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# Developing a Fuzzy Logic Decision Support System for Strategic Planning in Industrial Organizations

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***Abstract:*** *Internal – External (IE), Strategic Position and Action Evaluation (SPACE), Boston Consulting Group (BCG), and Grand Strategy matrices are important tools in generating and evaluating alternative output strategies which is the most important step in the formulation stage in strategic management process. Managers need to make difficult and important decisions on the basis of imprecise information and incomplete knowledge and select the right strategic position or alternative output strategies. Managers found it difficult to make the right decision when the values that resulted from the internal and external audits of an organization's environment fall in the middle or on the sharp edges in these matrices. It is found that each matrix depends on some factors that represent the internal and external environment of an organization and neglect the others. A systematic approach that incorporates fuzzy set theory in conjunction with strategic planning is proposed to assist managers in reaching the best alternative output set of strategies. The four matrices are combined by relations in order to integrate more than two fuzzy factors in selecting the best alternative output strategies. This make the suggested strategic plan robust and help organizations with limited resources to neglect alternative output strategies that do not depend on the four matrices jointly. The implementation of the developed Fuzzy Logic Decision Support System (FLDSS) is done using MATLAB fuzzy logic tools and the relations between these matrices are entered as rules in the Graphical User Interface (GUI) screens. The model was validated by a case study on a Jordanian company, and the results were satisfactory.*

***Keywords:*** *Fuzzy Logic, Decision Support System, Strategic Planning, Industrial Organization.*

## 1. Introduction

Strategic management allows an organization to be more proactive than reactive in shaping its own future. It allows an organization to initiate an influence (rather than respond to) activities - and thus to exert control over its own destiny. Small business owners, chief executive officers, presidents, and managers of many for-profit and non-profit organizations have recognized and realized the benefits of strategic management.

In the process of generating and selecting alternative output strategies in the formulation stage of the development of a strategic plan, there are mainly four matrices that are commonly used in formulating a strategy; these are: Strategic Position & Action Evaluation (SPACE) Matrix, Boston Consulting Group (BCG) Matrix, Internal – External (IE) Matrix, and the last one is the Grand strategy Matrix.

In BCG Matrix, viewing every product as a Star, Cash Cow, Dog, or Question Mark is an oversimplification. Many products fall right in the middle of the BCG Matrix and thus are not easily classified [1]. In most decision making process, decision-makers have to make decisions with incomplete information and under uncertain circumstances. These situations have been recognized by many researchers as a suitable field to use fuzzy set theory. Fuzzy logic is used in system control and analysis design because it shortens the time for engineering development and sometimes, in the case of highly complex systems, it is the only way to solve the problem. Fuzzy logic can apply also to economics, psychology, marketing, weather forecasting, biology, and politics [2]. Therefore, based on the concepts of decision support system (DSS), an integrated framework was developed that incorporates fuzzy theory in the strategic position selection. This framework provides managers with a flexible, expandable and interactive DSS to select and evaluate the alternative output strategies in the formulation stage.

Strategists must decide which alternative strategies will benefit the organization most, and therefore, a manageable set of the most attractive alternative strategies must be developed [1]. Strategists never consider all feasible alternatives that could benefit the organization because there is a large number of possible strategies and a large number of ways to implement them, as well as, because no organization has unlimited resources to pursue all alternative strategies.

This work integrated the process of generating and selecting the best alternative output strategy or set of strategies using fuzzy logic decision support system. Therefore, it ensures defining a well formulated, implemented, and evaluated strategic plan in the organization to reach its destination.

## 2. Literature review

The strategic management process consists of three stages: strategy formulation, strategy implementation, and strategy evaluation. Strategy formulation includes developing a vision and mission statements, identifying an organization's external opportunities and threats, determining internal strengths and weaknesses,

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establishing long-term objectives, generating alternative strategies, and choosing particular strategy to pursue. Strategy formulation issues include deciding what new business to enter, what businesses to abandon, how to allocate resources, whether to expand operations or diversify, or whether to enter international markets. Alternative strategies that an organization could pursue can be categorized into 11 main strategies which are: Forward integration, Backward integration, Horizontal integration, Market penetration, Market development, Product development, Related diversification, Unrelated diversification, Retrenchment, Divesture, and Liquidation.

### 2.1. Decision Support System

Some researchers defined a Decision Support System (DSS) broadly as a computer - based system that aids the process of decision making, while others define it as an interactive, flexible, and adaptable computer-based information system, especially developed supporting the solution of a non-structured management problem for improved decision making [3]. DSS combines the use of models and analytical techniques with conventional data access and retrieval functions and has features (including interactive features) which make its use by non-computer people easier. A Decision Support System provides one form of information technology that are capable of storing, retrieving, presenting, and manipulating data and models in an on-line, real time, and interactive manner to help decision makers to solve semi-structures problems [4].

### 2.2. Fuzzy Logic

In today's rapidly changing and highly uncertain environment, the strategic decisions have an extremely complex and fuzzy nature [5]. Generally, decisions are made with limited information because decision makers do not have full knowledge of the problem they face and generally cannot even determine a reasonable probability for alternative outcomes; thus, they must make their decisions under conditions of high uncertainty. In addition, many decisions in organizations, especially important one that have far-reaching effects on organizational activities and personnel, are made in groups. One problem with group decision making is that each member in the decision group has not the same knowledge of the problem as the others have. This means that decision makers will face a decision-making situation with various peers possessing different confidence levels regarding the problem to be handled. Thus, the domain of strategic management has already been recognized as a field appropriate for the application of a fuzzy set theory [6].

However, linguistic variables per se contain ambiguity and multiplicity of meanings and therefore, the information obtained can be expressed as a range of fuzzy sets, instead of a single value in traditional methods. Applying fuzzy logic seems to be the most appropriate method for strategic decision making [7]. The field of strategic management has been recognized as an appropriate field for the application of the fuzzy set theory because of the fuzziness of the main concepts and terms, since the contexts of strategic management belong to the area of uncertainty and vagueness [8].

Lin and Hsieh [8] developed an integrated framework that incorporates fuzzy theory into strategic portfolio selection based on the concepts of decision support system (DSS). This framework provides managers with a flexible, expandable and interactive DSS to select projects for portfolio management. They used the GE Multifactor Portfolio matrix (that developed jointly by General Electric and McKinsey and company) to express the competitive position of the organization which is based primarily on two variables: industry attractiveness (IA) and business strength (BS), and used the 3Cs model (which concerned with the business' customer relations, process capabilities, and functional competencies) to evaluate the feasibility of the strategic plans.

Ghazinoory et al., [5] attempted to solve certain structural problems of the SWOT matrix by following the fuzzy approach to the internal and external factors (in the form of fuzzy membership functions). They recommended in their research to combine more than two fuzzy factors for extracting a single strategy. Ghazinoory et al., [9] evaluated both internal and external factors in linguistic terms and in terms of fuzzy triangular numbers. The fuzzy numbers are fed into an industry attractiveness-business analysis matrix. The matrix is composed of zones, which represent pre-defined sets of strategies. The evaluation of an organization's internal and external conditions results in a position (usually a point) in one of the strategy zones. Keropyan and Gil-Lafuente [10] demonstrated the effects of different decision styles on strategic decisions and likewise, on an organization. The technique that was presented in the study is based on the transformation of linguistic variables to numerical value intervals.

This fuzzy methodology approach allows examining the relations between decision making styles and strategic management processes when there is uncertainty. The purpose of this work is to provide results to companies that may help them to exercise the most appropriate decision making style for its different strategic management processes. The research is leaving more research topics for further studies that may be applied to other decision making areas within the strategic management process.

As a conclusion there is a limited number of researches that use fuzzy logic decision support system to formulate the organization's strategy. Also many researchers rely in their researches on two fuzzy factors to extract the best alternative output strategy that the organization must pursue to achieve its long term objective. In this research and based on the recommendations of previous researchers [5], more than two factors are used to reach for the best alternative output strategy or set of strategies. Eight factors or variables in the four matching stage matrices used jointly to evaluate the alternative output strategies, i.e., in the SPACE Matrix (Financial Position, Stability Position, Competitive Position, and Industry Position), in the BCG Matrix (Industry sales growth rate, and Relative market share position), in the IE Matrix (External Factor Evaluation, and Internal Factor Evaluation), and in the Grand strategy Matrix (Competitive position and Market growth rate ) as shown in Table 1.

## 3. Methodology

### 3.1. Integrating the four matrices

In this stage the most frequent alternative output strategies among the four matrices (SPACE, BCG, IE, and Grand ) will be determined directly using Fuzzy Logic Decision Support System (FLDSS) without generating and evaluating the alternative output strategies for each matrix separately. On the basis of outcomes emanating from the four matrices in the matching stage of a strategic development process, the alternative output strategies that an organization must pursue should be selected to achieve its long term objectives. The criterion for the selection of alternative output strategies is the frequency of choice.

**Table 1.**The possible value of the inputs that come in the middle of each matrix

| Matrix | Inputs | The possible values of the inputs |
|---|---|---|
| IE Matrix | IFE (Internal Factor Evaluation) | 1, 2, 3, 4 |
| | EFE (External Factor Evaluation) | 1, 2, 3, 4 |
| BCG Matrix | R.M.S.P (Relative Market Share Position) | 0, 0.5, 1 |
| | I.S.G.R (Industry Sales Growth Rate) | -20, 0, 20 |
| SPACE Matrix | (FP+SP)* | -6, 0, 6 |
| | (IP+CP)** | -6, 0, 6 |
| Grand strategy matrix | Market growth | 0.05 |
| | Competitive position | 1, 2.5, 4 |

* (FP+SP): The resultant of (Y – Axis) in SPACE Matrix.
** (IP+CP): The resultant of (X – Axis) in SPACE Matrix.

The four matrices will be integrated or linked by relations between these matrices to reach for the most frequent alternative output strategy or set of strategies in the different strategic positions using fuzzy logic decision support system model (FLDSS) to ensure formulating the strategy with lower cost in the organization that have limited resources. For example, Forward Integration Strategy will be found twice in SPACE Matrix: in the Aggressive position and Competitive position, once in BCG Matrix in Stars position, once in Grand strategy Matrix in Quadrant one position, and once in IE Matrix in Grow and Build region as shown in Table 2.

Figure 2 shows how each of the eleven alternative output strategies resulted from the combination of different strategic positions in the four matching stage matrices. These relations among the four matrices will help in setting the rules for each alternative output strategy in the model. The first column represents the three strategic positions of the IE Matrix (Grow and build, Hold and Maintain, Harvest or Divest), the second column represents the SPACE Matrix which has four strategic positions (Aggressive, Competitive, Conservative, and Defensive), the third column represents the BCG Matrix which has four strategic positions (Stars, Question marks, Cash cows, and Dogs), the fourth column represents the Grand Strategy Matrix that has four strategic positions (Quadrant 1, Quadrant 2, Quadrant 3, and Quadrant 4), and the fifth column represents the eleven main alternative output strategies (Forward integration, Backward integration, Horizontal integration, Market development, Market penetration, Market development, Retrenchment, Divesture, and Liquidation).

The relations among the four matrices for each alternative output strategy consist of the strategy's positions in the different strategic positions or regions in these matrices depending on the values of the inputs that are derived from the internal and external audit of the organization's environment. On contrary, to other matrices which have two ranges or levels in their variables, each strategic position (Grow and build, Hold and maintain, Harvest or divest)

**Table 2.** The repetition or frequency of the alternative output strategies in the different strategic positions of the four matrices

| No. | Strategy | 1. SPACE Matrix | | | | 2. BCG Matrix | | | | 3. IE Matrix | | | 4. Grand strategy Matrix | | | | Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Aggressive | Competitive | Conservative | Defensive | Stars | Cash cows | Question marks | Dogs | Grow and build | Hold and maintain | Harvest or divest | Q1 | Q2 | Q3 | Q4 | |
| 1 | **Forward Integration** | X | X | | | X | | | | X | | | X | | | | 5 |
| 2 | **Backward Integration** | X | X | | | X | | | | X | | | X | | | | 5 |
| 3 | **Horizontal Integration** | X | X | | | X | | | | X | | | X | X | | | 6 |
| 4 | **Market development** | X | X | X | | X | | X | | X | | | X | X | | | 8 |
| 5 | **Market penetration** | X | X | X | | X | | X | | X | X | | X | X | | | 9 |
| 6 | **Product development** | X | X | X | | X | X | X | | X | | | X | X | | | 9 |
| 7 | **Related diversification** | X | | X | | | X | | | | | X | X | | X | X | 6 |
| 8 | **Unrelated diversification** | X | | | | | X | | | | | | | | X | X | 4 |
| 9 | **Retrenchment** | | | | X | | X | | X | | | X | | | X | | 5 |
| 10 | **Divesture** | | | | X | | X | X | X | | | X | | | X | X | 7 |
| 11 | **Liquidation** | | | | X | | | | X | | | | | X | X | | 4 |

 

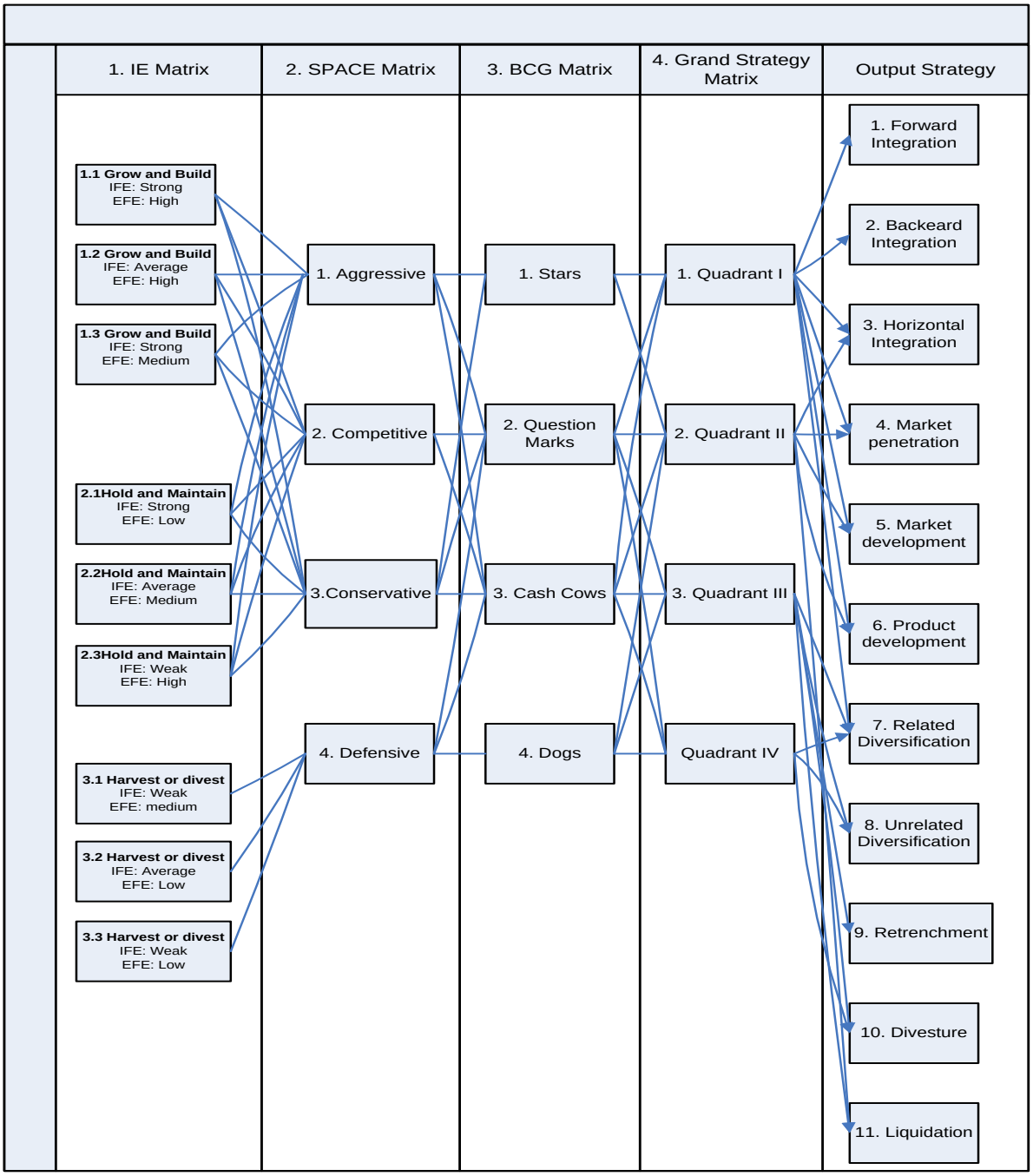


**Figure 2.** Overview of the integrated four matrices and the output strategies

in IE Matrix is resulted from three ranges or levels of the Internal Factors Evaluation (IFE) and External Factors Evaluation (EFE) matrices' variables. For example Grow and Build region resulted when:

1. IFE ranges between (3– 4) and EFE ranges between (3– 4).
2. IFE ranges between (2– 3) and EFE ranges between (3– 4).
3. IFE ranges between (3– 4) and EFE ranges between (2– 3).

There are eleven tables that represent the relations among the four matrices, in which each table represents an alternative output strategy, and each row in these tables represents a relation that combines the different strategic positions of the four matrices. For example, Table 3 shows the 6 combinations or relations between the four matrices that will lead to the Forward Integration strategy, and each row in the table indicates a relation or a condition that might be achieved.

There are 274 relations that lead to the eleven alternative output strategies, and each table is formed from five columns; the first four columns represent the strategic positions or regions of the four matrices that the alternative output strategy may fall in, and the fifth column represents the eleven alternative output strategies.

There are duplications or similarities in many relations or rows that lead to different alternative output strategies. This means that there is a conflict because different alternative output strategies have the same relation. For example, Table 4 represents how the same relation between the four strategic positions (Grow and Build (IFE: 3 - 4, EFE: 3 – 4), Aggressive, Stars, and Quadrant 2) of the four matrices will lead to the different alternative output strategies (Horizontal Integration, Market penetration, Market development, Product development).

**Table 3.** Forward Integration Strategy's rules in all strategic position of the four matrices

| 1. IE Matrix | 2. SPACE Matrix | 3. BCG Matrix | 4. Grand Strategy Matrix | Output Strategy |
|---|---|---|---|---|
| Grow and build (IFE:3 - 4,EFE:3 – 4) | Aggressive | Star | Quadrant 1 | Forward Integration |
| Grow and build (IFE:3 - 4,EFE:3 – 4) | Competitive | Star | Quadrant 1 | Forward Integration |
| Grow and build (IFE:2 - 3,EFE:3 – 4) | Aggressive | Star | Quadrant 1 | Forward Integration |
| Grow and build (IFE:2 - 3,EFE:3 – 4) | Competitive | Star | Quadrant 1 | Forward Integration |
| Grow and build (IFE:3 - 4,EFE:2 – 3) | Aggressive | Star | Quadrant 1 | Forward Integration |
| Grow and build (IFE:3 - 4,EFE:2 – 3) | Competitive | Star | Quadrant 1 | Forward Integration |

**Table 4.** The duplication of same rule for different outputs

| 1. IE Matrix | 2. SPACE Matrix | 3. BCG Matrix | 4. Grand Strategy Matrix | Output Strategy |
|---|---|---|---|---|
| Grow and build (IFE:3 - 4,EFE:3 – 4) | Aggressive | Stars | Quadrant 2 | Horizontal integration |
| Grow and build (IFE:3 - 4,EFE:3 – 4) | Aggressive | Stars | Quadrant 2 | Market penetration |
| Grow and build (IFE:3 - 4,EFE:3 – 4) | Aggressive | Stars | Quadrant 2 | Market development |
| Grow and build (IFE:3 - 4,EFE:3 – 4) | Aggressive | Stars | Quadrant 2 | Product development |

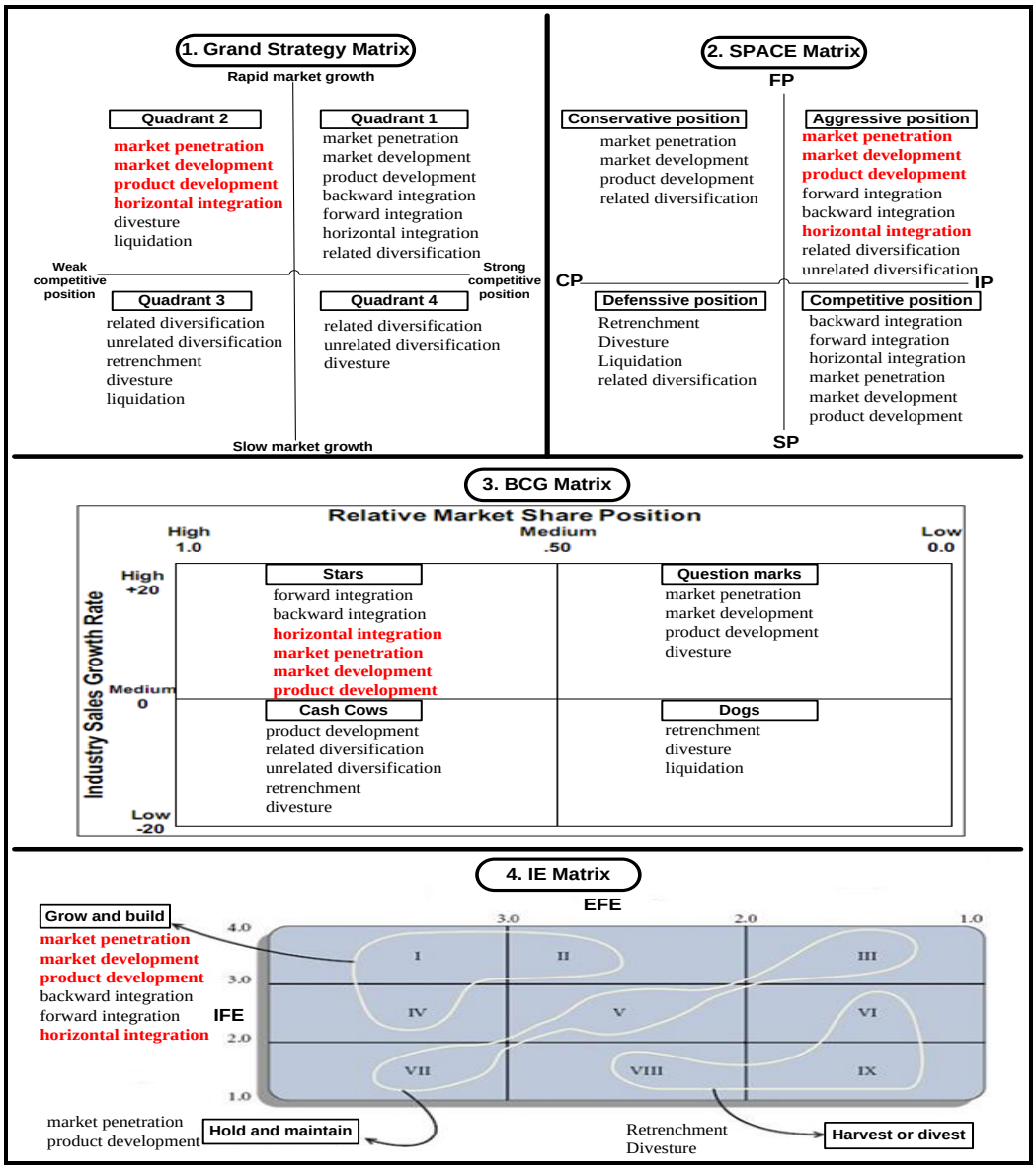


**Figure 3.** How the group of alternative strategies (Horizontal Integration, Market development, Market penetration, Product development) fall in different strategic position.

 

Figure 3 shows how this set of alternative output strategies (Horizontal Integration, Market Penetration, Market Development, Product Development) which are shown in Table 4 falls in the different strategic positions of the four matrices and should be pursued congruently when the internal and external audit of an organization lead to Quadrant 2 in Grand Strategy Matrix, Aggressive position in SPACE Matrix, Stars position in BCG Matrix, and Grow and Build region in IE Matrix. Also, it is noted that the alternative output strategies that are not similar to or frequent between these matrices will be neglected and these alternative output strategies are Divesture and Liquidation in Grand Strategy Matrix, Forward Integration, Backward Integration, Related Diversification, and Unrelated Diversification in SPACE Matrix, Forward and Backward Integration in BCG Matrix, and Forward and Backward Integration in IE Matrix).

So, there is a conflict because the same relation or condition leads to multi or different alternative output strategies. To solve this problem the duplications must be eliminated by combining the alternative output strategies which have the same relations or combination between the different strategic positions of the four matrices.

After combining the alternative output strategies that have the same relations, 134 are obtained relations and each one leads to one or group of alternative output strategies, ten outputs (strategy or set of strategies) were resulted from the different 134 relations, these ten outputs are:

1. Forward Integration, Backward Integration, Horizontal Integration, Market penetration, Market Development, Product Development.
2. Horizontal Integration, Market penetration, Market Development, Product Development.
3. Market penetration, Market Development, Product Development.
4. Market penetration and Product Development.
5. Product Development.
6. Related Diversification.
7. Related Diversification, Unrelated Diversification.
8. Retrenchment, Divesture.
9. Divesture.
10. Liquidation.

### 3.2. Building (FLDSS) Model

The process of generating and evaluating alternative output strategies is called matching stage, and this is the second and important stage in strategy formulation step. Four primary GUI tools were used for building, editing, and observing fuzzy inference systems in the toolbox:

1. Fuzzy Inference System (FIS) Editor.
2. Membership Function Editor.
3. Rule Editor.
4. Rule Viewer.

Each tool of the four primary GUI tools will be implemented in details to build the Fuzzy Logic Decision Support System model as in the following:

#### 3.2.1. Fuzzy Inference System (FIS) Editor

There are 8 inputs or variables and 1 output in the four matrices and in this screen these variables will be entered as the following:

***First: Inputs***

We have 8 inputs which are:

1. IFE: ranges from 1.0 to 4.0
2. EFE: ranges from 1.0 to 4.0
3. Relative Market Share Position (R.M.S.P.): ranges from 0 to 1
4. Industry Sales Growth Rate (I.S.G.R.): ranges from -20 to + 20
5. (IP+CP): It is the resultant of the two variables: Industry position (IP) & Competitive position (CP) in X - axis of the SPACE Matrix, (IP) ranges from 0 to +6, and (CP) ranges from -6 to 0, So, (IP+CP) ranges from -6 to +6
6. (FP+SP): It is the resultant of the two variables: Financial position (FP) & Stability position (SP) in Y - axis of the SPACE Matrix, (FP) ranges from 0 to +6, and (SP) ranges from -6 to 0, So, (FP+SP) which ranges from -6 to +6. Figure 4 shows how the (FP+SP) variable ranges from -6 to +6 on the Y – axis and how the variable (IP+CP) ranges from -6 to +6 on the X-axis
7. Market growth: the input of this variable is whether it exceeds or less than 0.05
8. Competitive position: ranges from 1.0 to 4.0

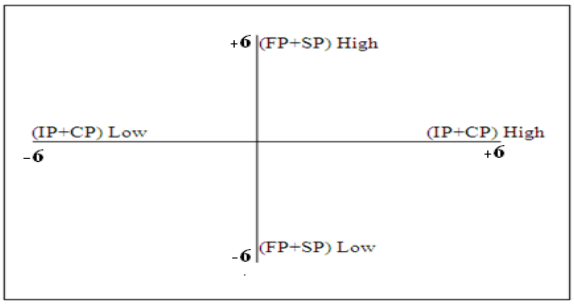


**Figure 4.** Explanation of (FP+SP) and (IP+CP) on SPACE Matrix

***Second: Output***

We have one output which is the alternative output strategy or set of strategies that the organization should pursue. Alternative output strategies: range from 0 to 1. Figure 5 shows the eight inputs (IFE, EFE, R.M.S.P., I.S.G.R, IP+CP, FP+SP, Market growth, and Competitive position) to the left and the output (alternative output strategy) to the right in the Fuzzy Inference System Editor screen.

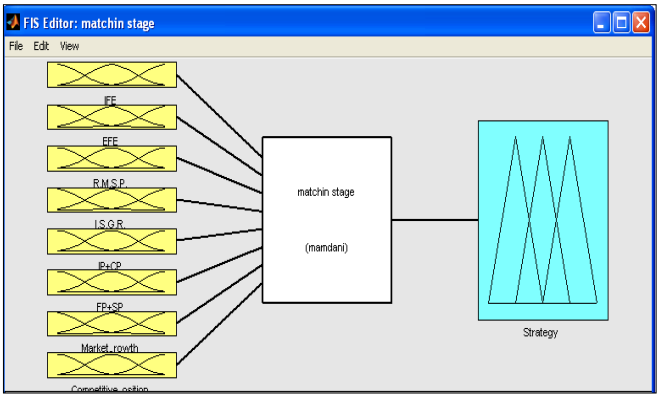


**Figure 5.** Fuzzy Inference System Editor screen

#### 3.2.2. Membership Function Editor

The Membership Function Editor is a tool that let users display and edit all of the membership functions associated with all inputs and outputs variables for the entire fuzzy inference system. Each input has a number of membership functions equal to the number of the conditions or states for it. For example, if the input has two ranges (1 – 2) and (2 – 3) then there are two membership functions (high and low). The model uses the Gaussian curve built-in membership function for the eight inputs and the Triangular-shaped built-in membership functions for the output which are the most and commonly used functions:

***Gaussian curve built-in membership function:***

The symmetric Gaussian function depends on two parameters σ (standard deviation) and c (mean) and given by the following equation:

$$f\ (x;\ c, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(x-c)^2}{2\sigma^2}} \qquad (1)$$

***Triangular-shaped built-in membership function:***

The triangular curve is a function of a vector, x, and depends on three scalar parameters a, b, and c, as given by:

$$f(x; a, b, c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ \frac{c-x}{c-b} & b \le x \le c \\ 0, & c \le x \end{cases} \qquad (2)$$

The parameters *a* and *c* locate the "feet" of the triangle and the parameter *b* locates the peak.

The membership functions for the inputs and output in this model are as the following:

***First: Inputs***

*1. IFE: The membership Functions are (Figure 6):*

(From 3 to 4): Strong.

(From 2 to 3): Average.

(From 1 to 2): Weak.

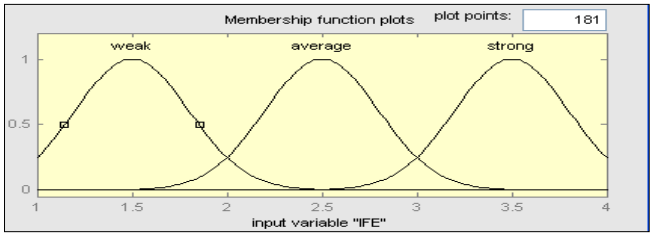


**Figure 6.** Membership Function of IFE

*2. EFE:*

The membership Functions are:

(From 3 to 4): High.

(From 2 to 3): Medium.

(From 1 to 2): Low.

*3. (IP+CP):*

The Membership Functions are:

(From -6 to 0): low.

(From 0 to +6): High.

*4. (FP+SP):*

The Membership Functions are:

(From -6 to 0): low.

(From 0 to +6): High.

*5. Relative Market Share Position (R.M.S.P.):*

The Membership Functions are:

(From 0.5 to 1): High

(From 0 to 0.5): Low

*6. Industry Sales Growth Rate:*

The Membership Functions are:

(From 0 to +20): High

(From -20 to 0): Low

*7. Competitive Position:*

The Membership Functions are:

(From 2.5 to 4): Strong.

(From 1 to 2.5): Weak.

*8. Market Growth:*

The Membership Functions are:

(Greater than 0.05): Rapid.

(Less than 0.05): Slow.

***Second: The Output***

The output is the ten alternative output strategies, so there are ten Membership Functions in this model which are:

1. (From 0 to 0.1) the Membership Function is: (1)* which indicates Liquidation.
2. (From 0.1 to 0.2) the Membership Function is: (2) which indicates Divesture.
3. (From 0.2 to 0.3) the Membership Function is: (3) which indicates Retrenchment, and Divesture.
4. (From 0.3 to 0.4) the Membership Function is: (4) which indicates Related Diversification.
5. (From 0.4 to 0.5) the Membership Function is: (5) which indicates Related Diversification, and Unrelated Diversification.
6. (From 0.5 to 0.6) the Membership Function is: (6) which indicates Product Development.
7. (From 0.6 to 0.7) the Membership Function is: (7) which indicates Market Penetration, and Product Development.
8. (From 0.7 to 0.8) the Membership Function is: (8) which indicates Market penetration, Market Development, and Product Development.
9. (From 0.8 to 0.9) the Membership Function is: (9) which indicates Horizontal Integration, Market penetration, Market Development, and Product Development.
10. (From 0.9 to 1) the Membership Function is: (10) which indicates Forward Integration, Backward Integration, Horizontal Integration, Market penetration, Market Development, and Product Development.

Figure 7 indicates the Membership Function's numbers from 1 to 10 for the alternative output strategies which mentioned above, respectively.

Because there is no space in the Membership function plots screen to write the membership functions' names over each one; the numbers from 1 to 10 indicate the names of these membership functions.

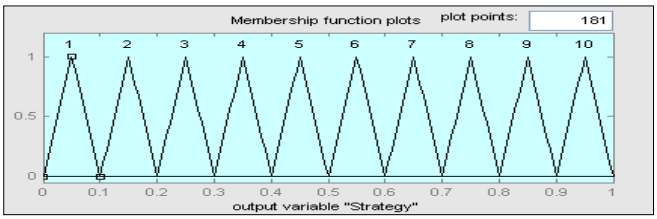


**Figure 7.** Membership Functions of the output (Strategy)

### 3.2.3. Rule Editor

There are 134 rules that resulted from the combination of the four matrices and installed in the rule editor screen, for example the first rule that was installed in this screen is as in the following:

"If (IFE is Average) and (EFE is High) and (R.M.S.P. is High) and (I.S.G.R. is High) and (FP+SP is High) and (IP+CP is High) and (Market growth is Rapid) and (Competitive Position is Strong) Then the Output is 10". This rule means: if (IFE) ranges between (2 - 3), (EFE) ranges between (3 - 4), Relative Market Share Position ranges between (0.5 to 1), Industry Sales Growth Rate ranges between (0 to +20), the resultant of Financial Position and Stability Position (FP + SP) ranges between (0 to +6), the resultant of Industry Position and Competitive Position (IP + CP) ranges between (0 to +6), Market growth exceeds 0.05, and Competitive Position ranges between (2.5 to 4), then the alternative output strategies that the organization should pursue are: Forward Integration, Backward Integration, Horizontal Integration, Market penetration, Market Development, and Product Development. Figure 8 shows the Rule Editor screen for the first 13 rules.

 

### 3.2.4. Rule viewer

This screen displays a roadmap of the whole fuzzy inference process. It is based on the fuzzy inference diagram. The nine plots across the top of Figure 9 represent the antecedent and consequent of the first rule. Each rule is a row of plots, and each column is a variable. The rule numbers are displayed on the left of each row. The first eight columns of plots show the membership functions referenced by the antecedent, or the "if-part" of each rule. The ninth column of plots shows the membership functions referenced by the consequent, or "then-part" of each rule.

The 135th plot in the ninth column of plots represents the aggregate weighted decision for the given inference system. This decision will depend on the input values for the system. The defuzzified output is displayed as a bold vertical line on this plot, and the defuzzified value has been achieved directly through the model, whereas, for the calculating the aggregate weighted decision for the given inference system manually, the common and useful defuzzification technique which is the center of gravity (COG) or center of area (COA) will be used. This method determines the centre of the area of the combined membership functions through the following equation:

$$COA = \frac{\int_{xmin}^{xmax} f(x)x\,dx}{\int_{xmin}^{xmax} f(x)} \quad (3)$$

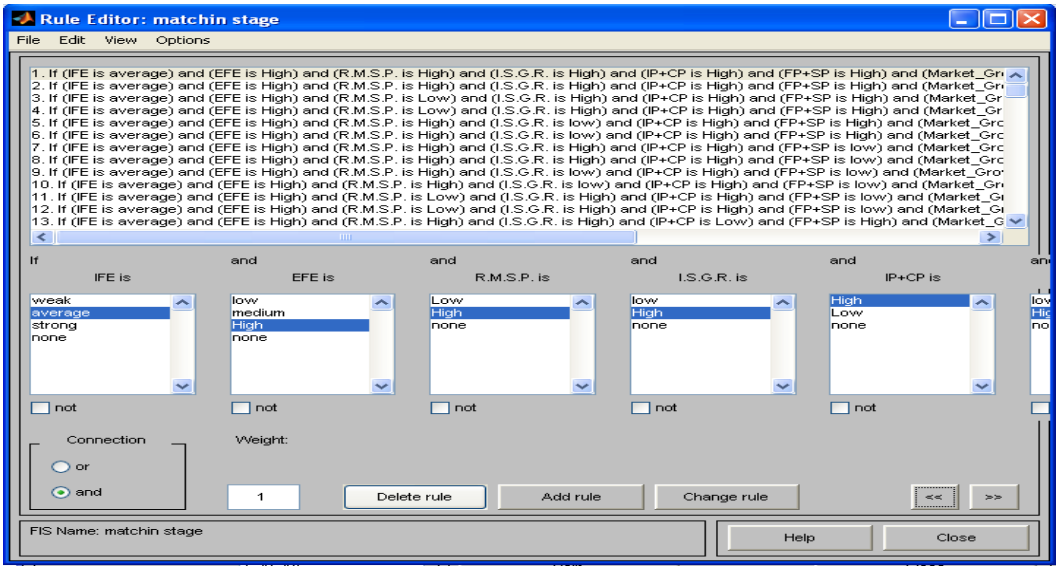


**Figure 8.** Rule Editor Screen

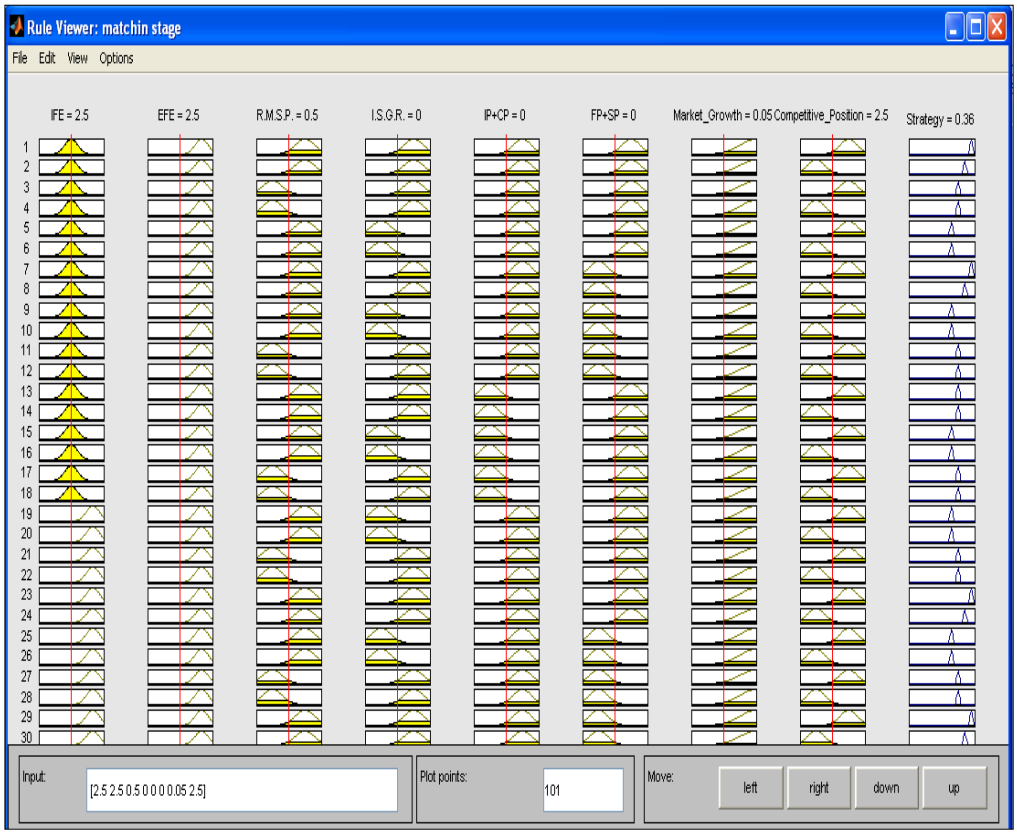


**Figure 9.** Rule viewer screen

## 4. Case Study

A case study on a Jordanian company called Alliance Chocolate Manufacturing Company (ACMC) was implemented to validate the model and to generate and evaluate the alternative output strategies that the company should pursue to achieve its long term objectives.

***Inputs***

The company has been visited and a thorough audit was performed to gather data and information regarding the current internally and externally status of the company. As a result, the variables or inputs for each matrix was obtained and summarized in Table 5 to start generating and evaluating the alternative output strategies using fuzzy logic decision support system model.

**Table 5.** The eight variables of the four matrices in ACMC Company

| Matrix | Input | Value |
|---|---|---|
| IE | IFE | 2.55 |
| | EFE | 2.7 |
| BCG | (R.M.S.P.) | 10% |
| | (I.S.G.R) | 0.2 |
| SPACE | (FP+SP) | 0.34 |
| | (IP+CP) | 1 |
| Grand strategy | Market growth | 0.2 |
| | Competitive position | 3 |

***Rule viewer***

The variables and their current values are displayed on top of the columns of the Rule viewer screen. In the lower left rectangle which marked in circle form in Figure 10, there is a text field Input in which the values from Table 5 is entered.

The Defuzzified alternative output strategy is 0.643 which is shown on the top of the 9th column of the Rule viewer and marked in the circle in Figure 4.2. The value of 0.643 falls in the membership function or in the range of (0.6 to 0.7) which corresponds to the Market Penetration and Product Development alternative output strategies. So, Market Penetration and Product Development strategies are the common and most frequent strategies between the four matrices. If the organization has limited resources then these alternative output strategies are the first option for the organization to pursue.

Market Penetration and Product Development are the achieved alternative output strategies using our FLDSS Model. It depends on the eight fuzzy factors or variables of the four matrices together on the contrary of taking the alternative output strategies in each matrix separately which depends on two fuzzy factors only. By pursuing these two alternative output strategies instead of pursuing all the alternative output strategies that resulted from the four matrices, the cost of implementing the strategic plan will be reduced.

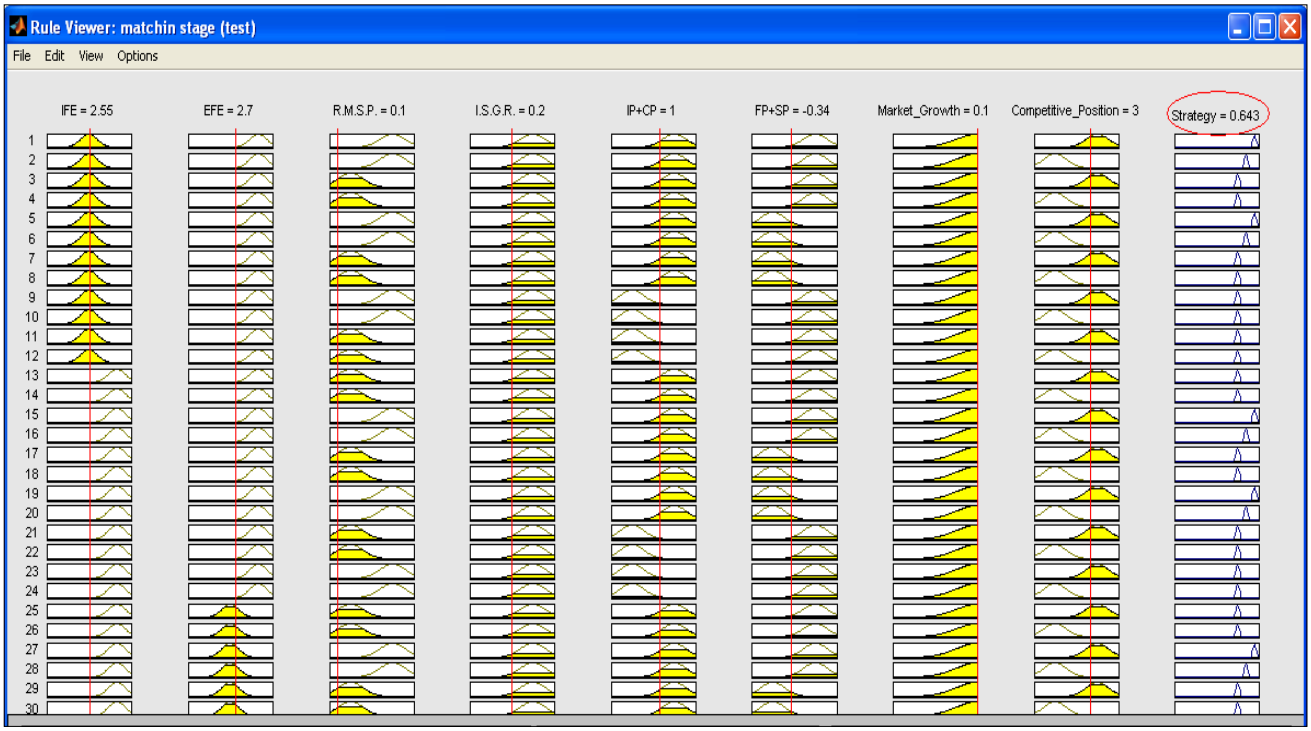


**Figure 10.** Defuzzified alternative output strategy in the Rule viewer screen

## 5. Conclusion and Recommendation

### 5.1. Conclusion

A Fuzzy Logic Decision Support System Model had been developed for generating and evaluating the alternative output strategies which are the most important step in the formulation stage of a strategic planning process. In this model, the four matching stage matrices (SPACE, IE, BCG, and Grand Strategy Matrix) have been combined by relations to select the most frequent alternative output strategy or set of strategies among these matrices. There are 134 relations or conditions that resulted from the combination. One relation may be occurred when evaluating the eight variables of the four matrices from the internal and external audit of an organization's environment.

The relations among the four matrices had been entered as rules in this model using Fuzzy Logic Toolbox™ software which is a collection of functions built on the MATLAB® technical computing environment, and relies heavily on graphical user interface (GUI) tools. This model is simple and unsophisticated and no previous experience with computers or knowledge of

strategic planning is required for the users. The point of value of work is to map an input space (the inputs of the four matrices) to an output space (the alternative output strategies), and the primary mechanism that is used for doing this is a list of if-then rule statements. These rules are useful because they refer to variables and the adjectives that describe those variables.

A fuzzy logic based approach o model inconsistencies during the model development process is proposed. Fuzzy logic offers a unique opportunity to model methodological rules and handle inconsistencies within the same framework. Linguistic variables allows capturing, as much as possible, the software engineer's perception in a natural way, as well as helping an organization to reach its destination with incomplete information and under uncertain circumstances. It is much easier to express the state of the variables of each matrix of the four matching stage matrices in linguistic terms (High, Low, Strong, Weak …) rather than using numbers. However, linguistic variables contain ambiguity and multiplicity of meanings and therefore, the information obtained can be expressed as a range of fuzzy sets, instead of a single value in the traditional methods. Also the developed model solved the problem of having values or inputs for the four matrices that fall in the middle or on the centreline between the strategic positions.

The main purpose for combining the four matrices in this model is for strategies who depend on more than two fuzzy factors of the external and internal organization's environment (as required by each matrix alone) to have an accurate strategies selection. On the other hand, an effective strategic plan for an organization that has limited resources can be obtained.

### 5.2. Limitations and Recommendations

This model is applicable only in profit making companies because of the nature of the eleven alternative output strategies in the four matching stage matrices. The aim of this work is to generate and evaluate these strategies to select the most frequent using Fuzzy Logic Decision Support System. Grand strategy matrix and IE matrix usually take into account the different strategic planning units (SBU) in an organization while SPACE Matrix and Grand strategy matrix don't take it into account. So this model is valid only for organizations that have no SBU's.

More alternative output strategies such as Michael Porter's Five Generic Strategies that are not found in the four matching stage matrices (SPACE, IE, BCG, and Grand Strategy Matrix) can be inserted in a future improvement of the developed model. One alternative output strategy is recommended to be selected in further researches to help an organization that has limited resources by having a mechanism to select the best alternative output strategy to achieve its long term objectives.

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