Fuzzy logic in decision – making process

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Abstract: The article deals with the practical use of the methods of the fuzzy sets theory while solving the manager decision-making middle-term and long-term tasks.

*Keywords***:** Fuzzy set, fuzzy logic, linguistic expression, management, strategic decision-making.

1 INTRODUCTION

Decision-making at the top and partly also middle management level is based on the managers‘ individual feeling in some situations. This way of accepting mostly strategic decisions results chiefly from the experience the management acquired while solving similar type of the problems The rational side of the process of accepting the decision expressed in the form of a general, precisely computational procedure, is usually suppressed. The way of accepting the decisions that are difficult to justify is usually connected with so called unstructured problems.

In the description of unstructured tasks there are often variables in the form of linguistic expressions. These expressions work with inexplicit, vague concepts, they are the product of human comprehension and people use them to express reality in a natural way. The fuzzy sets theory deals with the methodology of mathematization of linguistic expressions, i.e. transferring them into so called fuzzy sets, and the way how to carry out the mathematical operations.

The management strategic decision-making tasks are classified according to a large number of different criteria. Using the fuzzy sets theory device is unjustly neglected while using them, although similar methods and principles implemented and verified in practice in technical disciplines can be used by analogy.

2 DECISION – MAKING PROCESS

It is most appropriate to realize that ‘the old truth’ that a good product will sell itself does not hold true. At the present global market such products are sold the strongest one – in vast majority of cases a multinational company - decides to be sold.

As mentioned above, because of the total growth of the frequency of changes and uncertainty as far as the development of the world is concerned, there are higher and higher requirements on decision-making process and the management. The decision-making process includes the activities that can be classified as: **STRATEGIC PLANNING**, **MANAGERIAL CONTROL**, **OPERATION CONTROL**.

Therefore, the managers have the basic and main goal – to create the value for the owners (ex.: shareholders). The basic criterion for all the decisions (ex.: concerning the new investments in the technology, personal changes, stores, debts, supplier's evaluation, logistics optimalization but also introducing new ICT, etc.) is maximization the value added.

In present, quickly changing economic conditions the managers at all levels have to meet higher and higher requirements. The intensity and the speed of decision-making is getting higher and higher. To make a large number of decisions in extremely short time requires getting, processing and evaluating of a large amount of information. At the same time, the number of alternatives of the solutions of the problems increases. It is important to predict the solution condition, namely due to the ever increasing uncertainty. Considering the complexity of the operations that are carried out, the price of the wrong decisions can be very high [9] .

Aiming at lowering the risk, removing routine work etc., the importance of the ICT and efficient methods like fuzzy logic for the support of decision-making at all levels of management grows.

The decision-making process depends on the degree of complexity of the problem solved [4, 9]. From this point of view we can divide the tasks into:

1. STRUCTURED TASKS

These are the tasks that are repeated all the time, and there is a standard solution for them. The objects of these tasks, their inputs and outputs are exactly specified. The tasks can be described mathematically, algorithm developed. This category includes mainly the tasks of technical nature. In real life we come across such tasks least frequently.

2. SEMI-STRUCTURED TASKS

These are tasks solved by combining standard solution algorithms and individual judgments and hypotheses. We can say that we come across this type of tasks most often in real life.

3. NON-STRUCTURED TASKS

These are complex non-algorithm developed tasks; they solve complex fuzzy problems of real world. There are no algorithms, no exact description, and no standard solution. We use statistic methods to solve them, fuzzy mathematics using linguistic variables, heuristics, expert judgments, etc. The applications are mainly social systems, political systems, to a considerable extent economic system, etc.

In real life we often come across semi-structured and non-structured tasks. It is important to realize that in real world, therefore in a company as well; we have to solve much more of these tasks than of the structured ones.

To be able to use the methodology of the fuzzy sets theory for solving middle-term and long-term manager tasks, it is necessary to start with specifying the criteria for using the above mentioned mathematical device. The decision-making task must chiefly meet the following criteria:

1. It must be a strategic task, i.e. the task connected with accepting individual partial decisions depending on the change of the factors that can influence the strategic goal.
2. At the same time, the task description must contain factors that cannot be adequately expressed in the form of natural and real numbers. These factors must partake of linguistic expressions, it means that they can be verbally described in a usual way.

Linguistic expressions are mostly used for verbal description of qualitative as well as quantitative features of the real world objects. In practice it is a statement form from the sets theory area, verbally designating to what extent the particular element belongs to the corresponding group.

Linguistic variable can have different values from the set of “terms“. The terms represent possible verbal expression of the studied linguistic variable quality. At the same time it is always possible to determine the classification extent, mostly expressible by the open interval <0, 1>.

3 THE METHODOLOGY OF PROCESSING DECISION-MAKING TASKS

While processing decision-making tasks by means of mathematical fuzzy sets device it is subsequently necessary to carry out the following points:

1. To set a strategic goal that should be reached. The basic condition is the fact that the goal is met by means of gradual assessment of the current state followed by accepting partial decisions affecting the result of the process.
2. To identify linguistic variables being the part of the particular task. In this part, the vague expressions that occur in the task description are identified. The aim is to determine if the linguistic expression used can substantially affect the solution result. This phase plays a key role in the effectiveness of reaching the strategic role.
3. If the studied linguistic variables influence the task solving, it is necessary to carry out their fuzzification, i.e. transferring linguistic expressions into concrete fuzzy sets. It is also connected with the necessity of determining the universum, the fuzzy set width and shape.
4. The next step is to determine the basis of the decision-making rules in the form of IF <antecedent> THEN <consequent>. Within the framework of the antecedent, it is possible to use fuzzy logical operators AND, OR, NOT. The consequent, containing the corresponding action interference can be formed both by precise (numerical) value and by fuzzy statement.
5. The next phase includes consistency control and the connectedness of the suggested rules. The principle of decision-making rules consistency means that the set of the decision-making rules must not contain two rules with the same antecedent and the different consequent. The principle of consistence interdicts the situation when more rules could be applied simultaneously. The principle of connectedness rests in the necessity of the joint intersection of the adjacent rules
6. To remove the ascertained faults.
7. The following part consists of gradual assessment of the state and accepting partial decisions on the basis of the decision-making rules so that the required strategic goal could be met in successive steps.

4 APPLICATION EXAMPLE

As a practical example of fuzzy sets application in the conditions of strategic decision-making process we can use a model situation of setting a strategy of long-term financing of an advertising campaign depending on the market saturation extent and limited amount of finances designed for the advertising campaign of the particular product.

AD1) The given strategic goal is to reach the highest possible economic effect in the form of production maximalization and acquiring the highest possible share in the market.

AD2) The model example considers linguistic variables:

- Product A sales revenues within the period: almost zero, low, medium, high
- Product A share in the market: almost zero, low, medium, high
- Change in the investments in advertising within the given period: almost zero, low, medium, high

AD3) Linguistic variables fuzzification:

Product A sales revenues within the given period $< I, L_I, U_I, M_I >$

I denotation of the linguistic variable **"sales revenues within the given period"**

L_I = { N_I – almost zero, M_I – low, S_I – medium, V_I – high}

U_I = [0, 100] – universum, i.e. physical extent of the values in units [mil. Czech crowns/month]

M_I function that charts verbal values in the universum:

$$N_I \to \int_0^{100} L(I,10,30)/I \quad M_I \to \int_0^{100} \Pi(I,10,30,40,60)/I$$

$$S_I \to \int_0^{100} \Pi(I,40,60,70,90)/I \quad V_I \to \int_0^{100.} \Gamma(I,70,90)/I$$

Product A share in the market within the given perion: $< J, L_J, U_J, M_J >$

J denotation of the linguistic variable "Product A share in the market within the given month"

L_J = { N_J – almost zero, M_J – low, S_J – medium, V_J – high } U_J = [0, 100], universum, i.e. the physical extent of the values in units [%]

M_J function that charts verbal values in the universum:

$$N_J \to \int_0^{100} L(J,10,30)/J \quad M_J \to \int_0^{100} \Pi(J,10,30,40,60)/J$$

$$S_J \to \int_0^{100} \Pi(J,40,60,70,90)/J \quad V_J \to \int_0^{100} \Gamma(J,70,90)/J$$

Change in the monthly investments in advertising: $< K, L_K, U_K, M_K >$

K denotation of the linguistic variable „**Change in the monthly investments in product A advertising**"

L_K = { *NB* – negative big, *NM* – negative medium, *NS* – negative small, *Z0* – almost zero, *PS* – positive small, *PM* – positive medium, *PB* – positive big }

U_K = [-4, 4] – universum, i.e. the physical extent of the values in units [mil. Czech crowns]

M_K function that charts verbal values in the universum:

$$NB \to \int_{-5}^{5} L(K,-3,-2)/K \quad NM \to \int_{-5}^{5} \Lambda(K,-3,-2,-1)/K \quad NS \to \int_{-5}^{5} \Lambda(K,-2,-1,0)/K$$

$$Z0 \to \int_{-5}^{5} \Lambda(K,-1,0,1)/K$$

$$PS \to \int_{-5}^{5} \Lambda(K,0,1,2)/K \quad PM \to \int_{-5}^{5} \Lambda(K,1,2,3)/K \quad PB \to \int_{-5}^{5} \Gamma(K,2,3)/K$$

AD4) Setting the basis of the decision-making rules see Table 1:

Table 1: The basis of the decision-making rules

ID	INFERENTIAL RULE	ID	INFERENTIAL RULE
R(1)	if (I je N_I and (J je N_J) then (K je PB)	R(9)	*if (I je N_I) and (J je S_J) then (K je PS)*
R(2)	*if (I je M_I) and (J je N_J) then (K je PM)*	R(10)	*if (I je M_I) and (J je S_J) then (K je PS)*
R(3)	*if (I je S_I) and (J je N_J) then (K je PS)*	R(11)	*if (I je S_I) and (J je S_J) then (K je Z0)*
R(4)	*if (I je V_I) and (J je N_J) then (K je Z0)*	R(12)	*if (I je V_I) and (J je S_J) then (K je NM)*
R(5)	*if (I je N_I) and (J je M_J) then (K je PM)*	R(13)	*if (I je N_I) and (J je V_J) then (K je Z0)*
R(6)	*if (I je M_I) and (J je M_J) then (K je PM)*	R(14)	*if (I je M_I) and (J je V_J) then (K je NS)*
R(7)	*if (I je S_I) and (J je M_J) then (K je PS)*	R(15)	*if (I je S_I) and (J je V_J) then (K je NM)*
R(8)	*if (I je V_I) and (J je M_J) then*	R(16)	*if (I je V_I) and (J je V_J) then*

	(K je NS)		*(K je NB)*

AD5) Consistency control and the connectedness on the basis on graphic interpretation of the set of the rules. According to the illustrated results (see Figure 1), the set of the rules can be classified as consistent, i.e. it does not contain at least two rules with the same antecedent, but different consequent. The set of the rules intentionally does not meet the condition of the connectedness, it means that there are adjacent rules in it whose output fuzzy sets have zero intersection. The rules n. {7,8}, {11,12}, {10,14} and11,15} can be used as examples of discontinuous rules.

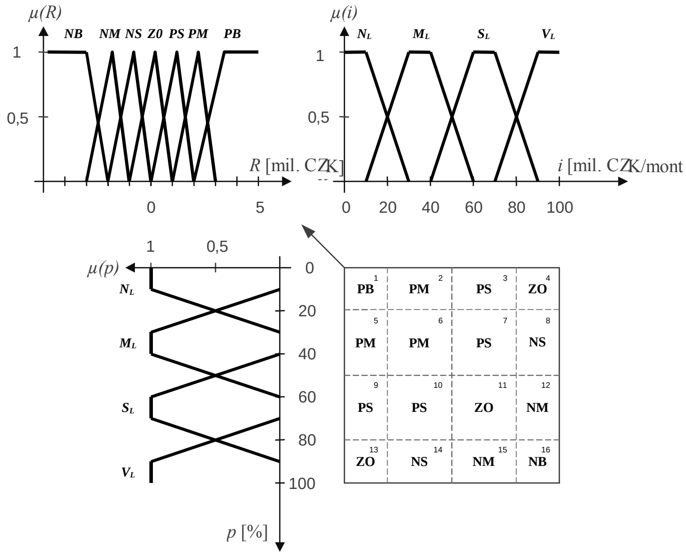

Fig. 1: Graphic representation of the set of the decision-making rules.

AD6) Removing the ascertained faults

Product A sales revenues within the period: $< I, L_I, U_I, M_I >$

L_I = { N_I – almost zero, M_I –low, S_I – medium, $\boldsymbol{X_I}$ **– extention**, V_I – high }

$$M_I = \{ M_I,\ X_I \to \int_0^{100.} \Lambda(I,70,80,90)/I \ \}$$

Product A share in the market within the given period $< J, L_J, U_J, M_J >$

L_J = { N_J – almost zero, M_J – low, S_J – medium, $\boldsymbol{X_J}$ **–extention**, V_J – high }

$$M_J = \{ \ M_J,\ X_J \to \int_0^{100.} \Lambda(J,70,80,90)/J \ \}$$

Table 2: Reparative decision-making rules

ID	INFERENTION RULE	ID	INFERENTION RULE
$R^{(4)}$	*if (I je V_I) and (J je N_J) then (K je NS)*	$R^{(21)}$	*if (I je M_I) and (J je X_J) then (K je Z0)*
$R^{(13)}$	*if (I je N_I) and (J je V_J) then (K je NS)*	$R^{(22)}$	*if (I je S_I) and (J je X_J) then (K je NS)*
$R^{(17)}$	*if (I je X_I) and (J je N_J) then (K je Z0)*	$R^{(23)}$	*if (I je X_I) and (J je X_J) then (K je NM)*
$R^{(18)}$	*if (I je X_I) and (J je M_J) then (K je Z0)*	$R^{(24)}$	*if (I je V_I) and (J je X_J) then (K je NB)*
$R^{(19)}$	*if (I je X_I) and (J je S_J) then (K je NS)*	$R^{(25)}$	*if (I je X_I) and (J je V_J) then (K je NB)*
$R^{(20)}$	*if (I je N_I) and (J je X_J) then (K je Z0)*		

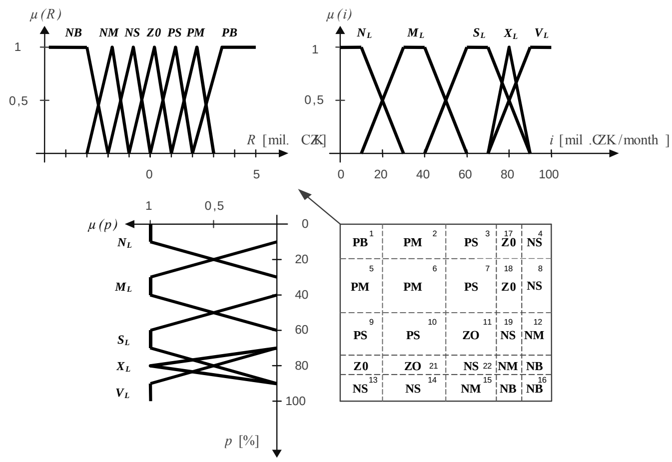

Fig. 2: Graphic representation of the compact set of the decision-making rules.

AD7) Assessing the state and the application of the rules

With the application of partial decisions according to the set of the decision-making rules, both basic (see Chart 3), and additional economic aspects can be determined within a longer time horizon; these aspects were not included in the original assignment, but they are able to influence the goal of the process. As an example we can use the situation of the gradual application of the rules {17, 4, 18, 8}.

Table 3: The outline of the costs and the sales revenues of the particular strategy

Period	1	2	3	4	5	Total
Rule	1	2	3	17	8	-

Change in the investment in the advertising [mil.Czech crowns]	4	2	1	0	-1	-
Monthly investment in the advertising [mil.Czech crown]	4	6	7	7	6	30
Monthly sales revenues [mil.Czech crowns]	10	30	70	80	90	280
Share of the advertising costs within the framework of monthly sales revenues [%]	40,00	20,00	10,00	8,75	6,67	10,71

The effect of the above mentioned rules can be interpreted in view of the fact that in the given moment there is no point in investing further finances in product A advertising, because in the conditions of limited production sources maximum possible sales revenues were achieved. Depending on other circumstances that has not been considered in this demonstrative case, a question arises whether further finances should be invested in extending production capacities. A partial answer to this question can be provided by comparison of the initial costs of starting the product A production with the total amount of money invested in promotion and advertising of this product (see Fig.3).

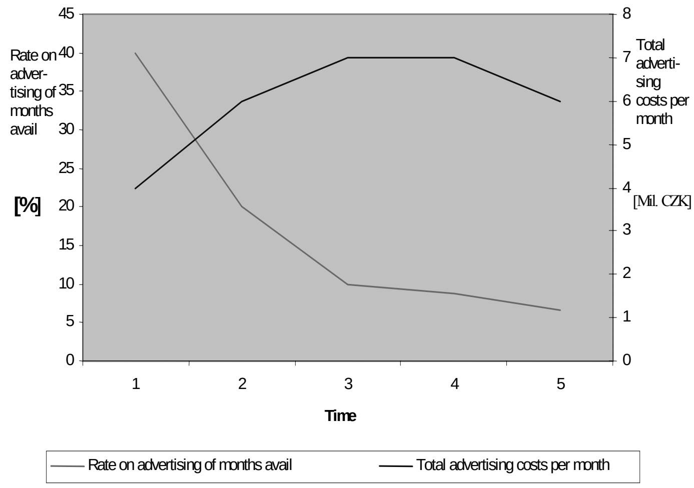

Fig. 3: Graphic representation of the share of the advertising costs within monthly sales revenue and the amount of total monthly investment in advertising

The gradual application of the rules {1, 5, 9, 21, 14} crates a completely different situation. The decision-making rules applied in this way finally mean that a maximum share in the market has been reached, but the production capacity has not been used to the full. In my opinion, the easiest solution of the given situation is to find a new potential supply area, which will make it possible to use the production capacity at the expense of additional costs connected with the transport and introducing the product to the market.

4 CONCLUSION

On the basis of the analogy of using the fuzzy sets mathematical device for solving technical tasks in the area of regulation and management, the article tries to show the advisability of using similar principles while solving strategic management tasks. On the basis of setting a general methodology for solving typzied decision-making tasks and on the basis of the analysis of the results of the model example processing, we can state that the suggested methodology can be used in practice. From the point of view of time demandingness of hand processing we cannot expect the direct use of the suggested methodology by the top management. The suggested solution procedure is suitable for implementation within the company information system

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