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An Extension of Fuzzy SWOT Analysis: An Application to Information Technology

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Abstract: When considering today's uncertain atmosphere, many people and organizations believe that strategy has lost its meaning and position. When future is predictable, common approaches for strategic planning are applicable; nonetheless, vague circumstances require different methods. Accordingly, a new approach that is compatible with uncertainty and unstable conditions is necessary. Fuzzy logic is a worldview compatible with today complicated requirements. Regarding today's uncertain and vague atmosphere, there is an absolute requirement to fuzzify the tools and strategic planning models, especially for dynamic and unclear environment. In this research, an extended version of Strengths, Weaknesses, Opportunities and Threats (SWOT) fuzzy approach has been presented for strategic planning based on fuzzy logic. It has solved the traditional strategic planning key problems like internal and external factors in imprecision and ambiguous environment. The model has been performed in an information technology corporation to demonstrate the capabilities in real world cases.

Keywords: strategic planning; fuzzy logic; factors aggregation; prioritization

1. Introduction

Classic Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis has been developed based on stable environment that means if the environment of an organization were steady, invariable, and predictable, the classic SWOT analysis could be performed for the organization. In today's world, environment of organizations is stormy, fast changing, unpredictable, and with uncertainties. For instance, external (or internal) factors of an organization are not always opportunity (strength) or threat (weakness); in other words, in different conditions, they have different meanings. For encountering with today's complicated and ambiguous environment, fuzzy SWOT analysis is useful and can solve some problems of classic SWOT analysis [1]. The highlights of this paper are using tri-angular membership function, using three α-cut planes for defuzzifying, and a combinational method consisting of TOPSIS and the weighted average for prioritization.

SWOT (an acronym standing for Strengths, Weaknesses, Opportunities and Threats) analysis is a commonly used tool for analyzing internal and external environments in order to attain a systematic approach and support for decision making [2–10]. The SWOT approach is based on the aggregation of the internal (strengths, weak-nesses) and external (opportunities, threats) factors for adopting strategies. In other words, the extracted strategies of SWOT matrix is comprised of four categories of factors combinations:

- Strengths and Opportunities (S-O);
- Strengths and Threats (S-T);
- Weaknesses and Threats (W-T); and,
- Weaknesses and Opportunities (W-O) [11].

Helms and Nixon in 2010 presented a research in which academic researches of the last decade in the field of strategic management, and especially the SWOT method, were analyzed [12]. Moreover, similar researchers analysed and reviewed the performance of SWOT analysis and illustrated its applications, performance and future possible contributions [13]. The previous approaches have not considered quantitative methods to evaluate and sort the strategies under uncertain situations; however, the illustrated literature review that is presented in Section 2 overviews some possible methods for this matter. One possible approach that deals with uncertainty is fuzzy logic.

A fuzzy set is a class of objects with grades of membership. A membership function is between zero and one [14]. Fuzzy logic is derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. It allows for the model to easily incorporate various subject experts' opinion in developing critical parameter estimates [15]. In other words, fuzzy logic enables us to handle uncertainty [16,17]. There are some kinds of fuzzy numbers. Among the various shapes of fuzzy number, triangular fuzzy number (TFN) is the most popular one. It is represented with three points as follows: A = (a1, a2, a3). The membership function is illustrated in Figure 1. Let A and B are defined as A = (a1, a2, a3), B = (b1, b2, b3). Then C = (a1 + b1, a2 + b2, a3 + b3) is the addition of these two numbers. Besides, D = (a1 − b1, a2 − b2, a3 − b3) is the subtraction of them. Moreover, E = (a1 × b1, a2 × b2, a3 × b3) is the multiplication of them [15,18,19].

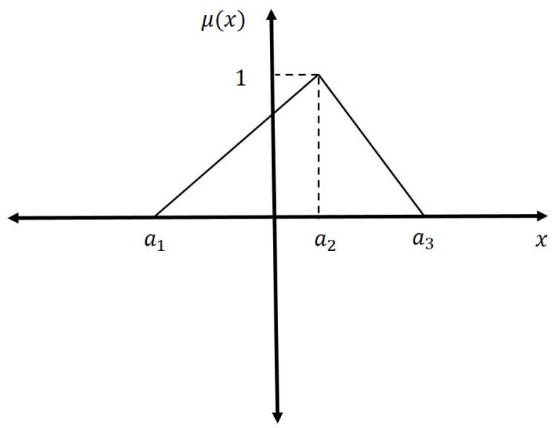

Figure 1. Membership function.

The remainder of this research is organized as follows. Initially, the existing research on fuzzy SWOT are presented in Section 2, afterward, Section 3 represents algorithm of proposed fuzzy SWOT. Finally the proposed model is applied to a case analysis for checking the applicability of the model.

2. Literature Review

Ghazinoory et al. presented a method based on fuzzy logic to solve SWOT structural problems, like lack of considering uncertain and two sided factors and the lack of prioritization [11]. In this paper, the triangular membership function has been defined for all factors; the minimum of internal and external factors was calculated for aggregating. In defuzzifying, α-cut plane technique was used and prioritization has been done based on the amount of each fuzzy area in SWOT matrix quadrants. Kheyrkhah mentioned structural problems of classic SWOT like not to prioritize internal and external factors and disability to consider vagueness in some of internal and external factors, and they stated that fuzzy SWOT analysis could solve these problems [20]. Moreover, they compared the extracted strategies from fuzzy SWOT analysis with strategies extracted from classic SWOT analysis in order to show supremacy of fuzzy SWOT analysis. Hosseini Nasab described one of classic SWOT defects and proposed a fuzzy SWOT approach to solve this problem [21,22].

In this paper, three points as a triangular area in EFE-IFE coordinate specified and according to the strategic triangular position (relative position of three points) a realistic strategy has been extracted. Ecmekcioglu proposed multi-criteria fuzzy SWOT to solve classic SWOT problems like not to prioritize strategies and vagueness of factors. The proposed model has three parts. First, using fuzzy AHP to specify the weight of internal and external vector, second, using fuzzy TOPSIS for prioritization, and third, specifying the best strategy proposal by evaluating the internal and external factors [23]. Chernov indicated that there are different uncertainties and vagueness in real competitive market and real economic conditions causing classic SWOT to be ineffective [24].

Amin presented a novel method using fuzzy logic, triangular fuzzy numbers and SWOT analysis to deal with vagueness of human thought. Their quantified SWOT was applied in the context of supplier selection. Moreover, they proposed a fuzzy linear programming model to specify how much should be purchased from each supplier [18]. Ghazinoory illustrated a literature review of SWOT analysis of about 577 papers that have been published up to the end of 2009. Historical development of SWOT, methodological development of SWOT, suggestions and challenges are explained. Furthermore, they stated some problems of SWOT analysis and suggested a proposed model to solve the problems [25].

Kazaz as a first part analysed 50 large construction firms in Turkey by SWOT analysis. They identified each firm primary goal. The results of the first part were used to develop a fuzzy model for determining the main objectives of the firms. Finally extracted strategies related to the firm's main goal were introduced [26]. Dimic used a SWOT analysis and fuzzy Delphi method as the basis to evaluate impact factors. Fuzzy SWOT analysis is applied to formulate strategic options and the selection of the optimal option is realized through DEMATEL (Decision-making and Trial and Evaluation Laboratory)-based ANP (Analytic Network Process) [27]. Beheshti presented a hybrid COPRAS G with MODM model to optimize the strategy portfolio optimization based on strategies emanated from SWOT Matrix under uncertain circumstances. They applied their proposed model in Iranian mercantile exchange to validate their model [28].

In this paper, a solution that has used fuzzy logic and fuzzy sets theory in SWOT analysis is pro-posed and a mathematical method for different phase of the solution is presented. The strategy selection process, especially the closeness coefficient for the fuzzy area has been extended by adding a step based on TOPSIS method.

3. Algorithm

Algorithm of the proposed fuzzy SWOT analysis consists of six stages as follows:

- Membership Function;
- Aggregation;
- Defuzzification;
- Prioritization;
- Extracting strategies;
- Final Prioritization.

The first two stages are based on paper of Ghazinoory et al. [11]. The general scheme of the algorithm is shown in Figure 2. The last two stages encompassing extracting strategies and final prioritization are the extension and changes added by the authors to the FSWOT based approach.

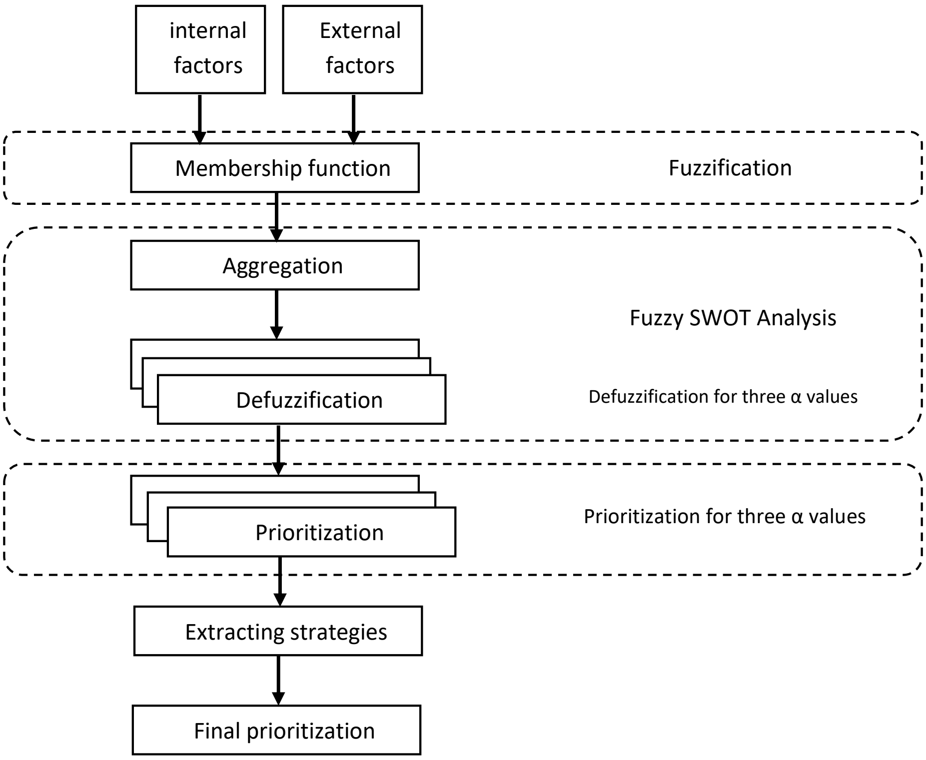

Figure 2. Scheme of algorithm.

3.1. Membership Function

Membership function is triangular and specified by tree parameters, as follows:

$$trn(x : a, b, c) = \begin{cases} 0 & x < a \\ (x-a)/(b-a) & a \le x \le b \\ (c-x)/(c-b) & b \le x \le c \\ 0 & x > c \end{cases} \quad (1)$$

where a, b, and c are pessimistic, probable, and optimistic values, respectively. This membership function is defined for each external and internal factor in the range -10 to 10. An example of the triangular membership function is shown in Figure 3 [29,30].

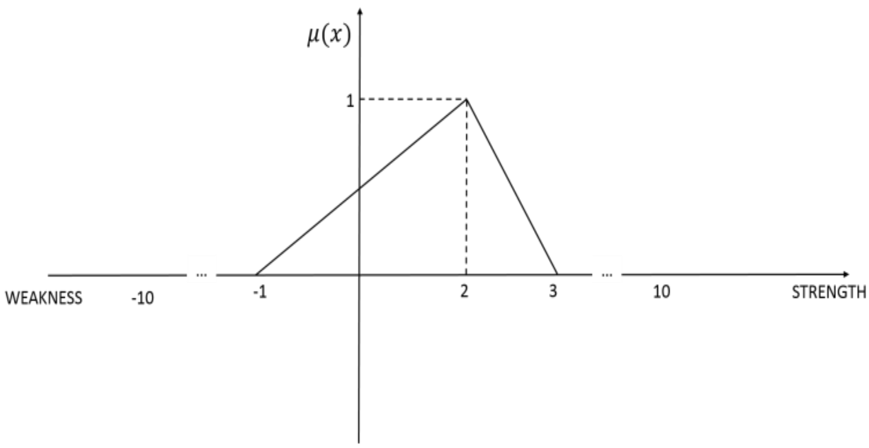

Figure 3. Example of triangular membership function for values {−1 ,2, 3}.

3.2. Aggregation

Membership functions aggregation is based on following equation:

$$\mu_{\mathrm{S}}(x,y) = \min\{\mu_{\mathrm{I}}(x), \mu_{\mathrm{E}}(y)\} \tag{2}$$

$\mu_{\mathrm{I}}(x)$ and $\mu_{\mathrm{E}}(y)$ are membership functions of internal and external factors respectively and $\mu_{\mathrm{S}}(x,y)$ is the result of aggregation that forms a three-dimensional (3D) surface. Figure 4 shows how this surface is made.

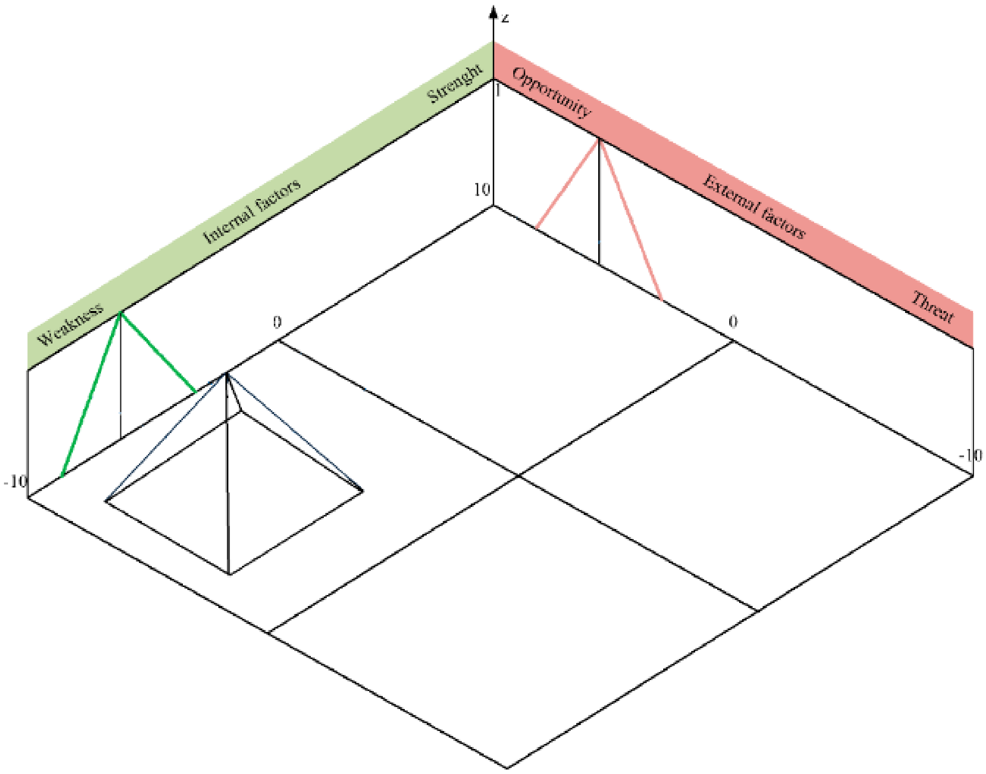

Figure 4. Aggregation [27].

3.3. Defuzzification

In this stage, three α-cut surfaces parallel to SWOT matrix plane are defined for cutting the aggregated surface resulted in previous stage. The value of each of the three surfaces is between 0 and 1 and depends on experience of strategist. If the company is in turbulent and unpredictable market, α value can be close to 0 and if the market is stable and predictable, the values can be close to 1. A rectangular area is generated by crossing the aggregated surface and α-cut plane. In this paper, Picture of the rectangular area in SWOT matrix plane is named "fuzzy area". Figure 5 shows defuzzification with one α plane.

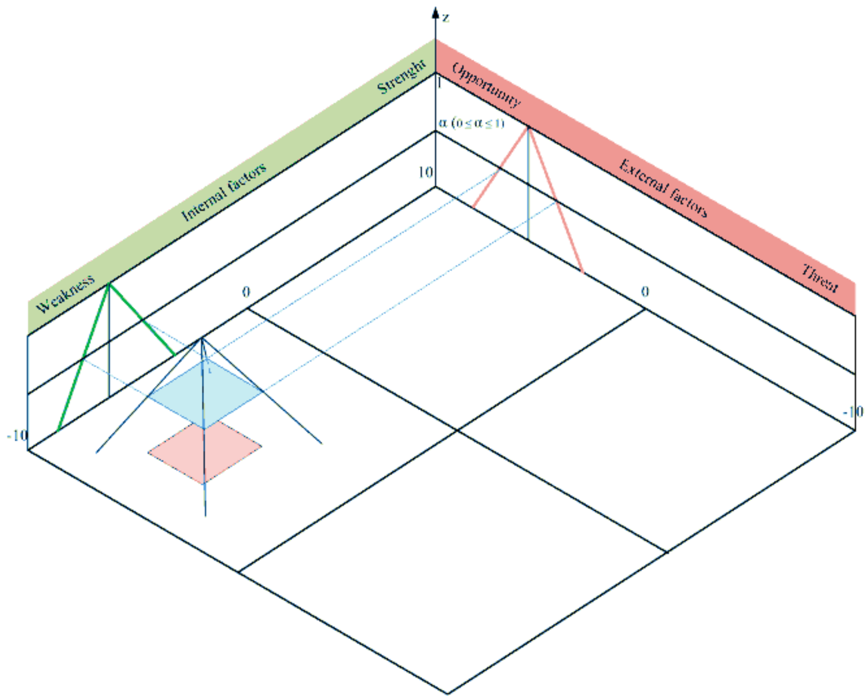

Figure 5. Defuzzification [27].

3.4. Prioritization

There is $n_i \times n_e$ for each α value where n_i and n_e are the numbers of internal and external factors, respectively. Prioritization is done for every three α value, as Figure 6.

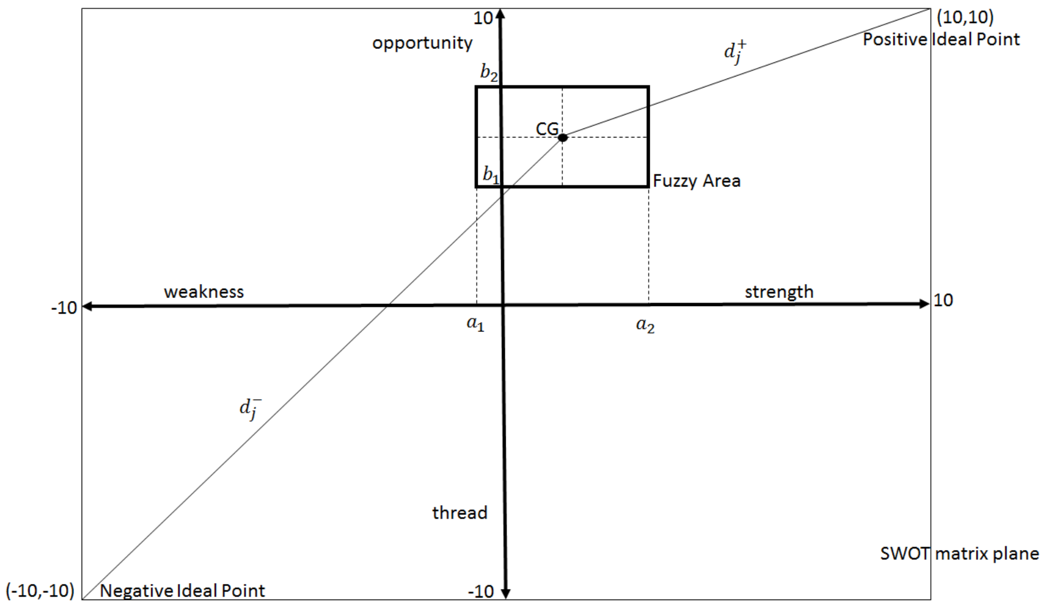

Figure 6. Center of gravity and coefficient of closeness.

- According to Figure 4, the center of gravity for every fuzzy area is calculated as [31]:

$$x_{cg} = \frac{|a_2 - a_1|}{2} \tag{3}$$

$$y_{cg} = \frac{|b_2 - b_1|}{2} \tag{4}$$

- In the second step, according to Figure 3, the closeness coefficient for the fuzzy area is calculated as [14,32]:

$$cc_j = \frac{d_j^-}{d_j^- + d_j^+}, j = 1 \text{ to } n_i \times n_e \tag{5}$$

where d_j^+ is the distance between center of gravity and positive ideal point (+10, +10) and d_j^- is the distance between center of gravity and negative ideal point (-10, -10). d_j^+ and d_j^- are calculated, as follows [33]:

$$d_j^+ = \sqrt{(10 - x_{cg})^2 + (10 - y_{cg})^2} \tag{6}$$

$$d_j^- = \sqrt{(-10 - x_{cg})^2 + (-10 - y_{cg})^2} \tag{7}$$

Prioritization is done based on cc_j value, each fuzzy area with greater cc_j has higher priority.
Location of fuzzy areas in SWOT matrix plane has three states as follows:
State 1: one quadrant fuzzy area as shown in Figure 7.

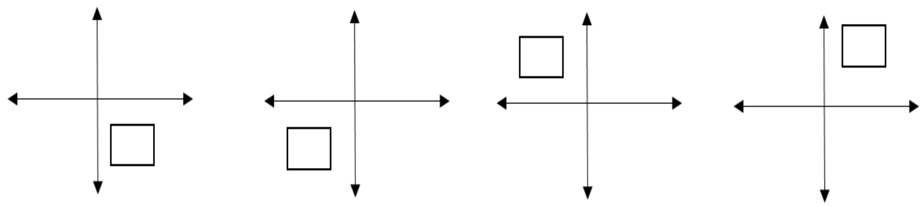

Figure 7. One quadrant fuzzy area.

State 2: two quadrant fuzzy area, as shown in Figure 8.

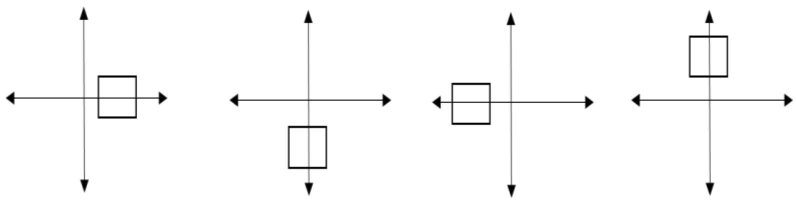

Figure 8. Two quadrant fuzzy area.

State 3: four quadrant fuzzy area as shown in Figure 9.

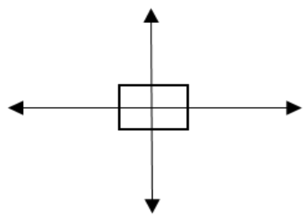

Figure 9. Four quadrant fuzzy area.

3.5. Extracting Strategies

Every fuzzy area is the aggregation result of two internal and external factors and can result in strategy if the two factors are related together. Being related or not depends on the strategist's experience. Extracted strategy should be based on SWOT matrix quadrant. If the fuzzy area is two/four quadrant, the extracted strategy should be based on quadrant including greater part of the fuzzy area, if extracting strategy is not possible, strategy should be based on the smaller part of fuzzy area. If all parts of the fuzzy area are equal, then strategies are extracted from related quadrant.

3.6. Final Prioritization

The aforementioned stages are performed and analyzed for three α value. Consequently, the score of strategies with three α values is resulted. The priority of any strategy varies according to α value. In this stage, the weighted average for all strategies is calculated as:

$$r_a = \sum_{i=1}^{3} \alpha_i \times p_i \tag{8}$$

where α_i is specified by strategist and p is priority of each strategy depending on α values. Final prioritization is based on r_a value. Strategy with smaller r_a value has higher priority.

4. Case Study

To examine the applicability of the described algorithm, the proposed method was conducted for an IT company. As described before the stages of the proposed model are illustrated in Figure 10.

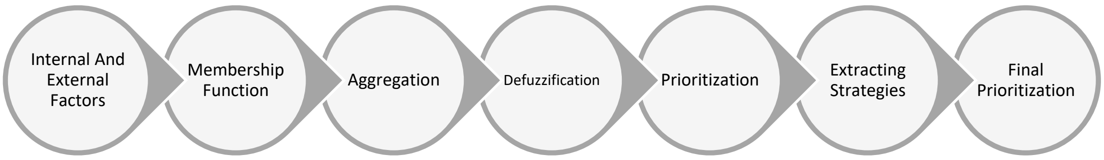

Figure 10. The stages of the proposed model.

Internal and external factors were identified and membership functions were determined by questioning company experts about a, b and c values as shown in Tables 1 and 2. The values are indicating fuzzy triangular numbers (FTN) for analyzing strength, weakness, opportunity, and threats of the considered organization. These amounts were first gathered by linguistic terms from the expert's opinion and subsequently transferred to FTN quantitative values.

Table 1. Internal factors.

ID	Description	Values		
		A	B	C
I_1	Great and effective relationship	7	8	9
I_2	Great team work culture	6	7	9
I_3	Great liquidity	5	7	9
I_4	Delay in product designing	−9	−7	−5
I_5	Employees low level motivation	−9	−7	−4
I_6	Insufficient publicity	−5	−3	1
I_7	Imperfective processes	−5	−3	−2
I_8	Inexperienced managers	−9	−7	−5
I_9	Imperfective planning	−10	−8	−6
I_{10}	Human resource shortcomings	−5	−2	2
I_{11}	Human resource shortcomings in required technologies	−6	−4	3
I_{12}	Job stress	−5	−3	3
I_{13}	Imperfective organizing	−7	−5	−3
I_{14}	Low creativity and innovation	−8	−6	−4

Table 2. External factors.

ID	Description	Values		
		A	B	C
E_1	Upper hand organization support	−4	2	6
E_2	Cooperator companies	−7	3	5
E_3	Profitable market	6	8	9
E_4	Supply exclusivity	−4	2	4
E_5	Customers' dissatisfaction	−9	−8	−6
E_6	Universities' capabilities in product designing	2	4	6
E_7	Employee's low paid salary	−7	−5	2
E_8	High price of product	−7	−6	−3
E_9	Threats increasing in IT field	2	4	6

Based upon the factors mentioned above, the SWOT matrix is denoted as Table 3.

According to the proposed method, membership functions for all of the internal and external factors were generated. In the next stage, aggregation was performed. Aggregation result of I_{11} and E_1 factors is shown in Figure 11.

Table 3. Strengths, Weaknesses, Opportunities and Threats (SWOT) Matrix of Considered IT Organization.

<table>
<tr><td colspan="2" rowspan="2">SWOT for IT organization</td><td colspan="2">External Factors</td></tr>
<tr><td>Opportunities
• Universities' capabilities in product designing
• Upper hand organization support
• Cooperator companies
• Profitable market
• Supply exclusivity</td><td>Threats
• Threats increasing in IT field
• Employee's low paid salary
• High price of product
• Customers' dissatisfaction</td></tr>
<tr><td rowspan="2">Internal Factors</td><td>Strengths
• Great and effective relationship
• Great team work culture
• Great liquidity</td><td>SO Strategies</td><td>ST Strategies</td></tr>
<tr><td>Weaknesses
• Delay in product designing
• Employees low level motivation
• Insufficient publicity
• Imperfective processes
• Inexperienced managers
• Imperfective planning
• Human resource shortcomings
• Human resource shortcomings in required technologies
• Job stress
• Imperfective organizing
• Low creativity and innovation</td><td>WO Strategies</td><td>WT Strategies</td></tr>
</table>

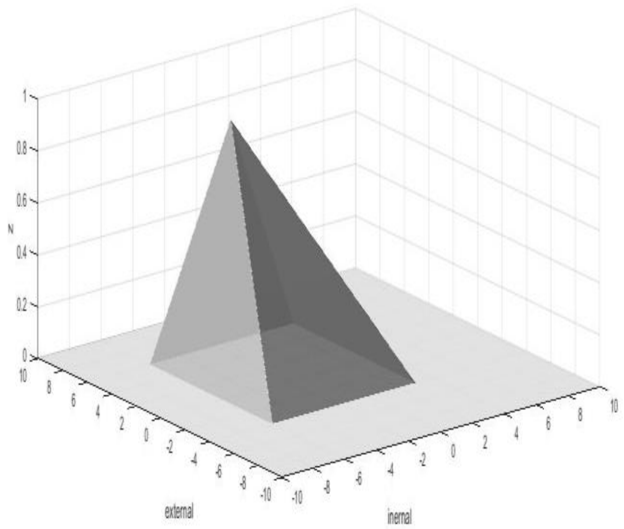

Figure 11. Aggregation result of I11 and E1 factors.

As described before, in this stage, three α-cut planes cut the resulted surface achieved from aggregation, as shown in Figure 12. In this paper, α values are: 0.1, 0.5, and 0.9. 0.1 is represented for almost indefinite condition, 0.5 is represented for semi-definite condition, and 0.9 is for the almost definite one. This process was done for all (14×9) pyramids.

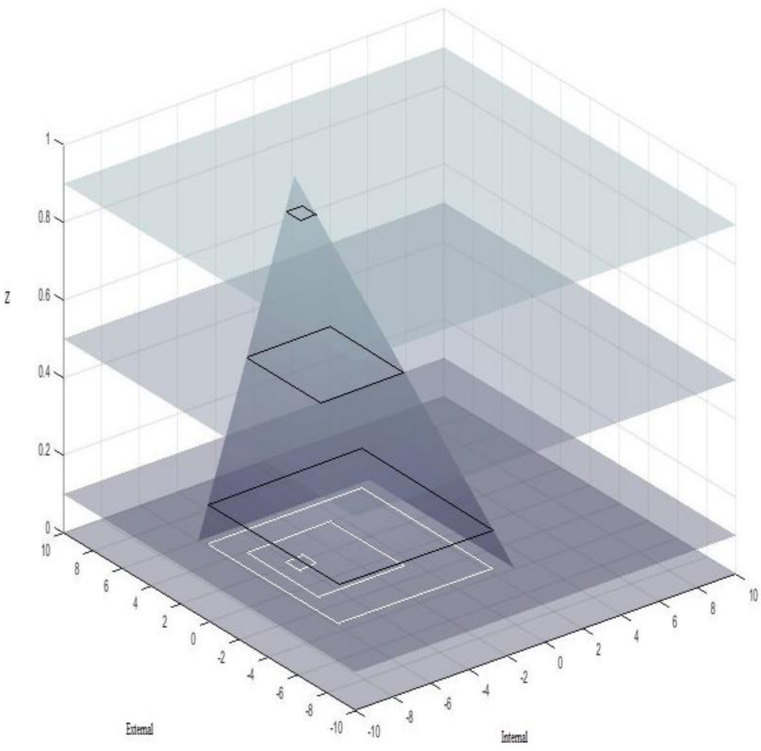

Figure 12. Three α-cut plane cut pyramid.

126 (14×9) pyramids were generated from aggregation that means there are 126 fuzzy areas for each α value. Figure 13 shows the fuzzy areas that resulted from three α-cut planes. As α increases from 0.1 to 0.9, the fuzzy areas decrease. For α = 0.1, the fuzzy area is four quadrant that has more flexibility in extracting strategies. For α = 0.9, fuzzy area is one quadrant and does not have flexibility for strategy.

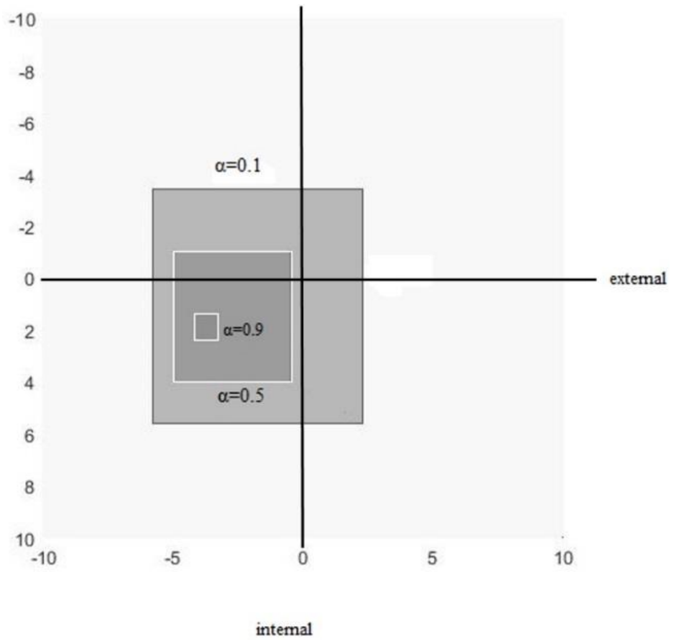

Figure 13. Fuzzy areas for $\alpha = 0.1,\ 0.5,\ 0.9$.

Prioritization was fulfilled for each bunch of fuzzy areas. As described before, prioritization is based on closeness of coefficient value. Table 3 shows the result of $\alpha = 0.1$ prioritization. Percent of each fuzzy area in SWOT matrix quadrants was calculated as shown in Table 4 that is useful for extracting strategies.

Not all of these 126 fuzzy areas result in strategy. The factors should be related and it depends on strategist. After considering and studying these 126 fuzzy areas, 16 strategies were extracted. Table 5 shows the extracted strategies, their priority, α value, and their quadrants. It should be noted that priority of each strategy varies as α value changes.

Table 4. Prioritization, $\alpha = 0.1$.

Row	I	E	Quadrant	Percent of Fuzzy Area in Quadrant 1	Percent of Fuzzy Area in Quadrant 2	Percent of Fuzzy Area in Quadrant 3	Percent of Fuzzy Area in Quadrant 4	Closeness of Coefficient
1	I1	E3	1	100.00	0.00	0.00	0.00	0.88825
2	I2	E3	1	100.00	0.00	0.00	0.00	0.87498
3	I3	E3	1	100.00	0.00	0.00	0.00	0.86317
4	I1	E6	1	100.00	0.00	0.00	0.00	0.78287
5	I1	E9	1	100.00	0.00	0.00	0.00	0.78287
6	I2	E6	1	100.00	0.00	0.00	0.00	0.77435
7	I2	E9	1	100.00	0.00	0.00	0.00	0.77435
8	I3	E6	1	100.00	0.00	0.00	0.00	0.76652
9	I3	E9	1	100.00	0.00	0.00	0.00	0.76652
10	I1	E1	14	62.22	0.00	0.00	37.78	0.69864
11	I2	E1	14	62.22	0.00	0.00	37.78	0.69077
12	I3	E1	14	62.22	0.00	0.00	37.78	0.68372
13	I1	E4	14	52.78	0.00	0.00	47.22	0.67411
14	I2	E4	14	52.78	0.00	0.00	47.22	0.66622
15	I3	E4	14	52.78	0.00	0.00	47.22	0.65921
16	I1	E2	14	44.44	0.00	0.00	55.56	0.65308
17	I2	E2	14	44.44	0.00	0.00	55.56	0.64514
18	I3	E2	14	44.44	0.00	0.00	55.56	0.63812
19	I12	E3	12	33.33	66.67	0.00	0.00	0.63133
20	I10	E3	12	25.40	74.60	0.00	0.00	0.62260
21	I11	E3	12	28.40	71.60	0.00	0.00	0.61769
22	I6	E3	12	11.11	88.89	0.00	0.00	0.60921
23	I1	E7	14	16.05	0.00	0.00	83.95	0.60057
24	I2	E7	14	16.05	0.00	0.00	83.95	0.59238
25	I3	E7	14	16.05	0.00	0.00	83.95	0.58523
26	I7	E3	2	0.00	100.00	0.00	0.00	0.57809
27	I12	E6	12	33.33	66.67	0.00	0.00	0.56549
28	I12	E9	12	33.33	66.67	0.00	0.00	0.56549
29	I10	E6	12	25.40	74.60	0.00	0.00	0.55681
30	I10	E9	12	25.40	74.60	0.00	0.00	0.55681
31	I11	E6	12	28.40	71.60	0.00	0.00	0.55191
32	I11	E9	12	28.40	71.60	0.00	0.00	0.55191
33	I1	E8	4	0.00	0.00	0.00	100.00	0.55051
34	I13	E3	2	0.00	100.00	0.00	0.00	0.54559
35	I6	E6	12	11.11	88.89	0.00	0.00	0.54343

Table 4. *Cont.*

Row	I	E	Quadrant	Percent of Fuzzy Area in Quadrant 1	Percent of Fuzzy Area in Quadrant 2	Percent of Fuzzy Area in Quadrant 3	Percent of Fuzzy Area in Quadrant 4	Closeness of Coefficient
36	I6	E9	12	11.11	88.89	0.00	0.00	0.54343
37	I2	E8	4	0.00	0.00	0.00	100.00	0.54203
38	I3	E8	4	0.00	0.00	0.00	100.00	0.53471
39	I14	E3	2	0.00	100.00	0.00	0.00	0.52652
40	I5	E3	2	0.00	100.00	0.00	0.00	0.51669
41	I7	E6	2	0.00	100.00	0.00	0.00	0.51207
42	I7	E9	2	0.00	100.00	0.00	0.00	0.51207
43	I4	E3	2	0.00	100.00	0.00	0.00	0.50899
44	I8	E3	2	0.00	100.00	0.00	0.00	0.50899
45	I1	E5	4	0.00	0.00	0.00	100.00	0.50701
46	I2	E5	4	0.00	0.00	0.00	100.00	0.49840
47	I12	E1	1234	20.74	41.48	25.19	12.59	0.49753
48	I9	E3	2	0.00	100.00	0.00	0.00	0.49299
49	I3	E5	4	0.00	0.00	0.00	100.00	0.49101
50	I10	E1	1234	15.80	46.42	28.18	9.59	0.48894
51	I11	E1	1234	17.67	44.55	27.05	10.73	0.48407
52	I13	E6	2	0.00	100.00	0.00	0.00	0.47922
53	I13	E9	2	0.00	100.00	0.00	0.00	0.47922
54	I6	E1	1234	6.91	55.31	33.58	4.20	0.47563
55	I12	E4	1234	17.59	35.19	31.48	15.74	0.47512
56	I10	E4	1234	13.40	39.37	35.23	11.99	0.46651
57	I11	E4	1234	14.99	37.79	33.81	13.41	0.46162
58	I14	E6	2	0.00	100.00	0.00	0.00	0.46006
59	I14	E9	2	0.00	100.00	0.00	0.00	0.46006
60	I12	E2	1234	14.81	29.63	37.04	18.52	0.45504
61	I6	E4	1234	5.86	46.91	41.98	5.25	0.45313
62	I5	E6	2	0.00	100.00	0.00	0.00	0.45027
63	I5	E9	2	0.00	100.00	0.00	0.00	0.45027
64	I10	E2	1234	11.29	33.16	41.45	14.11	0.44637
65	I7	E1	23	0.00	62.22	37.78	0.00	0.44418
66	I4	E6	2	0.00	100.00	0.00	0.00	0.44265
67	I8	E6	2	0.00	100.00	0.00	0.00	0.44265
68	I4	E9	2	0.00	100.00	0.00	0.00	0.44265
69	I8	E9	2	0.00	100.00	0.00	0.00	0.44265
70	I11	E2	1234	12.62	31.82	39.78	15.78	0.44145

Table 4. *Cont.*

Row	I	E	Quadrant	Percent of Fuzzy Area in Quadrant 1	Percent of Fuzzy Area in Quadrant 2	Percent of Fuzzy Area in Quadrant 3	Percent of Fuzzy Area in Quadrant 4	Closeness of Coefficient
71	I6	E2	1234	4.94	39.51	49.38	6.17	0.43288
72	I9	E6	2	0.00	100.00	0.00	0.00	0.42705
73	I9	E9	2	0.00	100.00	0.00	0.00	0.42705
74	I7	E4	23	0.00	52.78	47.22	0.00	0.42144
75	I13	E1	23	0.00	62.22	37.78	0.00	0.41107
76	I12	E7	1234	5.35	10.70	55.97	27.98	0.40186
77	I7	E2	23	0.00	44.44	55.56	0.00	0.40085
78	I10	E7	1234	4.08	11.97	62.63	21.32	0.39290
79	I14	E1	23	0.00	62.22	37.78	0.00	0.39189
80	I13	E4	23	0.00	52.78	47.22	0.00	0.38800
81	I11	E7	1234	4.56	11.49	60.11	23.84	0.38780
82	I5	E1	23	0.00	62.22	37.78	0.00	0.38217
83	I6	E7	1234	1.78	14.27	74.62	9.33	0.37889
84	I4	E1	23	0.00	62.22	37.78	0.00	0.37469
85	I8	E1	23	0.00	62.22	37.78	0.00	0.37469
86	I14	E4	23	0.00	52.78	47.22	0.00	0.36866
87	I13	E2	23	0.00	44.44	55.56	0.00	0.36696
88	I9	E1	23	0.00	62.22	37.78	0.00	0.35967
89	I5	E4	23	0.00	52.78	47.22	0.00	0.35890
90	I4	E4	23	0.00	52.78	47.22	0.00	0.35142
91	I8	E4	23	0.00	52.78	47.22	0.00	0.35142
92	I12	E8	34	0.00	0.00	66.67	33.33	0.34885
93	I14	E2	23	0.00	44.44	55.56	0.00	0.34737
94	I7	E7	23	0.00	16.05	83.95	0.00	0.34521
95	I10	E8	34	0.00	0.00	74.60	25.40	0.33941
96	I5	E2	23	0.00	44.44	55.56	0.00	0.33752
97	I9	E4	23	0.00	52.78	47.22	0.00	0.33650
98	I11	E8	34	0.00	0.00	71.60	28.40	0.33400
99	I4	E2	23	0.00	44.44	55.56	0.00	0.32999
100	I8	E2	23	0.00	44.44	55.56	0.00	0.32999
101	I6	E8	34	0.00	0.00	88.89	11.11	0.32452
102	I9	E2	23	0.00	44.44	55.56	0.00	0.31510
103	I13	E7	23	0.00	16.05	83.95	0.00	0.30909
104	I12	E5	34	0.00	0.00	66.67	33.33	0.30496
105	I10	E5	34	0.00	0.00	74.60	25.40	0.29516

Table 4. *Cont.*

Row	I	E	Quadrant	Percent of Fuzzy Area in Quadrant 1	Percent of Fuzzy Area in Quadrant 2	Percent of Fuzzy Area in Quadrant 3	Percent of Fuzzy Area in Quadrant 4	Closeness of Coefficient
106	I11	E5	34	0.00	0.00	71.60	28.40	0.28951
107	I14	E7	23	0.00	16.05	83.95	0.00	0.28812
108	I7	E8	3	0.00	0.00	100.00	0.00	0.28801
109	I6	E5	34	0.00	0.00	88.89	11.11	0.27954
110	I5	E7	23	0.00	16.05	83.95	0.00	0.27762
111	I4	E7	23	0.00	16.05	83.95	0.00	0.26966
112	I8	E7	23	0.00	16.05	83.95	0.00	0.26966
113	I9	E7	23	0.00	16.05	83.95	0.00	0.25426
114	I13	E8	3	0.00	0.00	100.00	0.00	0.24751
115	I7	E5	3	0.00	0.00	100.00	0.00	0.24028
116	I14	E8	3	0.00	0.00	100.00	0.00	0.22331
117	I5	E8	3	0.00	0.00	100.00	0.00	0.21104
118	I4	E8	3	0.00	0.00	100.00	0.00	0.20171
119	I8	E8	3	0.00	0.00	100.00	0.00	0.20171
120	I13	E5	3	0.00	0.00	100.00	0.00	0.19431
121	I9	E8	3	0.00	0.00	100.00	0.00	0.18385
122	I14	E5	3	0.00	0.00	100.00	0.00	0.16494
123	I5	E5	3	0.00	0.00	100.00	0.00	0.14924
124	I4	E5	3	0.00	0.00	100.00	0.00	0.13683
125	I8	E5	3	0.00	0.00	100.00	0.00	0.13683
126	I9	E5	3	0.00	0.00	100.00	0.00	0.11175

Table 5. Extracted strategies, their priority, α values, and quadrants.

ID	I	E	Strategy	Priority			Quadrant		
				ff = 0.1	ff = 0.5	ff = 0.9	ff = 0.1	ff = 0.5	ff = 0.9
S1	I1	E3	Monopolizing the designing and supplying products	1	1	1	1	1	1
S2	I3	E3	Mobile based products and services development	2	2	2	1	1	1
S3	I1	E6	Out sourcing design of products to universities	3	3	3	1	1	1
S4	I1	E9	Assigning the company as exclusive reference of designing and supplying the products	4	4	4	1	1	1
S5	I3	E9	Acquiring small and hi-tech companies	5	5	5	1	1	1
S6	I7	E3	Redesigning processes to improve company agility	6	7	7	2	2	2
S7	I1	E8	Out sourcing designing and producing to small companies	7	11	11	4	4	4
S8	I13	E3	Changing current organizational structure to horizontal structure	8	10	9	2	2	2
S9	I3	E8	Instituting suppliers evaluation system	9	13	13	4	4	4
S10	I14	E3	Instituting innovation and creativity framework	10	12	12	2	2	2
S11	I3	E5	Changing after-sale services structure to improve speed and quality of services	11	14	14	4	4	4
S15	I8	E9	Holding management skills instruction courses for managers	12	15	16	2	2	2
S13	I6	E3	Holding annual fairs	13	6	6	1,2	2	2
S14	I1	E7	Improving employees' salary structure	14	8	8	1,4	4	4
S15	I3	E7	Improving employees' welfare measures	15	9	10	1,4	4	4
S16	I11	E1	Employing elites with required proficiency	16	16	15	1,2,3,4	2,3	2

For final prioritization, the weighted average for each strategy was calculated. According to the Equation (8), r_a values were calculated. The strategy with smaller r_a has higher priority. Table 6 shows the final priorities.

Table 6. Final priorities.

ID	I	E	Strategy	Priority			r_a	Final Priority
				ff = 0.1	ff = 0.5	ff = 0.9		
S1	I1	E3	Monopolizing the designing and supplying products	1	1	1	1.5	1
S2	I3	E3	Mobile based products and services development	2	2	2	3	2
S3	I1	E6	Out sourcing design of products to universities	3	3	3	4.5	3
S4	I1	E9	Assigning the company as exclusive reference of designing and supplying the products	4	4	4	6	4
S5	I3	E9	Acquiring small and hi-tech companies	5	5	5	7.5	5
S13	I6	E3	Holding annual fairs	13	6	6	9.7	6
S6	I7	E3	Redesigning processes to improve company agility	6	7	7	10.4	7
S14	I1	E7	Improving employees' salary structure	14	8	8	12.6	8
S8	I13	E3	Changing current organizational structure to horizontal structure	8	10	9	13.9	9
S15	I3	E7	Improving employees' welfare measures	15	9	10	15	10
S7	I1	E8	Out sourcing designing and producing to small companies	7	11	11	16.1	11
S10	I14	E3	Instituting innovation and creativity framework	10	12	12	17.8	12
S9	I3	E8	Instituting suppliers evaluation system	9	13	13	19.1	13
S11	I3	E5	Changing after-sale services structure to improve speed and quality of services	11	14	14	20.7	14
S12	I8	E9	Holding management skills instruction courses for managers	12	15	16	23.1	15
S16	I11	E1	Employing elites with required proficiency	16	16	15	23.1	16

5. Conclusions

Regarding to problems of classic SWOT for analyzing today's environment, a different method of SWOT analysis that was based on fuzzy logic for enriching SWOT analysis for analyzing today's environment was proposed. This method has specifications, like considering two sided factors, more flexibility in extracting strategies, and optimized prioritization. In the contrary to classic SWOT, this method is useful for analyzing unstable and turbulent environment. It is more applicable and reliable than classic SWOT. The highlights of this paper are using triangular membership function, using three α-cut planes for defuzzifying, and a combinational method consisting of TOPSIS and the weighted average for prioritization. The fuzzy logic type one has been implemented in this paper.

When considering the vagueness of environment, velocity of changes in IT industry in Iran, while considering the time frame and the low accuracy of forecasting SWOT factors in future, the SWOT analysis was considered and analyzed under uncertain circumstances by applying fuzzy logic in this research.

The proposed approach for evaluating and selecting the appropriate strategies are completely useful considering vague circumstances. As a case in point in this research, the scheduled approach was performed in an information technology enterprise to solve the complexity and undesirable approaches that were previously employed within their organizations. For increasing applicability and reliability, other fuzzy types are proposed for future researches encompassing hesitant fuzzy linguistic term set, interval valued intuitionistic fuzzy, intuitionistic fuzzy preferences relations, etc. Furthermore, on the basis of strategies ranking, budget limitations, and other structural or organizational policies, a novel stochastic or fuzzy strategy portfolio optimization model could be designed and presented for future researches.

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References

1. Zakharova, A.A. Fuzzy SWOT Analysis for Selection of Bankruptcy Risk Factors. *Appl. Mech. Mater.* **2013**, *379*, 207–213. [CrossRef]
2. Bas, E. The Integrated Framework for Analysis of Electricity Supply Chain Using an Integrated SWOT-fuzzy TOPSIS Methodology Combined with AHP: The case of Turkey. *Electr. Power Energy Syst.* **2012**, *44*, 897–907. [CrossRef]
3. Dyson, R. Strategic Development and SWOT Analysis at the University of Warwick. *Eur. J. Oper. Res.* **2004**, *152*, 631–640. [CrossRef]
4. Haile, M.; Krupka, J. Fuzzy Evaluation of SWOT Analysis. *Int. J. Supply Chain Manag.* **2016**, *5*, 172–179.
5. Houben, G.; Lenie, K.; Vanhoof, K. A Knowledge-based SWOT-analysis System as an Instrument for Strategic Planning in Small and Medium Sized Enterprises. *Decis. Support Syst.* **1999**, *26*, 125–135. [CrossRef]
6. Kajanus, M.; Kangas, J.; Kurttila, M. The Use of Value Focused Thinking and the A'WOT Hybrid Method in Tourism Management. *Tour. Manag.* **2004**, *25*, 499–506. [CrossRef]
7. Kuo-liang, L.; Shu-chen, L. A Fuzzy Quantified SWOT Procedure for Environmental Evaluation of an International Distribution Center. *Inf. Sci.* **2008**, *178*, 531–549. [CrossRef]
8. Kotler, P. *Marketing Management: Analysis, Planning, Implementation and Control*; Prentice-Hall: Upper Saddle River, NJ, USA, 1988.
9. Kurttila, M.; Pesonen, M.; Kangas, J.; Kajanus, M. Utilizing the Analytic Hierarchy Process (AHP) in SWOT Analysis-a Hybrid Method and its Application to a Forest-Certification Case. *For. Policy Econ.* **2000**, *1*, 41–52. [CrossRef]
10. Stewart, R.; Moamed, S.; Daet, R. Strategic Implementation of IT/IS Projects in Construction: A Case Study. *Autom. Constr.* **2002**, *11*, 681–694. [CrossRef]
11. Ghazinoory, S.; Esmail Zadeh, A.; Memariani, A. Fuzzy SWOT Analysis. *J. Intell. Fuzzy Syst.* **2007**, *18*, 99–108.
12. Helms, M.M.; Nixon, J. Exploring SWOT analysis—Where are we now: A review of academic research from the last decade. *J. Strateg. Manag.* **2010**, *3*, 215–251. [CrossRef]
13. Emet, G.; Tat, M. SWOT Analysis: A Theoretical Review. *J. Int. Soc. Res.* **2017**, *10*, 994–1006.
14. Shakerian, H.; Dehqan, D.H.; Baradaran, Q.S. The Implementation of the Hybrid Model SWOT-TOPSIS by Fuzzy Approach to Evaluate and Rank the Human Resources and Business Strategies in Organizations (Case Study: Road and Urban Development Organization in Yazd). *Procedia Soc. Behav. Sci.* **2016**, *230*, 307–316. [CrossRef]
15. Zimmermann, H.J. *Fuzzy Set Theory and Its Applications*; Kluwer Academic Publishers: Boston, MA, USA, 2001.
16. Li, S.; Davies, B.; Edwards, J.; Kinman, R.; Duan, Y. Integrating Group Delphi, Fuzzy Logic and Expert Systems for Marketing Strategy Development: The Hybridization and its Effectiveness. *Market. Intell. Plan.* **2002**, *20*, 273–284. [CrossRef]
17. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. [CrossRef]
18. Hasanzadeh, A.S.; Razmi, J.; Zhang, G. Supplier Selection and Order Allocation Based on Fuzzy SWOT Analysis and Fuzzy Linear Programming. *Expert Syst. Appl.* **2011**, *38*, 334–342. [CrossRef]
19. Arabzad, S.M.; Qorbani, M.; Razmi, J.; Shirouyehzad, H. Employing Fuzzy TOPSIS and SWOT for Supplier Selection and Order Allocation Problem. *Adv. Manuf. Technol.* **2015**, *76*, 803–818. [CrossRef]

20. Kheyrkhah, A.S.; Esmaeilzadeh, A.; Ghazinoory, S. Developing Strategies to Reduce the Risk of Hazardous Materials Transportation in Iran Using the Method of Fuzzy SWOT Analysis. *Transport* **2009**, *24*, 325–332. [CrossRef]
21. Hosseini Nasab, H.; Hosseini Nasab, A.; Milani, A.S. Coping with Imprecision in Strategic Planning: A Case Study Using Fuzzy SWOT Analysis. *IBusiness* **2011**, *3*, 23–29. [CrossRef]
22. Hosseini Nasab, H.; Milani, A.S. An Improvement of Quantitative Strategic Planning Matrix Using Multiple Criteria Decision Making and Fuzzy Numbers. *Appl. Soft Comput.* **2014**, *12*, 2246–2253. [CrossRef]
23. Ekmekçioglu, M.; Kutlu, A.; Kahraman, C. A Fuzzy Multi-Criteria SWOT Analysis: An Application to Nuclear Power Plant Site Selection. *Comput. Intell. Syst.* **2011**, *4*, 583–595. [CrossRef]
24. Chernov, V.; Dorokhov, O.; Dorokhova, L. Fuzzy Logic Approach to SWOT Analysis for Economics Tasks and Example of Its Computer Realization. *Econ. Sci.* **2016**, *9*, 317–326.
25. Ghazinoory, S.; Abdi, M.; Azadegnamehr, M. SWOT methodology: A state of the art review for the past. A framework for the future. *J. Bus. Econ. Manag.* **2011**, *12*, 24–48. [CrossRef]
26. Kazaz, A.; Erl, B.; Ozdemir, B.E. A fuzzy model to determine construction firm strategies. *KSCE J. Civ. Eng.* **2014**, *18*, 1934–1944. [CrossRef]
27. Dimic, S.; Pamucar, D.; Ljubojevic, S.; Dorovic, B. Strategic transport management models: The case study of an oil industry. *Sustainability* **2016**, *8*, 954. [CrossRef]
28. Beheshti, M.; Amoozad Mahdiraji, H.; Zavadskas, E.K. Strategy Portfolio Optimization: A Hybrid MODM –COPRAS G Approach. *Transform. Bus. Econ.* **2016**, *15*, 500–520.
29. Celik, M.; Kandakoglu, A. Maritime Policy Development against Ship Flagging out Dilemma Using a Fuzzy Quantified SWOT Analysis. *Marit. Policy Manag.* **2012**, *4*, 401–421. [CrossRef]
30. Yüksel, I. An Integrated Approach with Group Decision-Making for Strategy Selection in SWOT Analysis. *Acad. Res. Bus. Soc. Sci.* **2012**, *2*, 134–161.
31. Ermi, I.; Voloshin, A. *Learning from Engineering Examples*; Springer: Berlin/Heidelberg, Germany, 2016.
32. Arun Kumar, S.; Gao, X.Z.; Ajith, A. Handbook of Research on Fuzzy and Rough Set Theory. In *Organizational Decision Making*; IGI Global: Hershey, PA, USA, 2016.
33. Larson, R. *Precalculus: Real Mathematics, Real People*; Cengage Learning: Boston, MA, USA, 2015.