \max\{\mu_A(z), \mu_b(z)\}.$$

This assessment may be considered as cautiously optimistic, focused mainly on the best variants, but at the same time is not completely eliminated the deterioration in the situation. It should be noted that:

$$\mu_{A \cup B}(z') = \mu_A(z_A) + \mu_B(z_B),$$

where $z' = z_A + z'_B$, $z_A \in SuppA, z_B \in SuppB$.

This variant characterized the super optimistic position when the resulting score is clearly shifted to above average (Figure 3).

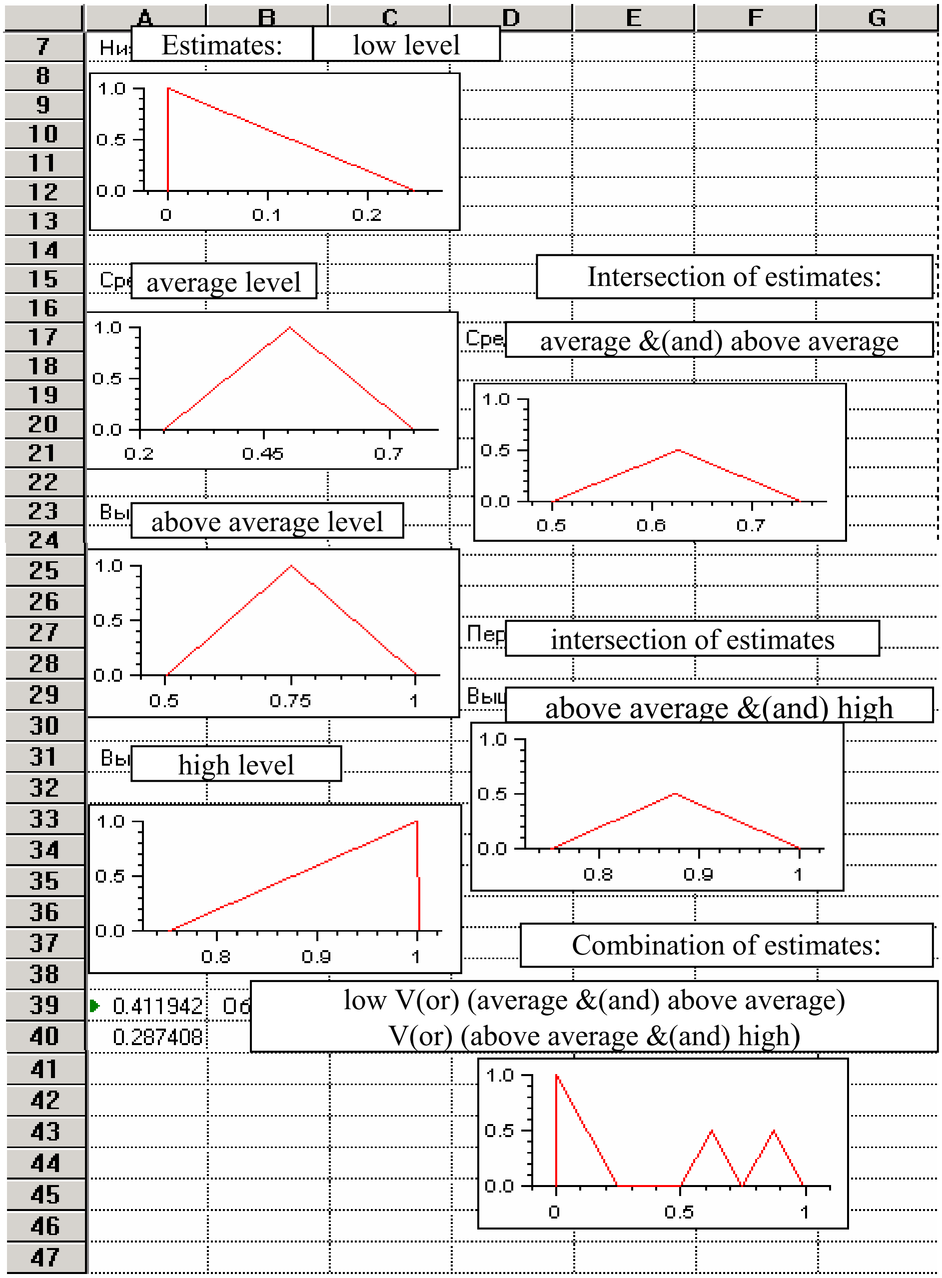


Figure1. Variants of estimates convolution in the case of a pessimistic position (all figures source: authors' calculation in FuziCalc program)

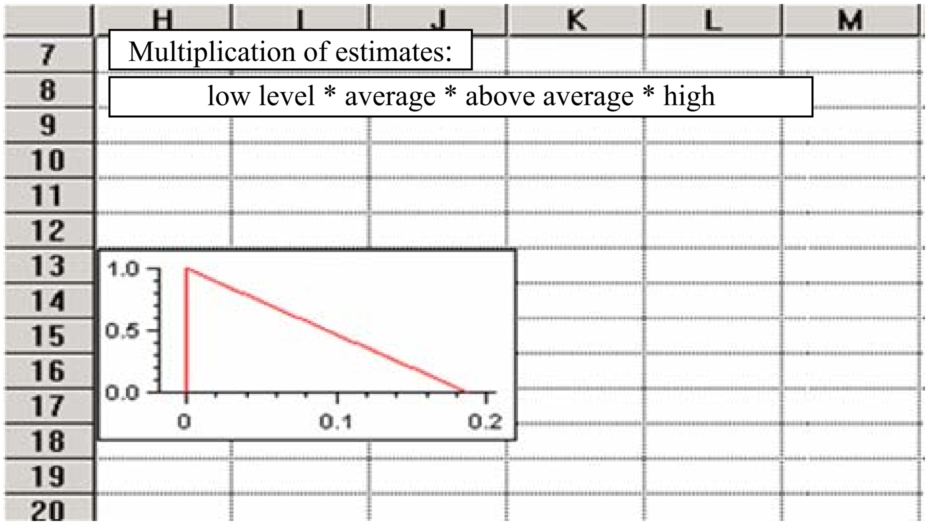


Figure 2. Estimates convolution in the case of multiplication for pessimistic position

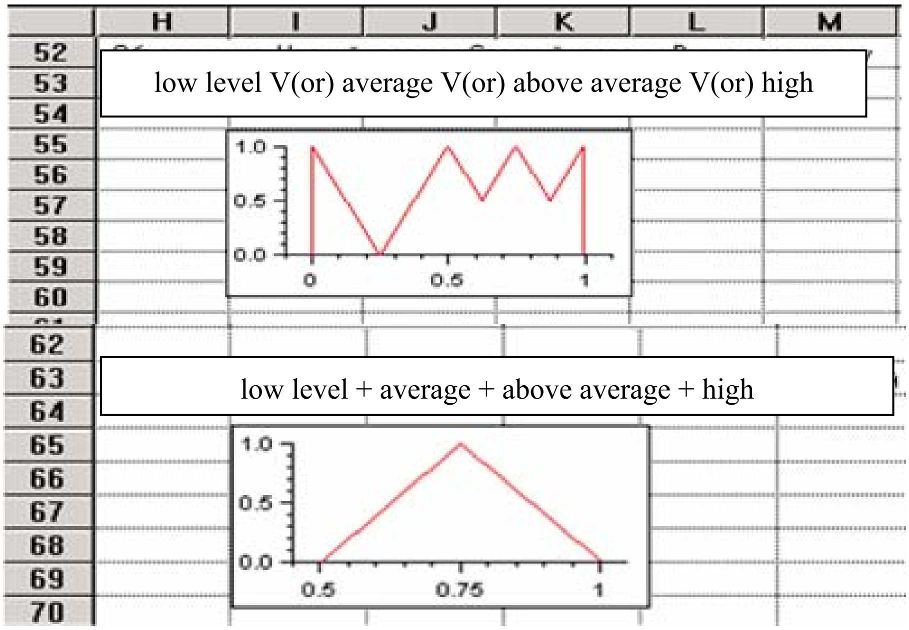
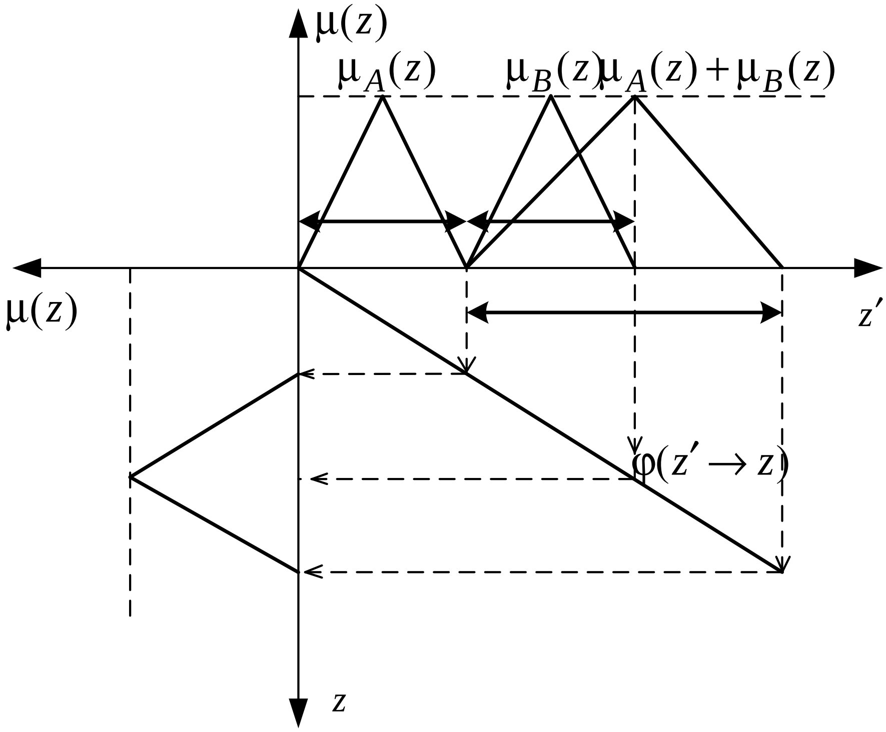


Figure3. Variants of estimates convolution in the case of an optimistic position: cautiously optimistic (top) and overoptimistic (bottom).

It should be noted that when using the last relations the value of argument for the resulting membership functions can go beyond the limits [0, 1].

In this case, we can use the simple recalculation procedure, the meaning of which is illustrated in Figure 4.



(source: authors' own interpretation)

1.0

Figure 4. Recalculation of membership function: procedure of values conversion for arguments of the resulting membership functions

After performing all the above procedures can be obtained integral estimates in the form of fuzzy sets:

$$ST' = \{\mu'_{ST}(z) / z, z \in [0,1]\},$$

$$Opp' = \{\mu'_{Opp}(z) / z, z \in [0,1]\},$$

1.0

$$W' = \{\mu'_{W}(z) / z, z \in [0,1]\},$$

0.25

$$Th' = \{\mu'_{Th}(z) / z, z \in [0,1]\}.$$

0.33

Guided by considerations similar to those previously discussed, it is possible to construct a fuzzy sets with integrated estimations of positive character $Pos(ST', Opp')$ and integrated estimations of negative character $NEG(W', Th')$. Eventually will be obtained membership functions $\mu_{Pos}(z)$ and $\mu_{Neg}(z)$.

To complete the analysis of the problem remained to compare fuzzy sets *POS* and *NEG* and take a final decision.

Methods used the final comparison of the resulting fuzzy sets may be the subject of a separate study, based on a number of well-known works.

It is obvious that in the given task is possible to use the weighted powers $P(POS), P(NEG)$ or special functions from the above-mentioned *FuziCalc* computer package $EffPeak(POS)$, $EffPeak(NEG)$.

If $P(POS) > P(NEG)$ or $EffPeak(POS) > EffPeak(NEG)$, then the final decision (integrated assessment of the results of fuzzy SWOT analysis) for project is positive, otherwise it is negative.

Also possible to take clarified decision by asking additionally the threshold of feasibility of assessment, namely considering $\mu_{POS}(z) \geq \alpha$ and $\mu_{NEG}(z) \geq \alpha$ where α is decision threshold.

4. Conclusions

Thus, the proposed approach and described technique of the SWOT-analysis for fuzzy statement takes into account not only the severity of weaknesses or strengths of the project as well as its possibilities and threats, but also the ratio of the decision-maker to the possibilities of their implementation.

It could significantly increase the degree of validity of the risk assessment during the investment project analysis for varying economic situations, the state and prospects of development of the enterprises, market, and similar problems of the analysis and forecasting under environmental uncertainties, various other processes and factors of economic decision-making.

5. References

Caprarescu, G., Stancu, D. and Aron, G., 2013. The SWOT analysis between myth and reality. *Knowledge Horizons – Economics,* 5, pp. 38-42.

Celik, M. and Kandakoglu, A., 2012. Maritime policy development against ship flagging out dilemma using a fuzzy quantified SWOT analysis. *Maritime Policy & Management*, 39, pp. 401-421.

Chis, A. and Belenesi, M., 2014. Swot analysis on sampling method. *Annals of Faculty of Economics - University of Oradea,* 1, pp. 587-592.

Deriy, M., 2013. SWOT analysis of automation for cash and accounts control in construction. *Accounting and Finance,* 2, pp. 106-112.

Ebonzo, A. and Liu, X., 2013. The use of axiomatic fuzzy set theory in AHP and TOPSIS methodology to determine strategies priorities by SWOT analysis. *Quality & Quantity: International Journal of Methodology,* 47, pp. 2671-2685.

Goranczewski, B. and Puciato, D., 2010. SWOT analysis in the formulation of tourism development strategies for destinations. *Tourism,* 20, pp. 45-53.

Hamidreza, S. and Fazlollahtabar, H., 2012. Designing an integrated AHP based fuzzy expert system and SWOT Analysis to prioritize development strategies of Iran agriculture. *Review of International Comparative Management* 13, pp. 117-129.

Nagara, G., Lam, W., Lee, N., Othman, F. and Shaaban, M., 2015. Comparative SWOT analysis for water solutions in Asia and Africa. *Water Resources Management,* 29, pp. 125-138.

Nistor, C., 2009. Swot analysis of the Romanian public accounting system. *Journal Studia Universitatis Babes-Bolyai Negotia,* 13, pp. 44-54.

Xunpeng, S., 2016. The future of ASEAN energy mix: A SWOT analysis. *Renewable and Sustainable Energy Reviews,* 53, pp. 672-680.