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FUZZY LOGIC: THE NEW PARADIGM FOR DECISION MAKING

by Carlo Bagnoli & Halbert C. Smith, CRE

A fairly new method of dealing with imprecision (called Fuzzy Logic) has been developed. So far its principal applications have been in the physical sciences, but some researchers are beginning to recognize its potential applicability to the social sciences—specifically real estate decision making.

Does an estimated rate of return on a real estate investment of 10.5 percent mean a return of 10.5 percent? Perhaps in a sense yes, but in reality, no. We all know that even a return calculated after disposition of a property is an estimate, and that an internal rate of return (IRR) of 10.5 percent means a return that could vary from perhaps 9.5 percent to 11.5 percent. The number, 10.5, is really a "best approximation" based on similarly imprecise estimates of the numbers used to calculate the IRR.

Does this lack of precision render the estimate useless? Certainly not. It can be compared with other, similarly imprecise estimates for decision-making purposes. For example, if we compare a forecast IRR of 10.5 with another forecast IRR of 9.5, and we believe that both forecasts are subject to the same degree of imprecision, we would (other things being equal) choose the investment yielding 10.5 percent. It does mean, however, that decisions based on the estimate may

be incorrect because the degree of imprecision may produce incorrect numbers for decision-making purposes (for example, the 10.5 percent may in reality be 9.8 percent, while the 9.5 percent may in reality be 10.2 percent).

Even historic estimates of some numbers are imprecise. For example, can we say with precision that a building depreciated by 10.0 percent over the preceding five years? Obviously, the 10.0 percent is also an imprecise estimate. Similarly, the estimated future net operating income (NOI), terminal capitalization rate, and tax liability are imprecise estimates. So, even in retrospect, an IRR is an imprecise number.

Other types of estimates are even more obviously imprecise. For example, access to a shopping center may be rated as convenient, inconvenient, or somewhere in-between. Or, we may rate the attractiveness of a shopping center as high, medium, or low. Similar imprecise ratings may be

required for a shopping center's layout, convenience of parking, adequacy of parking, ease of maintenance, energy efficiency, and signage. Such ratings will probably be required when either 1). estimating the value of the shopping center or 2). evaluating the performance of the shopping center. Analogous ratings would be required for other property types.

We live with imprecision in most aspects of life, and real estate decision making is no exception; the examples cited above are but a few illustrations of the imprecision that pervades all types of decisions. The question then becomes, how do we deal with imprecision? We could:

1. Ignore it. We base our decisions on numbers and ratings that we pretend are precise. The problem with this approach is that in effect we are gamblers, and we either win or lose. There is no protection against the possibility that our estimates are incorrect on the unfavorable side.
2. Recognize it implicitly. We hedge our bets and keep our options open, even when some hedges and some options cost more than their value. In other words, we know that our estimates are imprecise, but we have no estimates of how imprecise or in which direction.

Therefore, the ways in which we often deal with the imprecision of today are not satisfactory for making truly informed decisions. However, a fairly new method of dealing with imprecision (called Fuzzy Logic) has been developed. So far its principal applications have been in the physical sciences, but some researchers are beginning to recognize its potential applicability to the social sciences—specifically real estate decision making. The purpose of this article is to describe generally what fuzzy logic is, to show a simple example of its application to real estate, and to illustrate how a more complex fuzzy system might be constructed to deal with imprecision in real estate decision making.

It must be emphasized that fuzzy logic is not the same as probability theory; they are not substitutes for each other. Fuzzy logic is a system for managing imprecision of the present, while probability theory is a system for managing uncertainty about the future. This is an important distinction, because some decisions must be made about conditions in the present period (for example, whether to sell or buy a property at a given price), while other decisions must be based on probability estimates of future events (for example, the future income and expenses for inclusion in a cash flow forecast).

GENERAL NATURE OF FUZZY LOGIC

First, it must be emphasized that, as Gene Dilmore has said, "Fuzzy logic is not..."¹ That is, fuzzy logic is **not** fuzzy thinking. Rather, it is a method that recognizes the inherent "fuzziness" of many numbers and evaluations, such as those illustrated by the examples above. The method is based on mathematical set theory, in which an observation (e.g., a person or an object) is either a member of a set or is not a member of the set. For example, in the set of even numbers, 2 is a member, while 3 is not. While some applications are well served by such a system (yes or no; 1 or 2; on or off)—such as computers which are built around a set of switches that can be turned on and off very rapidly in order to represent different numbers—many applications are not well served by this system. For example, we cannot rate the attractiveness or market acceptability of properties by categorizing them yes or no, or 1 or 2.

Fuzzy logic uses fuzzy sets, in which one may partially belong and partially not belong to the set. For example, a 6-foot tall man might partially belong and partially not belong to the set of tall men. The extent to which the man belongs to the set of tall men is termed the degree of membership, while the degrees of membership that men of various heights would have in the fuzzy set of tall men is termed the membership function. The degrees of membership within the function can vary from zero to one.

The membership function of the fuzzy set of tall men (called A) can be illustrated by *Figure 1* having the following values:

$$m_A(x) = 1 \text{ if } x \geq 74 \text{ inches}$$

$$m_A(x) = [(x - 68)/6] \text{ if } 68 \text{ inches} < x < 74 \text{ inches}$$

$$m_A(x) = 0 \text{ if } x \leq 68 \text{ inches}$$

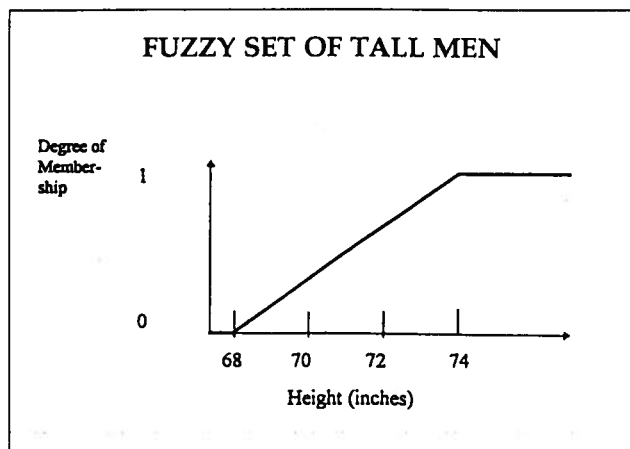
where: $m_A(x)$ = degree of membership of observation x to fuzzy set A

As can be seen from these specifications and in *Figure 1*, men who are equal to or taller than 74 inches have a degree of membership in the set of tall men of 1.0. Men who are taller than 68 inches but shorter than 74 inches have a degree of membership greater than zero but less than one, and men who are 68 inches or shorter in height have a degree of membership of zero.

Thus, the membership degree of a 6-foot (72 inches) tall man would be:

$$\begin{aligned} m_A(x) &= [(72 - 68)/6] \\ &= .6667 \end{aligned}$$

Figure 1



That is, a man who is 6 feet tall is considered to belong to the set of tall men 66.67 percent and not to belong to this set by 33.33 percent.

Similarly, a shopping center could belong to the set of "attractive" shopping centers by 66.67 percent and could not belong by 33.33 percent, and a property tax bill of \$50,000 could belong and not belong to the set of "reasonable" tax bills by 66.67 and 33.33 percent.

THE POTENTIAL ADVANTAGES OF FUZZY LOGIC

The primary benefit of fuzzy logic is that it provides us with a methodology of reflecting the experience and knowledge of people in making informed but imprecise evaluations and decisions. We all make evaluations and decisions such as, "I like that house pretty well"; "The service in that store is not very good"; "I like that shopping center; it is attractive"; or "The property has an expense ratio of around 35 percent." We recognize implicitly that these evaluations and estimates are not precise, but we have no formal way of quantifying the degree of imprecision. Fuzzy logic enables us to recognize and measure the imprecision of such evaluations and decisions.

Fuzzy logic also allows us to distinguish between evaluations in the present and predictions of future events. For example, the question of whether an appraiser *estimates* today's present value of a property, or whether the appraiser *predicts* a future selling price has been debated for many years. The definition of market value propounded by the Appraisal Foundation suggests that appraisers predict future prices because the definition is framed in terms of probabilities ("...the *most probable* price

for which a property should sell..."). Yet appraisers are also taught that the value estimate is applicable only for the date of appraisal—not in the future. Fuzzy logic enables us to deal with the imprecision of an estimate of market value without implying that a property should sell for this price weeks or months in the future.

SIMPLE EXAMPLE OF A FUZZY SYSTEM

Fuzzy logic is used most meaningfully when two or more fuzzy sets are combined to produce usable results. For example, if the value of a one-acre vacant parcel of land is believed to be primarily determined by its location, the relationship between fuzzy sets representing the desirability of the location and fuzzy sets representing values of similar one-acre parcels could provide a fuzzy estimate of the value of such sites.

The desirability (or quality) of locations could be based on precise measures of distance from principal destinations or origins (such as a major intersection or a major employment center). Suppose, for example, that locations of 0.25 mile or less from the important destination are considered to be "undesirable" (because of traffic, noise, etc.), and locations between 0.25 and 2.0 miles away are considered to be "good." These distances and rankings are shown in Figure 2.

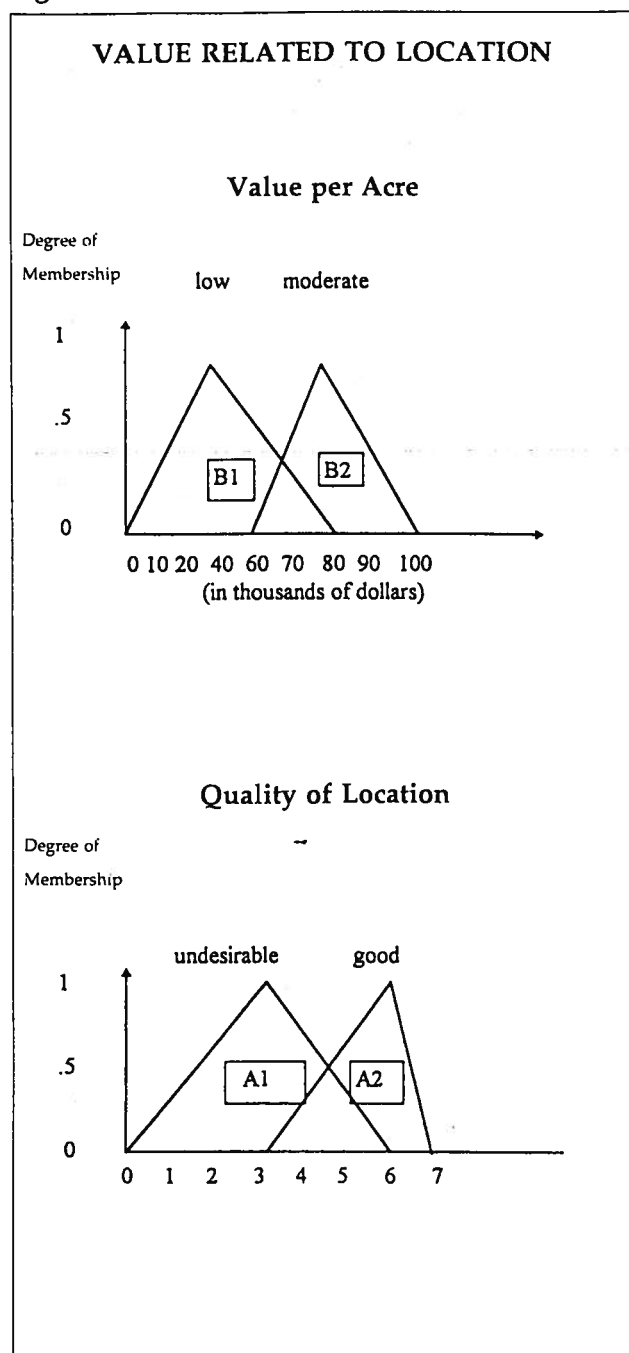
Figure 2

<u>Distance from Major Intersection</u>	<u>Ranking</u>	<u>Fuzzy Set</u>
0 to 0.25 mile	Undesirable	A1
0.25 to 2.0 miles	Good	A2

We could also construct fuzzy sets of low- and moderate-value sites and combine them with the fuzzy sets of undesirable and good locations, as depicted in Figure 3.

If we label the fuzzy sets pertaining to location quality as A_1 and A_2 , and the fuzzy sets pertaining to per acre values as B_1 and B_2 , we can then make some rules about how these fuzzy sets interact. We will say that if the quality of location is undesirable, the value per acre must be low; and if the quality of location is good, the value per acre must

Figure 3



be moderate. These rules are expressed as:

If A_1 then B_1 , and if A_2 then B_2

Note that in both sets there is overlapping; that is, parts of A_1 and A_2 cover the same area, and parts of B_1 and B_2 cover the same area. Thus, some locations can be considered both undesirable and good, and some locations some locations have values that are considered both low and moderate. Similarly, some values can be considered both low and moderate. In other words, the overlapping locations or values

partially belong to two different sets. This is a key characteristic of fuzzy logic—that there can be overlapping relationships among input characteristics and among output results.

Next, we must employ a formal method for assigning the degrees of membership between the two fuzzy sets ($A \times B$). We use what is known as the Cartesian Product, which is represented by the following expression.

$$m_{A_1 \times B_1}(x,y) = m_{R_1}(x,y) = \min [m_{A_1}(x); m_{B_1}(y)]$$

where: $m_{A_1 \times B_1}(x,y)$ = degree of membership of each y in set B_1 , given the degree of membership of each x in set A_1

$m_{R_1}(x,y)$ = membership rule 1 for establishing the relationships between x and y

$\min [m_{A_1}(x); m_{B_1}(y)]$ = minimum membership degree between each x and y

In effect, the formula says that we must combine the two fuzzy sets in a spreadsheet, showing the degree of membership associated with each x or y . The lower of the two membership degrees is then put into each cell in the spreadsheet. Thus, for the first rule, if A_1 then B_1 , the following results are obtained as shown in Figure 4. Note that the membership degree for each x is given in parentheses in the top row, and the membership degree for each y is shown in parentheses in the first column. The lower of the two is put into each cell.

Figure 4

RELATIONSHIP OF FUZZY SET A_1 WITH FUZZY SET B_1							
$x [m_{A_1}(x)]$	0	1	2	3	4	5	6
Membership $y [m_{B_1}(y)]$	(0)	(.25)	(.75)	(1)	(.75)	(.25)	(0)
0 (0)	0	0	0	0	0	0	0
20 (.5)	0	.25	.5	.5	.5	.25	0
40 (1)	0	.25	.75	1	.75	.25	0
60 (.5)	0	.25	.5	.5	.5	.25	0
70 (.25)	0	.25	.25	.25	.25	.25	0
80 (0)	0	0	0	0	0	0	0

Next, we must construct a similar table representing the combination of fuzzy sets A_2 and B_2 . This operation is represented by the following formula, which is similar to the formula for combining fuzzy sets A_1 and B_1 :

$$m_{A_2 \times B_2}(x,y) = m_{R_2}(x,y) = \min[m_{A_2}(x); m_{B_2}(y)]$$

Again, it says that we must combine fuzzy sets A_2 and B_2 by constructing a spreadsheet and inserting into each cell the minimum degree of membership. The results are shown in Figure 5.

Figure 5

RELATIONSHIP OF FUZZY SET A_2 WITH FUZZY SET B_2						
X	3	4	5	6	7	
$m_{A_2}(x)$	(0)	(.25)	(.75)	(1)	(0)	
y	$m_{B_2}(y)$					
60	(0)	0	0	0	0	
70	(.25)	0	.25	.25	.25	0
80	(1)	0	.25	.75	1	0
90	(.25)	0	.25	.25	.25	0
100	(0)	0	0	0	0	0

Next, we must formalize a union of all of the previous fuzzy rules: if A_1 then B_1 or if A_2 then B_2 . This is accomplished according to the following formula:

$$m_R(x,y) = \text{Max}[m_{A_1 \times B_1}(x,y); m_{A_2 \times B_2}(x,y)]$$

where: $m_R(x,y)$ = membership rule for the union of fuzzy sets

$\text{Max}[m_{A_1 \times B_1}(x,y); m_{A_2 \times B_2}(x,y)]$ = maximum membership degree when the results of two rules overlap

This is necessary to specify which rule governs when two or more rules act simultaneously—in other words when there is an overlap between rules. Overlapping occurs only for x 's of 3, 4, 5, and 6, and for y 's of 60, 70, and 80. The formula above requires that in these cases we choose the

maximum degree of membership. Note, for example, that for $x = 3$ and $y = 60$, Rule 1 produced a membership degree of 0.5, while Rule 2 produced a membership degree of 0.0. Thus, the higher of these two (0.5) is inserted in the cell $x = 3, y = 60$. The result obtained from this entire operation is shown in Figure 6.

Figure 6

UNION OF ALL FUZZY SETS								
X	0	1	2	3	4	5	6	7
Y								
0	0	0	0	0	0	0	0	0
20	0	.25	.5	.5	.5	.25	0	0
40	0	.25	.75	1	.75	.25	0	0
60	0	.25	.5	.5	.5	.25	0	0
70	0	.25	.25	.25	.25	.25	.25	0
80	0	0	0	0	.25	.75	1	0
90	0	0	0	0	.25	.25	.25	.25
100	0	0	0	0	0	0	0	.5

The final step is termed "formalizing the composition rule of inference," which results in an "output" of B , given an initial "input" of A . It is represented by the following formula:

$$m_{B\text{-output}}(y) = \max_x \min[m_{A\text{-input}}(x); m_R(x,y)]$$

where: $m_{B\text{-output}}(y)$ = resulting output of membership degrees for each y in set B

$\max_x \min[m_{A\text{-input}}(x); m_R(x,y)]$ = maximum membership degree for each y , i.e., across each row

According to this formula we must first decide on the input, which for demonstration purposes will be A_2 —the fuzzy set of "good" locations. The question is, therefore, given the fuzzy set of "good" locations, what is the membership degree of each per acre land value?

The first step in carrying out the formula is to compare the membership degree of each element (x) of fuzzy set A_2 with the membership degree

shown in the union of all fuzzy sets. If there is a difference, we must select the *lesser* degree of membership. Then, according to the formula we must select the maximum membership degree for each y value; in other words, we select the maximum number for each row of membership degrees. For example, note in Figure 5 that the membership degree for $x = 3$ and $y = 60$ is 0.0, while in the union of all fuzzy sets (Figure 6), the membership degree is 0.5. In Figure 7, therefore, the cell for $x = 3$, $y = 60$ contains a 0. Also, the maximum degree of membership across $y = 60$ is 0.25, and this value is shown in bold. These two operations for all combinations are shown in Figure 7 below.

Figure 7

FORMALIZATION OF THE COMPOSITION RULE OF INFERENCE								
X	0	1	2	3	4	5	6	7
Y								
0	0	0	0	0	0	0	0	0
20	0	0	0	0	.25	.25	0	0
40	0	0	0	0	.25	.25	0	0
60	0	0	0	0	.25	.25	0	0
70	0	0	0	0	.25	.25	.25	0
80	0	0	0	0	.25	.75	1	0
90	0	0	0	0	.25	.25	.25	0
100	0	0	0	0	0	0	0	0

Therefore, the final output shows the degree of membership for each y (e.g., when $y = 80$, the degree of membership is 1.0):

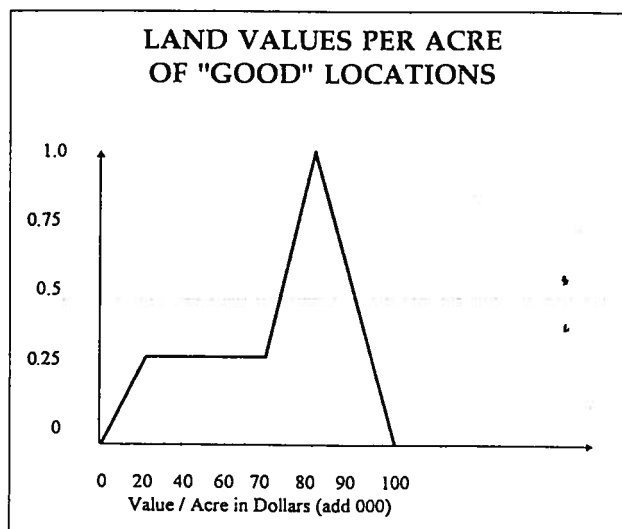
$$B_{\text{output}} = \{(0, 0); (20, .25); (40, .25); (60, .25); (70, .25); (80, 1.0); (90, .25); (100, 0)\}$$

Geometrically, the operation of the rule can be represented as shown in Figure 8.

The figure demonstrates that the output represents a union of fuzzy sets B_2 and B_1 . While B_2 is almost totally operational, however, B_1 is only partially operational, as indicated by the truncated figure

between 0 and 70. The shape of the figure is determined by the different weights assigned to the two sets by operation of the connecting rules.

Figure 8



INTERPRETING THE RESULTS OF THE COMPOSITION RULE OF INFERENCE

We can summarize the fuzzy results by saying that within the set of "good" locations ranked (3 to 7), we might find parcels of vacant land ranging in value from \$20,000 per acre to \$90,000 per acre. Those valued from \$20,000 to \$70,000 and around \$90,000, however, have a degree of membership of only 0.25, while those valued at \$80,000 per acre have a degree of membership of 1.0.

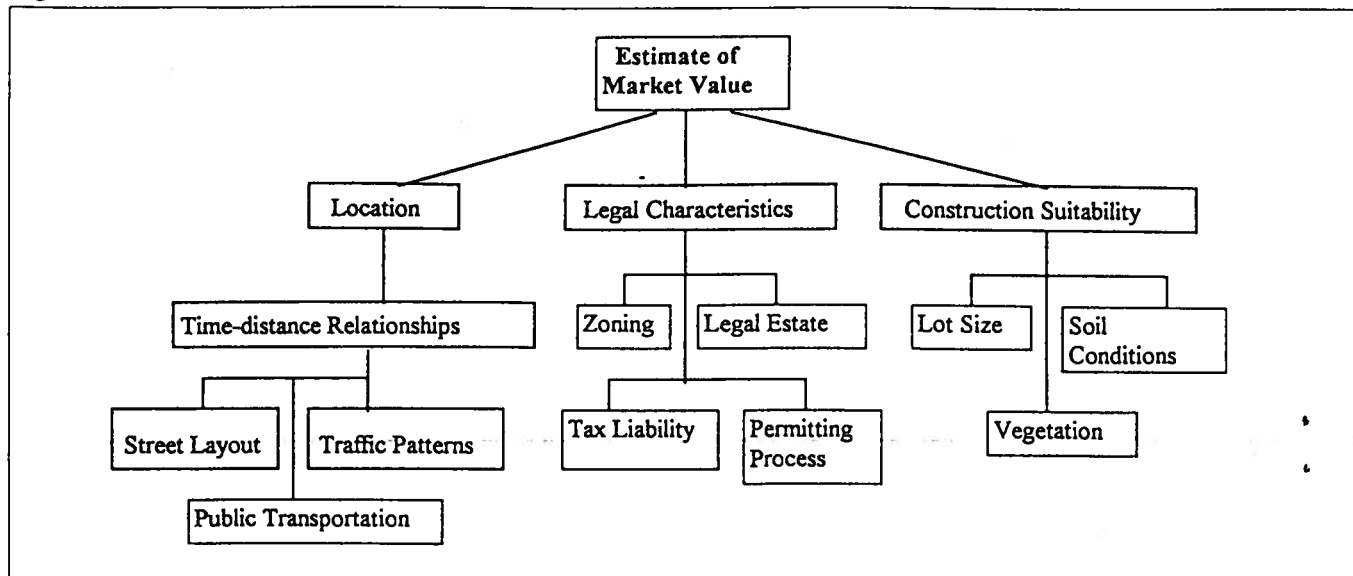
Thus, if we are seeking to find a "good" location for a client, he or she could spend from \$20,000 per acre to \$90,000 per acre. Sites priced around \$80,000 would definitely be considered "good," while sites having prices between \$20,000 and \$70,000 per acre might in reality be "undesirable," and sites having prices around \$90,000 might in reality be better than "desirable"—perhaps "excellent."

Obviously these results provide considerably more information to a client than the appraised value of a single site, or even appraised values or several sites. The use of fuzzy logic enables the analyst to quantify the degree of precision attached to the values of "good" locations.

EXTENDING THE FUZZY SYSTEM

A true fuzzy system is highly complex and requires a multi-step process in which each step is constructed similarly to the example above. For example, if location is regarded as the most general

Figure 9



criterion influencing the value of vacant land parcels, we would next have to determine what attributes determine the quality of location. There might be several criteria, each of which would have to be reduced to a fuzzy set. One such criterion might be the time-distance relationships between a parcel and the origins and destinations of likely customers of the most likely users of the site. These time-distance relationships would be ranked or categorized in some way, and a fuzzy system would be programmed to determine which locational rankings are produced by which time-distance relationships. Similarly, the time-distance relationships might be determined by such factors as layout of the streets, types of public transportation, and traffic patterns.

On the same level as location might also be factors such as the legal characteristics of the property and its suitability for the construction of improvements. Behind the legal criterion there could be zoning, the permitting process, property tax liability, the legal estate that would be conveyed in a sale, *et al.* Behind the construction suitability criterion might be size of lot, terrain, soil conditions, and vegetation. Thus, the system could be depicted as a tree diagram of fuzzy sets (see Figure 9).

CONCLUSION

True fuzzy systems for real estate analysis have not yet been developed, although the fuzzification of numbers within conventional analytical systems (e.g., discounted cash flow analysis) is now employed in several computer programs. While such applications are not true fuzzy systems, they represent a step toward fuzzy analysis.

Highly complex fuzzy systems have been developed for electronic applications such as controlling the subway in Sendai, Japan (which enables riders to have a much smoother ride than conventional systems), enabling computers to "learn" someone's handwriting, and controlling air conditioning systems and other electronic devices. Thus, it seems only a matter of time until true fuzzy systems that deal with the imprecision inherent in the evaluation of property performance and the estimation of market values are developed.^{REI}

NOTES

1. Dilmore, Gene, "Fuzzy Set Theory: An Introduction to its Application for Real Estate Analysts," paper given at the annual conference of the American Real Estate Society, Key West, Florida, 1993.

ABOUT THE AUTHORS

Carlo Bagnoli, Dott. R., is a professor of accounting and finance at the University of Venice, where he received the Laurea (undergraduate degree) and the Doctor of Research degree. He also teaches at the University of Udine and the CUOA Graduate School of Business in the Vicenza, Italy. Additionally, Dr. Bagnoli consults with several large private companies, and in 1996 he spent five months at the University of Florida conducting research.

Halbert C. Smith, CRE, is a professor of real estate in the Graduate School of Business at the University of Florida and is President of Faro Associates International, a private counseling firm. He served as President of the American Real Estate and Urban Economics Association and as Chief Economist for the Federal Home Loan Bank Board. In 1995 he was named a Fellow of the International Center for Economic Research in Turin, Italy, and he regularly teaches and does counseling work in Italy.

Azione e retorica del management

Carlo Bagnoli

Generalmente le introduzioni dei libri di management risultano interessanti da leggere solo per confermare l'idea che non sono assolutamente interessanti da leggere. Alcune volte, però, capita di imbattersi in pubblicazioni che possono essere comprese fino in fondo solamente partendo dall'introduzione e questo è sicuramente il caso di *Beyond the Hype*.

Già dalle prime pagine si intuisce infatti che il lavoro si differenzia da quelli che, costantemente nel tempo, presentano nuovi modelli per il ridisegno degli assetti organizzativi destinati, almeno nella visione e nelle parole dei proponenti, a fronteggiare il "sempre mutato" contesto ambientale.

Il messaggio fondamentale di *Beyond the Hype* è che per il miglioramento della performance aziendale non si debba solamente lavorare al ridisegno delle strutture organizzative e dei sistemi operativi, ma occorra anche ripensare all'importanza del ruolo dell'azione.

Per introdurre la prospettiva usata da Eccles e Nohria per guardare ai nuovi e vecchi problemi d'impresa, è necessario innanzi tutto affrontare due temi che gli autori considerano strettamente collegati a quello dell'azione: la retorica e l'identità.

L'azione è il test finale dell'agire manageriale: i ruoli della retorica e dell'identità

Gli autori evidenziano che un dirigente impiega gran parte del suo tempo parlando con i suoi collaboratori o riflettendo su come impostare alcuni discorsi tesi a stimolare certe azioni all'interno dell'impresa.

La conclusione tratta è che i manager vivono in un mondo permeato dalla retorica; un mondo dove il linguaggio è costantemente usato non solo per informare ma anche per persuadere e perfino per creare.

Quest'idea della retorica come stimolo all'azione può risultare al primo impatto di difficile comprensione visto che spesso si è abituati ad associare al termine un'accezione prevalentemente spregiativa (1).

Non è comunque sul significato

più o meno negativo che la retorica può assumere quale tecnica di comunicazione che gli autori si fermano, ma sulle sue potenzialità di favorire il raggiungimento di determinati risultati.

ZOOM

Anche se non recentissimo, il volume Beyond the Hype. Rediscovering the essence of management (Boston, Harvard Business School Press, 1992, pp. 278; US\$19.95) rappresenta un contributo originale e innovativo nel campo degli studi manageriali. Si tratta di una ricerca sui fondamenti culturali del management e delle dinamiche organizzative, tutta tesa a svelare, al di là di ogni ipocrisia, il ruolo vero che i simboli e i linguaggi giocano all'interno delle aziende. E sorprende che un'interpretazione così originale venga proprio da quel "tempo" dell'ortodossia manageriale costituito dalla Harvard Business School, istituto dove insegnano gli autori del libro, Robert G. Eccles e Nithin Nohria. Discute il volume Carlo Bagnoli, collaboratore di ricerca nell'Università Ca' Foscari di Venezia e dottorando in Economia Aziendale.

(1) In realtà si individuano due significati principali e in parte contrapposti di retorica: 1) (preg.) arte e tecnica del parlare e dello scrivere con efficacia persuasiva, secondo sistemi di regole espressive varie a seconda delle epoche e delle culture; 2) (spreg.) modo di scrivere o di parlare pieno di ornamenti o di ampollosità, ma privo di autentico impegno intellettuale e di contenuto affettivo. (Vocabolario della Lingua Italiana di N. Zingarelli).