A FUZZY RELATION BASED DECISION SUPPORT SYSTEM FOR FINANCIAL RATIO ANALYSIS

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Recently, attempts have been made to bring financial ratio analysis closer to reality in the context of formal decision models using financial ratios as inputs (Latha, 1990; Rathore and Latha, 1990) by applying fuzzy set theory. These models permit the use of knowledge regarding states of nature and outcomes expressed in linguistic and imprecise terms in a formal and systematic way.

However, with the introduction of PCs during the late 1970's, computers have been entering into decision making by business firms in a big way. The implication of such change is that if any new model of decision-making is developed, its framework should be such that it could be finally implemented with computerized decision-support system (DSS) with ease. Hence, a model-making exercise would be incomplete if it does not include the model working with a computerized DSS. The present paper aims at extending the previous research by showing how a DSS can incorporate a fuzzy data-base, incorporating fuzzy information and fuzzy relations through a simulation exercise. The basic purpose of this exercise is largely illustrative; therefore it concentrates on one financial ratio ROI, rate of return on investment. Of course, the analysis could be extended to any other ratio.

A DSS is designed to support the decisions of managers (Thierauf, 1982). It's aim is to help the manager in making decisions and not actually making decisions for him. Its manager/machine interface provides answers to "what if" questions that the manager can understand and can use such information for better decisions. Also, the merging of computer output with the subjective feelings of the manager provides a better basis for decision making.

To design a DSS, among other things, the most important requirement is to formulate knowledge about relations and rules in a functional form so that

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for a given input from the manager it provides a suitable output support for decisions. Such formulation requires specification of

(i) definitional relations, and
(ii) behavioural relations.

The 'definitional' formulations define some terms, assumptions and identities about a system behaviour while 'behavioural' formulations specify functional forms of equations connecting input and output variables. Such behavioural relations are of the form:

$$g(i) = f(x);\ i = 1, \ldots, n$$

where

$g(i)$ ≡ i^{th} output variables,
x ≡ a vector of input variables,
f ≡ a suitable functional operator.

f may be determined by accepted results of scientific research or may be subjectively decided on the basis of the experience of the designer in the absence of a scientifically accepted form. So far, in a DSS environment, f demands crisp data about x (Thierauf (1982)).

But, many users, (especially in the domain of Financial Statement Analysis), are not able to provide a crisp communication link in the manager/machine interface of a DSS environment. That limits the user's interactions with a DSS. Therefore, an alternative, more user-oriented approach, to DSS is needed that will allow the users to interact with a DSS using linguistic description of their knowledge which is usually fuzzy in nature. To develop such an alternative a DSS must consist of fuzzy relations because explicit and formal use of linguistic expressions of knowledge are formulated by fuzzy relations only.

In the absence of empirical data, a simulation model is adopted to show how a DSS could be designed which accepts linguistic description about Gross Margin and Assets Turnover and outputs linguistic description about ROI. This model evolves rules (called Fuzzy Rules) regarding behavioural relation between inputs and outputs. An example for such a rule is:

- if Gross Margin is very low and assets turnover is very low then ROI is very low.

In designing the model, the linguistic variables – Gross Margin, Assets Turnover and ROI are assigned the following values–

1. Very low
2. Low
3. Medium

4. High
5. Very high

Because of in-built fuzziness in these variables, the linguistic variables – Gross Margin, Assets Turnover and ROI are transformed into fuzzy sets and their membership functions are shown in Figure 1, Figure 2 and Figure 3 respectively. These membership functions are based on intuitive support. Of course, it is quite possible to make use of empirically verified membership functions. The choice lies with the decision maker.

As stated earlier, the structure of rules used in the model is:

if Gross Margin is . . . AND Assets Turnover is . . . , (Premises)

then, ROI is . . . (Conclusion).

Since Gross Margin and Assets Turnover variables are transformed into Fuzzy sets, a suitable operator for AND in Fuzzy sets is needed. For this purpose, two operators – MIN and PRODUCT – are considered. 'Min' is defined as:

$$\mu(x)_{A\&B} = MIN\,(\mu_A(x), \mu_B(x) \tag{1}$$

and 'Product' as:

$$\mu(x)_{A\&B} = \mu_A(x)\,.\,\mu_B(x) \tag{2}$$

To decide which operator provides better results, a quantity, squared distance D, is defined as:

$$D = \underset{\mu(x)_{ROI}}{\text{Hypothetical}} \;—\; \underset{\mu(x)_{GM\&AT}}{\text{Derived}} \tag{3}$$

where

$\mu_{GM\&AT}(x) \equiv$ membership derived under 'Min' or 'Product' operator for Gross Margin and Assets Turnover

and

$\mu_{ROI}(x) \equiv$ membership function of ROI

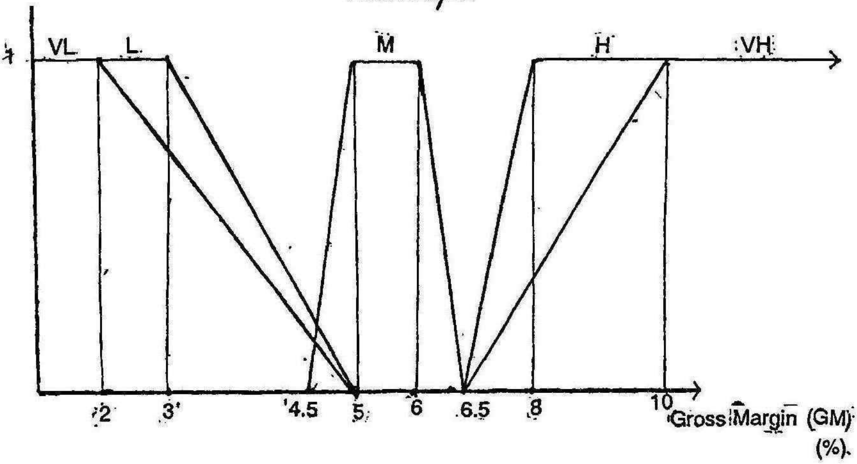
An operator that minimizes ΣD, is considered to be a better operator.

The model developed has following features:

* **Objective**

To derive fuzzy rules of the type
If Gross Margin is .... AND Assets Turnover is ...., then ROI is ....

FIGURE 1



$$\mu_{GMVL} = \begin{cases} 1 & ; \quad GM \le 2\% \\ \dfrac{0.05 - GM}{0.03} & ; \quad 2\% \le GM \le 5\% \\ 0 & ; \quad \text{Otherwise} \end{cases}$$

$$\mu_{GML} = \begin{cases} 1 & ; \quad GM \le 3\% \\ \dfrac{0.05 - GM}{0.02} & ; \quad 3\% \le GM \le 5\% \\ 0 & ; \quad \text{Otherwise} \end{cases}$$

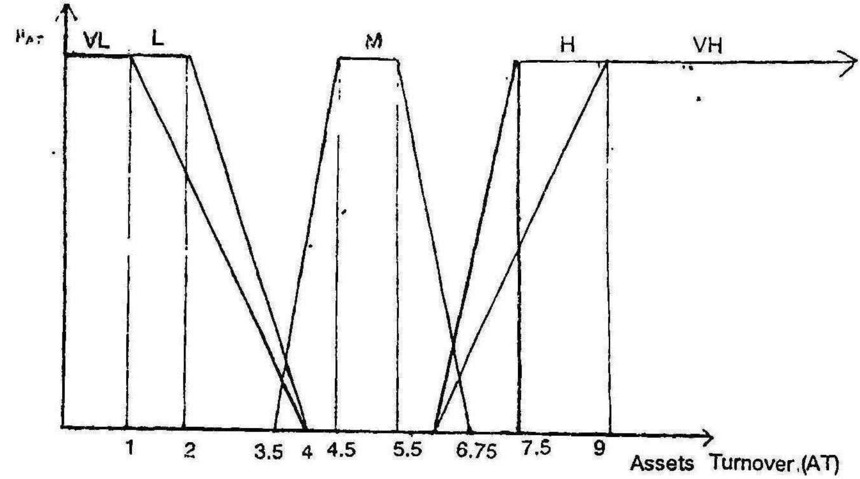
$$\mu_{GMM} = \begin{cases} 0 & ; \quad GM \le 4.5\% \\ \dfrac{GM - 0.045}{0.0075} & ; \quad 4.5\% \le GM \le 5.5\% \\ 1 & ; \quad 5.5 \le GM \le 6\% \\ \dfrac{0.065 - GM}{0.0050} & ; \quad 6\% \le GM \le 6.5\% \\ 0 & ; \quad 6.5\% \le GM \end{cases}$$

$$\mu_{GMH} = \begin{cases} 0 & ; \quad GM \le 6.5\% \\ \dfrac{GM - 0.065}{0.0150} & ; \quad 6.5\% \le GM \le 8\% \\ 1 & ; \quad \text{Otherwise} \end{cases}$$

$$\mu_{GMVH} = \begin{cases} 0 & ; \quad GM \le 6.5\% \\ \dfrac{GM - 0.065}{0.0350} & ; \quad 6.5\% \le GM \le 10\% \\ 1 & ; \quad \text{Otherwise} \end{cases}$$

Note: GM* = Membership function for * (VL, L, M, H, VH) with respect to Gross Margin (GM).

FIGURE 2



$$\mu_{ATVL} = \begin{cases} 1 & ; \quad AT \le 1 \\ \dfrac{4-AT}{3} & ; \quad 1 \le AT \le 4 \\ 0 & ; \quad \text{Otherwise} \end{cases}$$

$$\mu_{ATL} = \begin{cases} 1 & ; \quad AT \le 2 \\ \dfrac{4-AT}{2} & ; \quad 2 \le AT \le 4 \\ 0 & ; \quad \text{Otherwise} \end{cases}$$

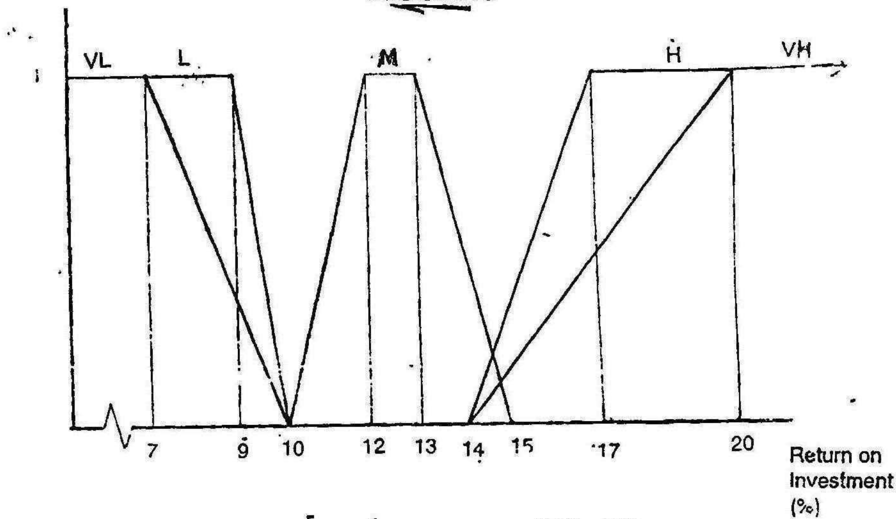
$$\mu_{ATM} = \begin{cases} 0 & ; \quad AT \le 3.5 \\ \dfrac{AT-3.5}{1.0} & ; \quad 3.5 \le AT \le 4.5 \\ 1 & ; \quad 4.5 \le AT \le 6.75 \\ \dfrac{6.75-AT}{1.25} & ; \quad 5.5 \le AT \le 6.75 \\ 0 & ; \quad 6.75 \le AT \end{cases}$$

$$\mu_{ATH} = \begin{cases} 0 & ; \quad AT \le 5 \\ \dfrac{AT-5}{2.5} & ; \quad 5 \le AT \le 7.5 \\ 1 & ; \quad 7.5 \le AT \end{cases}$$

$$\mu_{ATVH} = \begin{cases} 0 & ; \quad AT \le 5 \\ \dfrac{AT-5}{4} & ; \quad 5 \le AT \le 9 \\ 1 & ; \quad 9 \le AT \end{cases}$$

Note: AT* = Membership function for * (VL, L, M, H, VH) with respect to Gross Margin (AT).

FIGURE 3



$$\mu_{ROIVL} = \begin{cases} 1 & ; \quad ROI \le 7\% \\ \dfrac{0.10 - ROI}{0.03} & ; \quad 7\% \le ROI \le 10\% \\ 0 & ; \quad \text{Otherwise} \end{cases}$$

$$\mu_{ROIL} = \begin{cases} 1 & ; \quad ROI \le 9\% \\ \dfrac{0.10 - ROI}{0.01} & ; \quad 9\% \le ROI \le 10\% \\ 0 & ; \quad \text{Otherwise} \end{cases}$$

$$\mu_{ROIM} = \begin{cases} 0 & ; \quad ROI \le 10\% \\ \dfrac{ROI - 0.10}{0.02} & ; \quad 10\% \le ROI \le 12\% \\ 1 & ; \quad 12\% \le ROI \le 13\% \\ \dfrac{15 - ROI}{0.02} & ; \quad 13\% \le ROI \le 15\% \\ 0 & ; \quad 15\% \le ROI \end{cases}$$

$$\mu_{ROIH} = \begin{cases} 0 & ; \quad ROI \le 17\% \\ \dfrac{ROI - 0.14}{0.03} & ; \quad 14\% \le ROI \le 17\% \\ 1 & ; \quad 17\% \le ROI \end{cases}$$

$$\mu_{ROIVH} = \begin{cases} 0 & ; \quad ROI \le 14\% \\ \dfrac{ROI - 0.14}{0.06} & ; \quad 15\% \le ROI \le 20\% \\ 1 & ; \quad 20\% \le ROI \end{cases}$$

Note: ROI* = Membership function for * (VL, L, M, H, VH) with respect to Gross Margin (ROI).

*** Inputs**

(a) Linguistic variables GM, AT and ROI assume the following values:-

- Very low
- Low
- Medium
- High
- Very high

(b) Some suitable defined membership functions, $\mu_{GM}^{(x)}$, $\mu_{AT}^{(x)}$, $\mu_{ROI}^{(x)}$.

*** Processing**

(a) To process data, two fuzzy operators — MIN and PRODUCT are used.
(b) The model is a simulation model.

*** Algorithm**

The Algorithm adopted for the model involves following steps:

(0) set n = 0, D = 0
(1) Read a random number and thereby select a value of GM and corresponding $\mu_{GM}^{(x)}$
(2) Read another random number and thereby select a value of AT and corresponding $\mu_{AT}^{(x)}$
(3) Find ROI = GM * AT and corresponding $\mu_{ROI}^{(x)}$ using 'Min' and 'Product' operator
(4) Find D as defined in equation (3) for 'Min' and 'Product' and increase old D by adding D calculated at this step
(5) Print out results
(6) Set n = n + 1
(7) Is n = required number of trials? If yes, STOP. Otherwise, go to step 1.

A computer programme of this is given in Appendix-A.

While running the model on a computer, it is assumed implicitly that fuzzy membership values are fuzzy truth values i.e. the truth value of a statement like — 'ROI is low' equals $\mu_{ROI}^{(x)}$. In a number of trials, it is observed that Σ D is constantly minimum for 'MIN' operator and not for 'PRODUCT' operator. Hence, the final rules are based on 'MIN' operator. To show how 'MIN' works in defining fuzzy rules, consider the following table which contains partial fuzzy rules derived from the simulation model.

TABLE 1

	CONDITION				CONCLUSION	
	GM		AT		ROI	
Rule No.	Linguistic Value	Truth Value	Linguistic Value	Truth Value	Linguistic Value	Truth Value
1.	VL	0.749	VL	0.805	VL	0.749
2.	VL	0.266	VH	0.607	VH	0.266
3.	VH	0.545	L	0.977	H	0.545
4.	VH	0.783	VH	0.861	VH	0.783

Rule No. 1 of Table 1 says that if GM is very low (with truth value = 0.749) and AT is also very low (with truth values = 0.805), then ROI is very low (with truth value = 0.749). Other rules are also interpreted in the same way.

The simulation model under consideration outputs possible combinations of fuzzy values with different truth value of GM and AT along with conclusions about ROI. Some conclusions have higher truth values, some low; they are compared with predefined ROI alongwith its membership function. Then, a statistic D, defined by (3), is found for each conclusion. To identify fuzzy relations (or rules) would mean minimization of D. For that one can look for a proper optimization technique and thereby find a cut off point for the identification of fuzzy rules. No formal optimization technique is used but subjectively, a cut-off point of 0.2 of D is selected. Therefore, a rule with D = 0.2 is to be accepted, otherwise it should be rejected. Following this, some rules are derived. These are given in Appendix-B.

Once such rules are derived, one can make them an integral part of an expert system/a decision support system. That system would provide a "LINGUISTIC" man-machine interface.

APPENDIX-A

```
C*******************************************************************
C**                                                               **
C**   FUZZY RULE BASED FINANCIAL RATIO SYSTEM                     **
C**   A SIMULATION MODEL                                          **
C**                                                               **
C*******************************************************************
C
      REAL MARG, MEM3
      DIMENSION R (5)
      CHARACTER *2 R,LABEL
      DATA R/'VL', 'L', 'M'; 'H', 'VH'
      DO 1000 K1 = 1,8
C-------------INITIALISATION PROCESS--------------------------------
      KOUNT = 0
      SUM1 = 0.0
      SUM2 = 0.0
C-------------------------------------------------------------------
C     WRITE (*,800)
C     WRITE (*,801)
C-------------MARGIN-BLOCK------------------------------------------
      DO 100 I=1,5
      DO 200 J=1,5
      READ (*,*),RAN0
      IF (RAN0.NE.1.0) GO TO (110,120,130,140,150),I
      READ (*,*),RAN1
      GO TO (111,121,1131,141,151),I
C-------------VL-BLOCK----------------------------------------------
110   MARG=0.05-0.03*RAN0
      GO TO 199
111   MARG=0.02*RAN1
      GO TO 199
C-------------L-BLOCK-----------------------------------------------
120   MARG=0.05-0.02*RAN0
      GO TO 199
121   MARG=0.03*RAN1
      GO TO 199
C-------------M-BLOCK-----------------------------------------------
130   READ (*,*),RAN2
         IF (RAN2.GE.0.5) THEN
         MARG=0.065-0.005*RAN0
         GO TO 199
         ELSE
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        MARG=0.0475+0.0075*RAN0
        GO TO 199
        ENDIF
131   MARG=0.055+0.005*RAN1
        GO TO 199
C-------------H-BLOCK-----------------------------------------------------------------
140   MARG=0.065+0.015*RAN0
        GO TO 199
141   MARG=0.08+0.08*RAN1
        GO TO 199
C-------------VH-BLOCK----------------------------------------------------------------
150   MARG=0.065+0.035*RAN0
        GO TO 199
151   MARG=0.10+0.10*RAN1
199   CONTINUE
C-------------TURNOVER-BLOCK----------------------------------------------------------
        READ (*,*),RAN10
        IF (RAN10.NE.1.0) GO TO (210,220,230,240,250),J
        READ (*,*), RAN11
        GO TO (211,221,231,241,251),J
C-------------VL-BLOCK----------------------------------------------------------------
210   TURN = 4.0-3.0*RAN10
        GO TO 299
211   TURN = 1.0*RAN11
        GO TO 299
C-------------L-BLOCK-----------------------------------------------------------------
220   TURN = 4.0-2.00*RAN10
        GO TO 299
221   TURN = 2.00*RAN11
        GO TO 299
C-------------M-BLOCK-----------------------------------------------------------------
230   READ (*,*)RAN12
        IF (RAN12.GE.0.5) THEN
        TURN=6.75-0.50*RAN10
        GO TO 299
        ELSE
        TURN=3.5+1.00*RAN10
        GO TO 299
        ENDIF
231   TURN=4.50+1.0*RAN11
        GO TO 299
C-------------H-BLOCK-----------------------------------------------------------------
240   TURN=5.0+2.5*RAN10
        GO TO 299
241   TURN=7.5+8.0*RAN11
        GO TO 299
```

```
C--------------VH-BLOCK--------------------------------------------------
250   TURN=5.0+4.0*RAN10
        GO TO 299
251   TURN=9.0+9.0*RAN11
299   CONTINUE
C------------ROI-BLOCK----------------------------------------------------------------
        ROI=MARG*TURN
        PROD=RAN0*RAN10
        RMIN=AMIN1 (RAN0,RAN10)
        READ (*,*),RAN20
        IF (ROI.LE.0.07) THEN
        LABEL=R(1)
        GO TO 398
        ENDIF
        IF (ROI.LE.0.09) THEN
        IF (RAN20.GE.0.5) THEN
        LABEL=R(2)
        GO TO 398
        ENDIF
350     LABEL=R(1)
        MEMB=(0.10-ROI)/0.03
        GO TO 399
        ENDIF
        IF (ROI.LE.0.10) THEN
        IF (RAN20.GE.0.5) THEN
        LABEL=R(2)
        MEMB=(0.10-ROI)/0.01
        GO TO 399
        ELSE
        GO TO 350
        ENDIF
        ENDIF
        IF (ROI.LE.0.12) THEN
        LABEL=R(3)
        MEMB=(ROI-0.10)/0.02
        GO TO 399
        ENDIF
        IF (ROI.LE.0.13) THEN
        LABEL=R(3)
        GO TO 398
        ENDIF
        IF (ROI.LE.0.140) THEN
360     LABEL=R(3)
        MEMB=(0.15-ROI)/0.02
        GO TO 399
        ENDIF
```

```
      IF (ROI.LE.0.15) THEN
      IF (RAN20.GE.0.67) GO TO 360
      IF (RAN20.GE.0.34) THEN
370   LABEL=R(4)
      MEMB=(ROI-0.140)/0.03
      GO TO 399
      ENDIF
380   LABEL=R(5)
      MEMB=(ROI-0.14/0.06
      GO TO 3399
      ENDIF
      IF (ROI.LE.0.17) THEN
      IF (RAN20.GE.0.5) GO TO 370
      GO TO 380
      ENDIF
      IF (ROI.LE.0.20) THEN
      IF (RAN20.LE.0.50) GO TO 380
      LABEL=R(4)
      GO TO 398
      ENDIF
      LABEL=R(5)
398   MEMB=1.0
399   CONTINUE
C-----------------------------------------------------------------------
      ERROR1=(MEMB-PROD)**2
      ERROR2=(MEMB-RMIN)**2
        SUM1=SUM1+ERROR1
        SUM2=SUM1+ERROR2
      KOUNT=KOUNT+1
      IF (ERROR1.LE.0.15) GO TO 55
      WRITE(*,802)KOUNT,R(I),MARGIN,R(J),TURN,
     1 LABEL,ROI,PROD,RMIN,ERROR1,ERROR2
      GO TO 56
55    WRITE(*,805)KOUNT,R(I),MARGIN,R(J),TURN,
     2 LABEL,ROI,PROD,RMIN,ERROR1,ERROR2
56    WRITE(*,803) RAN0,RAN10
200   CONTINUE
100   CONTINUE
1000  CONTINUE
802   FORMAT(9X,I2,2(11X,A2,2X,F8.6),9X,A2,5(F8.6,3X))
805   FORMAT(9X,I2,2(11X,A2,2X,F8.6),9X,A2,3(F8.6,3X),'£££',
      3F8.6)
      WRITE(*,804)SUM1,SUM2
803   FORMAT(10X,2('(',F8.6')',5X))
804   FORMAT(19X,'SUM1=',F12.4,5X,'SUM2=',F12.4)
      STOP
      END
```

APPENDIX-B

RULE NO.	CONDITIONS		CONCLUSION*
	MARGIN	SALES TURN OVER	ROI
1.	VERY LOW	VERY LOW	VERY LOW
2.	VERY LOW	LOW	VERY LOW
3.	VERY LOW	MEDIUM	LOW
4.	VERY LOW	HIGH	LOW
5.	VERY LOW	VERY HIGH	MEDIUM
6.	LOW	VERY LOW	LOW
7.	LOW	LOW	LOW
8.	LOW	MEDIUM	LOW
9.	LOW	HIGH	MEDIUM
10.	LOW	VERY HIGH	MEDIUM
11.	MEDIUM	VERY LOW	LOW
12.	MEDIUM	LOW	LOW
13.	MEDIUM	MEDIUM	MEDIUM
14.	MEDIUM	HIGH	MEDIUM
15.	MEDIUM	VERY HIGH	HIGH
16.	HIGH	VERY LOW	MEDIUM
17.	HIGH	LOW	MEDIUM
18.	HIGH	MEDIUM	HIGH
19.	HIGH	HIGH	HIGH
20.	HIGH	VERY HIGH	VERY HIGH
21.	VERY HIGH	LOW	MEDIUM
22.	VERY HIGH	LOW	MEDIUM
23.	VERY HIGH	MEDIUM	HIGH
24.	VERY HIGH	HIGH	VERY HIGH
25.	VERY HIGH	VERY HIGH	VERY HIGH

* Truth Value of the conclusion is obtained through MIN - operator.

NOTES AND REFERENCES

1. Latha, K., *Fuzzy Set Theory Approach to Financial Ratio Analysis*, Unpublished M.Phil Dissertation submitted to University of Delhi, 1990.
2. Rathore, S. and Latha, K., 'A Fuzzy Decision Approach to Financial Ratio Analysis', *Productivity*, Vol. 31(3), Oct.-Dec. 1990.
3. Thierauf, R.J., *Decision Support Systems for Effective Planning and Control: A Case Study Approach*, Prentice Hall Inc, Englewood Cliffs: N.J. 1982.