Fuzzy logic identifier of the short-term objectives

Fuzzy logický identifikátor krátkodobých cílů

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Abstract: This article presents a new science-based approach which identifies the most effective current-period short-term objective of an enterprise, which is usually set based on the pure judgment of top management members or enterprise's experts. The method is based on fuzzy-decision-making system and makes robust utilization of enterprise's experts' knowledge, intuition and expertise. A simple illustrative example is provided to demonstrate how the method can be efficiently and effectively used in practice. The proposed approach can be used to identify the short-term objective of any profit-making-enterprise, and is specially applicable to business industries that are full of qualitative, stochastic, uncertain, and vague variables such as the case in agricultural business (e.g., agro-food companies, fertilizers, and agro-chemical producers), and industrial firms (e.g., electronics, home appliances, machine tools companies ... etc.), and is generally applicable to any other business sector.

Keywords: short-term objectives, fuzzy decision-making-system, fuzzy expert-system

Abstrakt: Článek uvádí novou metodu, která vědecky identifikuje nejefektivnější krátkodobý cíl podniku, který se obvykle stanovuje na základě pouhého posouzení vrcholových manažérů nebo podnikových expertů. Metoda je založena na fuzzy systému pro podporu rozhodování a zdůrazňuje využití expertní znalosti a intuice. Jednoduchý ilustrativní příklad demonstruje jak lze metodu účinně a efektivně použít v praxi. Předkládanou metodu lze použít k stanovení krátkodobého cíle libovolného zisk vytvářejícího podniku a je obzvlášť vhodná pro podniky, kde je mnoho kvalitativních, stochastických, nejistých nebo neurčitých proměnných. Typickým představitelem jsou podniky agro-potravinářského komplexu (zemědělská prvovýroba, výroba hnojiv a zemědělských chemikálií, zpracovatelský sektor, odchod), ale je obecně použitelná i v dalších podnikatelských sektorech (např. domácí spotřebiče, elektronika, výroba strojů, apod.).

Klíčová slova: krátkodobý cíl, fuzzy systém pro podporu rozhodování, fuzzy expertní systém

INTRODUCTION

Objectives represent a managerial commitment to producing specified results in a specified time frame. They direct attention and energy to what needs to be accomplished. The main purposes of objectives are (Kotler 1972):

(i) Company objectives provide ultimate criteria for resolving difficult company decision.
(ii) Company objectives are the basis for long-range planning.
(iii) Company objectives produce consistency in the decentralized decision making of company executives.
(iv) Company objectives provide employees with a sense of purpose that makes their works worthwhile.

There are two types of objectives: long-run objectives, and short-run objectives. The company's long-run objectives, such as maximization of return on investment, and societal welfare, are permanent and called organizational goals. Short-run objectives, on the other hand, such as maximization of sales volume, maximization of profit margin, maximization of customer satisfaction, reinforcing company's competitive position are taken up for a short period (a year, quarter, ... etc.) to reflect the most important beneficial focus of the top management. Short-term objectives are adjustable and adoptable periodically to cope with the rapidly changing environmental forces and economic conditions, such as fluctuating costs of resources, changing competition level, new forecasts, new technology, new ideas and products, new opportunities, new threats, new regulations and taxes, and other various changing variables. The problem of setting short-term objectives of an enterprise have been dealt with subjectively, in that it is usually a decision which is based on the pure judgment, intuition, experience of the top management members or company's experts, without a scientific treatment and quantification of various effects of input quantitative and qualitative factors. The proposed approach makes use of such intuition, knowledge, and expertise of the company's experts, but in a science-based, systematic way.

THE AIM AND METHOD

The aim of this article is to develop a science-based, systematic approach to identify the current-period short-term objective of an enterprise based on the aggregation of the enterprise's expert's opinions, some of which might be conflicting, and taking into account the vague, uncertain, and dynamic nature of the input factors affecting such decision. The approach is to be used as a reliable expert model assisting the top management vigorously in short-term objective identification. In order to develop the proposed method, first a subjective study of the logical and causal relationships among most relevant company objectives, from one side, and the determinants, or motivators of such objectives, in the other side, is conducted. The determinants of objectives are investigated and most affecting ones are selected regardless of their quantitative or qualitative nature. A quantification of such determinants is then proposed, which is necessary to permit inclusion of qualitative determinants along with quantitative ones. Fuzzy decision-making system (Dweiri, Meier 1996) is then to be adapted to model the problem to give finally an output, which is the most important current-period objective to focus upon.

THE DETERMINANTS OF SHORT-TERM OBJECTIVES AND ASPECTS OF VAGUENESS: RATIONAL OF USE OF FUZZY LOGIC SETS

The short-term objectives of a profit-making company or an enterprise are periodically altered and adopted subjectively by the management in response to frequent changes in some affecting variables, conditions, opportunities and motivations of such objectives, which are called determinants or motivators of company objectives. Among them there are new sales forecasts, new opportunities, change in competition levels, new threats, changing economic or political conditions and others. Figure 1 shows the causal relationship between the short-term objective decision as an output, and the most generic determining factors as inputs. The majority

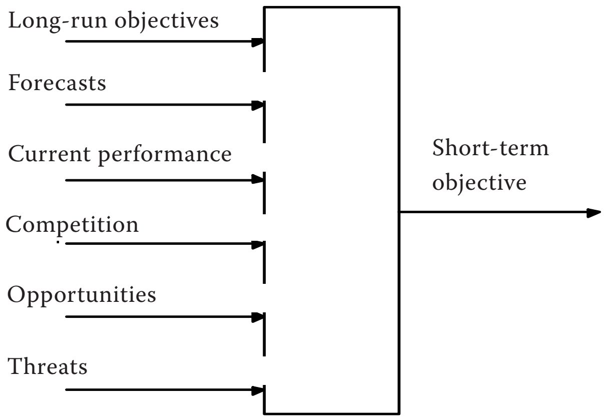

Figure 1. Determinants and motivators of short-term objectives

of these determinants and motivators are changing frequently, which necessitates alteration and adoption of a parallel, adequate objective, in a way that can cope with such dynamic changes, and to realize the greatest benefits to the company as well.

The problem of objective identification involves mapping the dependency of the objective decision on a set of multiple *quantitative and qualitative* factors. Consequently, mathematical models, which mostly consider only quantitative factors, are not adequate, since they ignore the qualitative effects. Over and above, the output or solution variable, namely, the objective, is a *subjective decision* not a quantitative value. Moreover, the values of some variables that affect the objective decision are not exactly defined, *uncertain*, or *stochastic* such as in case of forecasts of sales, or costs, or other economic variables. In addition, the quantification of some qualitative or subjective input factors such as competition level is based on the experts' judgment and accordingly they should be viewed as *vague or inexact* ones. So, in order to take account for all such issues described above, namely, inexactness, uncertainty, vagueness, dynamic nature, it is more adequate to handle the value of input determinants as ranges, and not as exact value, and then to describe them using natural language (high, low, medium, very low, very high, likely, etc.). The human expert use natural language efficiently based on his knowledge, expertise and intuition to control complex systems, for which it is hard and inadequate to mathematically model the relationships between their inputs and outputs using exact numerical expressions. Fuzzy logic sets enable to mathematically quantify such knowledge, expertise and intuition, to model such complex systems.

FUZZY DECISION-MAKING SYSTEM (FDMS)

Fuzzy set theory was introduced by Zadeh (1965) to deal with vague, imprecise and uncertain problems. The lack of data is the reason for uncertainty in many daily problems. Fuzzy set theory has been used as a modeling tool for complex systems that are hard to define precisely, but can be controlled by human expert. Human expert can make decision in the absence of clearly defined boundaries based on the expertise and general knowledge of the task of the system in consideration. The human's decision and actions are based on IF-THEN rules developed over years of knowledge and experience. A detailed description of the fuzzy decision making system can be found in Dweiri and Meier (1996), Cox (1995) and Ross (1995).

FUZZY LOGIC IDENTIFIER OF THE SHORT-TERM OBJECTIVE

Figure 2 depicts the FDMS adapted to model the relationship between the company's objective, as an output, and the determinants of objectives as inputs. The fuzzification interface converts the ranges of values of quantitative determinants and quantified qualitative factors into corresponding universes of discourses, and then divides them into fuzzy sets. The current actual values of input determinants are converted into fuzzy sets by applying the maximum operator. The inference engine then applies the relevant experts' If-Then decision rules contained in the rule-base on the fuzzified input values, which express the experts' opinions about how the values of input determinants are converted into objective decision. A set of rules may fire each of which gives its opinion about what the objective should be in form of an implied fuzzy set. The defuzzification interface finally combines the consequents of all fired rules to give final crisp consequent that is the most significant current period short-term objective, which constitutes a compromise of the requirement of multiple input determinants.

APPLICATION OF FUZZY LOGIC IDENTIFIER OF OBJECTIVES TO AN ABC COMPANY: A DETAILED ILLUSTRATIVE NUMERICAL EXAMPLE

Supposing that the experts of an ABC enterprise have recognized that the every-period objective of the company should be selected among one of the following objectives:
- O_1 : Maximize profit margin.
- O_2 : Maximize sales volume.
- O_3 : Maximize customer satisfaction.
- O_4 : Increase market share.
- O_5 : Reinforce company's competitive position.

One of these objectives is to be taken up each period (quarter or year, etc.). Let the company's experts have also recognized that the essential determinants and motivators of the current period objectives include 5 quantitative factors and 2 qualitative factors as follows:
- I_1 : Expected sales volume (CZK).
- I_2 : Average unit manufacturing cost (CZK/unit).
- I_3 : Inventory level (CZK).
- I_4 : Company's product price (CZK).
- I_5 : Competitor's product price (CZK).
- I_6 : Company's competitive strength.
- I_7 : Competition level.

Hereinafter are the four components of the adapted fuzzy-decision-making system.

Fuzzification of input determinants

In this step, the values of input variables, the determinants of objectives, and the output variable, the objective, are fuzzified. Based on opinion of the experts

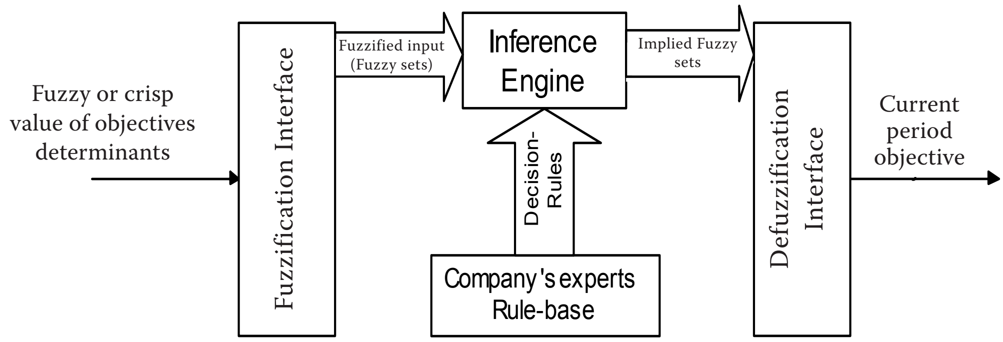

Figure 2. Fuzzy-logic identifier of company's short-term objectives

and/or the analysts, a membership functions shapes are chosen. For simplicity, and it is most commonly used, triangular membership functions are assumed. Five fuzzy sets are used for quantitative determinants: "Very Low" as VL, "Low" as L, "Medium" as M, "High" as H, and "Very High" as VH. Examples of how quantitative variables could be fuzzified are in Figures 3, 4, 5 and 6. The maximum operator (for resolve the partial membership in two fuzzy sets) is used to determine fuzzy sets for actual current values of variables. As an example, in Figure 3., the value of sales I_1 = 325 belongs partially in two fuzzy sets "Medium" with degree of membership, μ = 0.75, and "High" fuzzy set with the degree of membership, μ = 0.25. Then, the maximum operator assign this value to the fuzzy set which has the maximum degree of membership; here the "Medium" fuzzy set.

For the remaining two qualitative determinants, company competitive strength, and competition level, they must be first quantified, and then fuzzified. Let us consider first the company competitive strength. The procedure described by Thompson-Strickland (1987) used to rate the competitive strength of the company is followed. The competitive strength of both company and rivals are judged based on a number of key success factors and competitive measures revealed through industry and competitive analyses. First, key success factors are listed, the experts are asked to rate each company with respect to each key success factors, using a rating scale from 1 to 10. The rate of

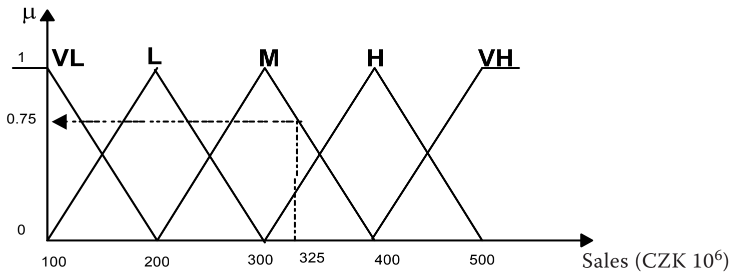

Figure 3. Fuzzification of sales

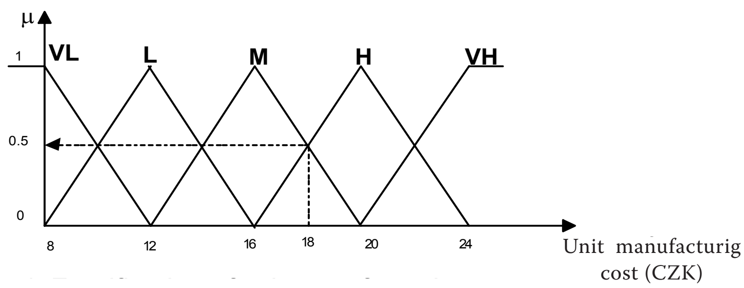

Figure 4. Fuzzification of unit manufacturing cost

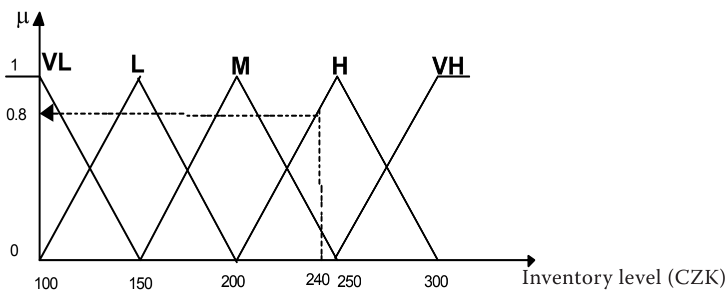

Figure 5. Fuzzification of inventory level

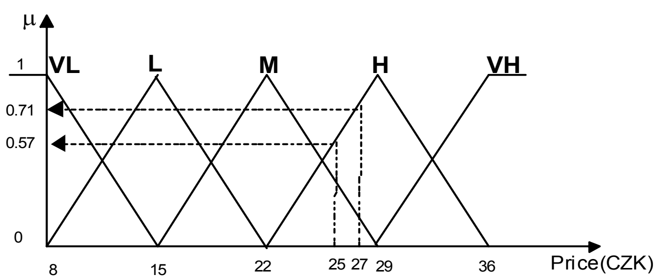

Figure 6. Fuzzification of price

Table 1. Competitive strength assessment

Key success factors/Strength measures	Rivals				
	ABC	Rival 1	Rival 2	Rival 3	Rival 4
Product quality	8	5	10	1	6
Reputation/Image	8	7	10	1	6
Manufacturing capabilities	2	10	4	5	1
Technological skills	10	1	7	3	8
Dealer network	9	4	10	5	1
Marketing/Advertising	9	4	10	5	1
Financial strength	5	10	7	3	1
Relative cost position	5	10	3	1	4
Customer service	5	7	10	1	4
Σ Overall rating	61*	58	71	25	32

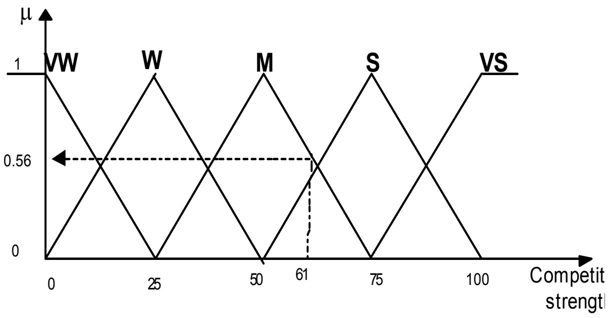

Figure 7. Fuzzification of competitive strenghscale

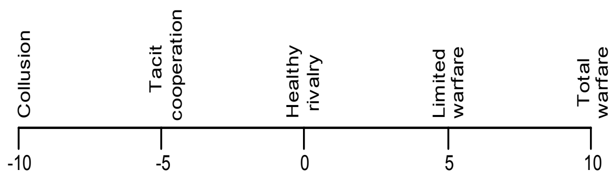

Figure 8. Spectrum of competition states

1 equal very weak, whereas the rate of 10 equal very strong. Then the individual strength of a company is summed to obtain an overall competitive strength rate. Table 1 illustrates the procedure.

The company competitive strength is rated 61. The nearest strength rating is for rival 1 (58), and this will be considered the first competitor to the company. It is clear that the procedure of quantification of the qualitative variable, which is based on rating made by the human experts, reveals the importance of using fuzzy logic sets to handle values of such kind of variables, since such ratings should be viewed as vague or inexact, because it is based on pure judgment of a human. The determinant competitive strength is fuzzified as in Figure 7.

The last input determinant is the competition level. The level of competition is rated by the experts utilizing the rating scale described by Philip Kotler (1972), see Figure 8. The level is first quantified utilizing an arbitrary rating scale which ranges from –10 to +10. Any other arbitrary scale can be used. For instance, the scales from 0 to 100 or from –100 to +100. Fuzzification of the competition level is illustrated in Figure 9. The five fuzzy sets are changed to: “Collusion” as C, “Tacit

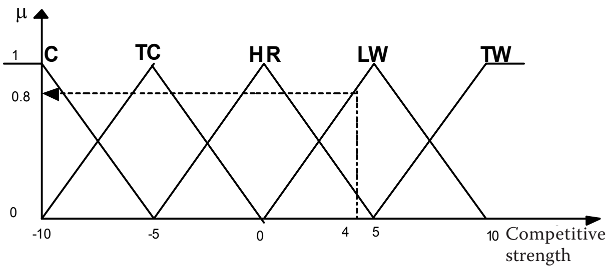

Figure 9. Fuzzification of competition level scale

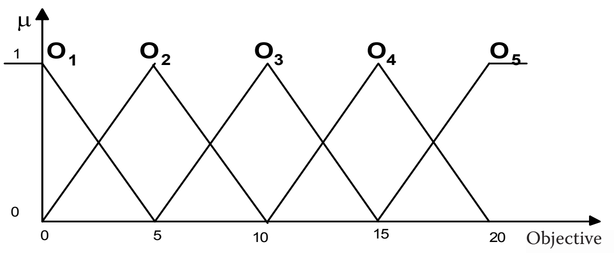

Figure 10. Fuzzification of current period objective scale

Table 2. Fuzzy sets and associated membership degrees of input values

Variable name	Fuzzy set	
	Label	μ (degree of membership)
Expected sales (I_1)	Medium	0.75
Unit manufacturing cost (I_2)	High	0.5
Inventory level (I_3)	High	0.8.
Company price (I_4)	Medium	0.57
Competitor price (I_5)	High	0.71
Competitive strength (I_6)	Medium	0.56
Competition level (I_7)	Limited warfare	0.8

Cooperation" as TC, "Healthy Rivalry" as HR, "Limited Warfare" as LW, "Total Warfare" as TW.

Similarly, the output objective is fuzzified to enable evaluation of multiple implied fuzzy sets from multiple rules (Figure 10).

Now, after fuzzification of input determinants, the actual values of input determinants for the current period is to be manipulated by the model through finding the relevant fuzzy set and associated membership degree. Table 2 shows the relevant fuzzy sets and associated membership degrees.

Rule-base

The rule-base contains experts' knowledge about how the values of input determinants are mapped into the output objective decision. This knowledge is expressed in form of If-Then decision rules. The structure and design of rule-base depends mainly on the view of experts about correlated variables, and joint relationships between input determinants. For instance, experts' knowledge is expressed by the following statements:

Table 3. Joint relationship between sales and unit cost, and the consequent objective

Then objective		If Expected sales (I_1)				
		VL	L	M	H	VH
And if Unit manufacturing cost (I_2)	VL	O_2	O_2	O_2	O_3	O_3
	L	O_2	O_2	O_2	O_3	O_3
	M	O_2	O_2	O_4	O_4	O_4
	H	O_1	O_1	O_1	O_1	O_1
	VH	O_1	O_1	O_1	O_1	O_1

Table 4. Joint relationship between sales and inventory level, and the consequent objective

Then objective		If Expected sales (I_1)				
		VL	L	M	H	VH
And if Inventory l evel (I_3)	VL	O_4	O_4	O_1	O_1	O_1
	L	O_4	O_4	O_1	O_1	O_1
	M	O_2	O_2	O_2	O_4	O_4
	H	O_2	O_2	O_2	O_2	O_2
	VH	O_2	O_2	O_2	O_2	O_2

If *Expected sales* are High and *Manufacturing cost* is Low, then *objective* is to Maximize customer satisfaction.
Or in short:
If I_1 is **H** and I_2 is **L** then O is O_3.

If *Company's price* is Low and *Competitor's price* is High, then *objective* is to Maximize sale volume.
Or in short:
If I_4 is **L** and I_5 is **H** then O is O_2.

If *Competition level* is Collusion, then *objective* is to Maximize profit margin.
Or in short:
If I_7 is **C** then O is O_1.

All experts' decision rules of the rule-base, as specific to our demonstrative example of pair-wise motivators, are tabulated in the tables below (see Tables 3, 4, 5, 6, 7). Generally, the table of all combinations of motivators can be considered. Then the inference procedure will be different.

Inference engine

Two tasks are performed:

(1) **Matching**: In this task, the fuzzified values of input determinants are matched with the corresponding value of input determinants in the premises of the rules contained in the rule-base. The matched rules are said to fire. In our example application, the current values of input determinants fire the following rules:

Rule 1:
If ***Expected sales*** (***I***$_1$) is M and ***Manufacturing costs*** (***I***$_2$) are High, then ***objective*** (***O***) is to **Maximize profit margin (O$_1$)**.

Rule 2:
If ***Expected sales*** (***I***$_1$) is M and ***Inventory level*** (***I***$_3$) is H, then ***objective*** (***O***) is to **Maximize sales volume (O$_2$)**.

Rule 3:
If ***Company's price*** (***I***$_4$) is M and ***Competitor price*** (***I***$_5$) is H, then ***objective*** (***O***) is to **Increase market share (O$_4$).**

Rule 4:
If ***Company's competitive strength*** (***I***$_6$) is M, then ***objective*** (***O***) is to **Reinforce company's competitive position share (O$_5$)**.

Rule 5:
If ***Competition level*** (***I***$_7$) is LW, then ***objective*** (***O***) is to **Maximize customer satisfaction (O$_3$)**.

(2) **Inference**: In this task, the consequent of each rule is determined. The consequent is the implied

Table 5. Joint relationship between company price and competitor price, and the consequent objective

Then objective		If Company price (I_4)				
		VL	L	M	H	VH
And if Competitor price (I_5)	VL	O_5	O_3	O_3	O_3	O_3
	L	O_4	O_5	O_3	O_3	O_3
	M	O_4	O_4	O_5	O_3	O_3
	H	O_4	O_4	O_4	O_5	O_3
	VH	O_4	O_4	O_4	O_2	O_5

Table 6. Competitive strength as input, and the consequent objective

	If Competitive strength (I_6)				
	VW	W	M	S	VS
Then objective	O_5	O_5	O_5	O_1	O_1

Table 7. Competition level as input, and the consequent objective

	If Competition level (I_7)				
	C	TC	HR	LW	TW
Then objective	O_1	O_1	O_4	O_3	O_5

fuzzy set, the objective that should be adopted by the company currently, and the associated degree of membership, its truth. This membership value is determined by applying the minimum operator to the membership values of fuzzy sets contained in the premise of the rule. The following are the rules consequents inferred:

<u>Rule 1:</u>
Consequent: $\mathbf{O_1}$, Truth: 0.5

<u>Rule 2:</u>
Consequent: $\mathbf{O_2}$, Truth: 0.75

<u>Rule 3:</u>
Consequent: $\mathbf{O_4}$, Truth: 0.57

<u>Rule 4:</u>
Consequent: $\mathbf{O_1}$, Truth: 0.56

<u>Rule 5:</u>
Consequent: $\mathbf{O_3}$, Truth: 0.8

Defuzzification

In order to identify the crisp current period objective, the composite-maximum defuzzification method is used to directly identify the objective that is considered the most important to focus on. According to the composite-maximum method, the final crisp output is the center value of the implied fuzzy set which has the maximum truth. Investigating the inferred implied fuzzy sets, the consequent of the 5^{th} rule fired has the maximum truth, 0.8; hence, according to the requirements of the input determinants, the current-period objective that the company should concentrate on, is:

$\mathbf{O_3}$: Maximize customer satisfaction.

APPLICABILITY AND ECONOMIC IMPACT OF THE PROPOSED METHOD

The proposed method can be applied in any scientific field to efficiently determine the short-term objectives. In agriculture, the method can be used to identify the short-term objective of an agro-food company or agricultural projects, where the determinants of objectives, such as economic condition, climate, demand, forecasts ... etc., exhibit a lot of uncertainty, vagueness, and subjectivity are strong candidates for relying upon experts and fuzzy models. The method can be used in any industrial company to assess the impact of qualitative, quantitative, stochastic, and vague variables on the decision regarding the objective. The method can be also applied to non-profit institutions, where the problem of objectives determination exhibits a lot of subjective variables. The economic impact of utilizing method is implied through focusing on the most beneficial objective that will lead to a logical economic improvement. In addition, the method identifies the short-term objective, instead of relying on the pure experts, or management members' judgment, and incurring the associated economic risk.

CONCLUSION

A method for setting short-term objectives has been described. The method scientifically identifies the current period short-term objective of a company or enterprise, based on company's experts' transformation of requirements of multiple non-homogeneous input variables. The method is based on the fuzzy decision-making systems for the purpose of dealing with the vague, stochastic, uncertain, and subjective, and dynamic nature of the input variables and relationships involved in such problem. This paper has showed how fuzzy approach can ably deal with such problems. The fuzzy method has demonstrated how efficiently human experts' knowledge expressed in natural language and in form of If-Then decision rules is conveniently utilized to solve complex problems for which the use a conventional quantitative approaches is unfeasible. The method can handle any types of input variables, subjective or objective, and permit any arbitrary quantification of qualitative variables, the inclusion of which is essential for obtaining realistic solutions. The method can accept conflict opinions of a group of experts, and give finally a compromise solution for them. Finally, the main achievement of this article is the development of a scientific non-conventional method to identify the most significant current-period short-term objective, that quantifies opinions of a group of valid experts, and to be able to dynamically repeat the process each adequate period.

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