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Fuzzy Framework for Understanding Investment Decision in Information Technology

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Abstract. Information Technology (IT) is a service to provide an organization with a tool to improve transaction processing, employee productivity and additionally to enhance day-to-day business processes. Also IT is looked as an aid to develop intellectual capital such as decision-making power and to add value to the organization products and services for which it has to bear a cost.

IT implementation and support cost comprises one of the most expensive elements in an organization's shared services or support function [1]. The decision on investment in IT is generally taken by top management decision makers who often fail to integrate their concerns with the expected outcome of an investment in IT. The problem is aggravated by the fact that the return on IT investment, that is the value addition to the organization, is often estimated by some qualitative assessments and business decision based on educated guess. Quantitative evaluation of IT investment is difficult to achieve because assessing IT investment is not restricted to a strict quantification of clearly identifiable costs and benefits, but a more balanced approach combining hard metrics and mission-critical intangibles.

But in reality, can the standard economic models (e.g. NPV or the IRR method) be taken up for the evaluating the worth of an IT investment? Investments in Information Technology do exhibit some different characteristics to many other business investments. These differences include the fact that IT investment opportunities frequently evolve, not only over long periods of time, but during the relatively short periods while the information system is actually being developed. This means that the final investment is sometimes not known in detail at the outset of the work. Added to this, any organization undergoes simultaneous investments in other branches of business and consequently the part of return in the business due to IT investment cannot be specifically assimilated.

As because it is difficult to ensure the exact association of the return on investment in IT with the expenditure incurred in IT with standard economic models, this paper attempts to present a non-conventional approach, the fuzzy logic principle, to achieve the objective. This is based on the empirical data available on IT investment in an organization ("Input Space" of the fuzzy domain) and probable benefit areas ("Output Space"). The objective is to map the input space to the output space. For this the membership functions of each

element of the input and output space on the available data set is defined. Then we define a set of fuzzy rules, which shows the relationship between the elements of input and output space, based mostly on educated guess. As a final step the analysis can be carried out through the defuzzification process; which in a crisp manner determines how much moderation should be made in the Input space elements (IT investment areas in this case) to have a desired outcome in the Output space elements (benefit areas of business).

Keywords: Information Technology, NPV, IRR, Fuzzy logic, Input Space, Output Space, membership function, fuzzy rules, defuzzification.

1 Introduction – The Strategic Roadmap to IT Investment

Organizations need to look first at their strategic roadmap and align IT services with that roadmap both in the near and long term. Assessing IT investment should shift from a strict quantification of clearly identifiable costs and benefits to a more balanced approach combining hard metrics and mission-critical intangibles. Organizations should consider customer service, improved management decision-making, and other top-line-related factors to be vital ingredients in any assessment of IT investment – fresh or continued. Other measures of IT value, such as productivity gains and cost reductions, should continue to be key considerations as well [2].

In the light of the above discussions, a formal process for strategic planning for IT investment is absolutely valuable. Strategic IT investment planning is required, even if the reasonable planning horizon is a short-term one.

In the prevalent scenario most of the enterprises uses a rough-cut business analysis to determine whether an outlined piece of IT investment provides added value. At the most, only in special cases, a qualitative business case is prepared (please refer to the diagram below). In more matured organizations, the prevalent approach is to derive an objective function and optimize it subject to some constraints so as to arrive at a strategic decision for investment in IT [3].

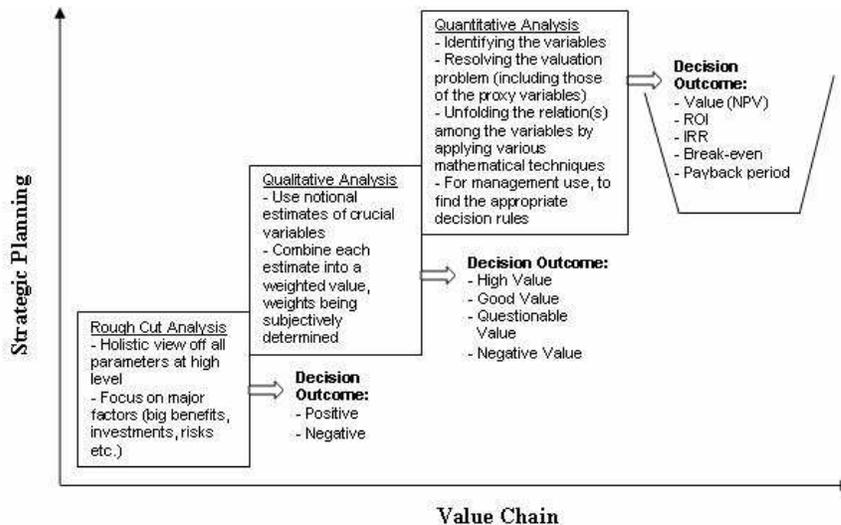


Fig. 1. IT Investment Analysis Techniques.

2 IT Benefit Evaluation Based on Standard Economic Principles

The current prevalent techniques used for this type of analysis include capital investment appraisal, which involve the calculation of financial ratios such as the Net Present Value (NPV) and the Internal Rate of Return (IRR) [4]. It is normal practice not to just produce one financial statement but rather to produce several different scenarios or financial pictures. The procedure to arrive at a decision point for adopting IT investment in an organization based on the above methodology is enumerated below:-

2.1 Assumptions

- Let the cost of Capital be C_0 (implies a machine is being installed at the cost of C_0)
- The firm gets a stream of income (return) over a time horizon $t = 1, 2, 3, 4, \dots, T$
- In each year there is a gross return r_t and the added cost C_t
- Where r_t is being captured by profit/net sales
- C_t is the variable cost associated with C_0 , i.e. depreciation, yearly fixed cost if any etc.

2.2 Model (NPV and IRR)

The Net Present Value may be defined as the difference between the sum of the values of the cash-in flows, discounted at an appropriate cost of capital, and the present value of the original investment. Provided the NPV is greater than or equal to zero the investment will earn the firm's required rate of return.

Net Present Value (NPV) of the investment project is calculated as below:

$$\text{Net return in each year} = r_t - C_t \quad (1)$$

$$\text{Discounted present value} = \frac{r_t - C_t}{(1 + r)^t} \quad r \Rightarrow \text{rate of return} \quad (2)$$

Therefore Net Present Value (NPV):

$$= \sum_{t=1}^T \frac{(r_t - C_t)}{(1 + r)^t} - C_0 \geq 0 \quad (3)$$

The Internal Rate of Return is the rate of interest which will cause the NPV to be zero.

We make NPV = 0. Therefore:

$$\sum_{t=1}^T \frac{(r_t - C_t)}{(1 + r)^t} = C_0 \quad (4)$$

Given r_t and C_t and C_0 and $t = 1, 2, 3, 4, \dots, T$, we obtain the value of r . If r is viable then the project is to be adopted.

3 Limitations of IT Benefit Evaluation Based on NPV and IRR

In reality, can the NPV method or the IRR method be taken up for evaluating the worth of an IT project?

Given C_0 as the project specific cost related to specified functional areas and $t = T$ for the terminal period when the technological obsolescence takes place (without a terminal value of the technology), so that a new investment of C_0 becomes necessary, the NPV or IRR method could be applied. However, on further analysis of the nature of IT investment it becomes quite evident that the above models will result in imprecise results in the IT benefit evaluation in the enterprise.

3.1 Nature of IT Investment

Information systems do exhibit some quite different characteristics to many other business investments which need to be understood and accommodated in an IT business case. These differences include the fact that IT investment opportunities or challenges frequently evolve, not only over long periods of time, but during the relatively short periods while the information system is actually being developed. This means that the final destination of the journey that constitutes the investment is sometimes not known in any detail, at the outset of the work. Specifically, the requirements of an IT development project can end up materially quite different to what was thought was needed when it first started.

This intrinsic propensity to change is one of the key differences between IT investment projects and other business investment projects. This can be seen as both a major disadvantage, as well as a challenging opportunity.

The pattern of IT expenditure in major enterprises normally follows a one shot investment (for reducing cost in various functional areas), followed by a maintenance cost for the period for which the given IT enabled service is to remain effective. Further investment are called for when newer functional areas are to be integrated with the initial one as also when the decision support system for the old functional areas undergoes a change due to technological obsolescence [5].

3.2 Factor of Obsolescence

The improved version of the technology is always more efficient in information management NPV or IRR depends on the concept of r_t and C_t for a given r (or a given C_0 , r_t and C_t in case of IRR).

r_t can be captured from the Profit and Loss statement of the organization, which provides income, cash inflow, cash outflow, sales Profit Before Tax (PBT) and Profit After Tax (PAT); provided we know from PL or Balance Sheet (BS), which part of r_t can be assigned to investment in IT (C_0 and C_t in this case).

In the above models we assume "other things remaining the same", i.e. there is no investment in the other branches of business, which is impossible to realize. The proportion of IT investment in total investment in a year can be calculated (or obtained from PL statement and BS), but the part of r_t due to IT investment cannot be assimilated.

Also the concept of the business functional area may itself undergo a change even when the technological obsolescence is yet to appear. IT is not an investment in plant and machinery. It increases the functioning in every branch of business, including the production activities by:

- a) Reducing information gap.
- b) Reducing the Operational time.

This is reflected in the normalized values of the cost related variables in various wings of business, thus increasing the Rate of Return. In other words, it facilitates every branch of investment that the company has made.

In an ideal scenario, this can be evaluated provided there are no simultaneous investments in non-IT inputs, which is not realizable in a practical scenario.

4 Why Use Fuzzy Logic?

Fuzzy logic starts with the concept of a fuzzy set. A fuzzy set is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. A classical set is a container that wholly includes or wholly excludes any given element. Fuzzy Logic enters into the realm where sharp edged yes-no logic stops being helpful. The following statement lays the foundations for fuzzy logic approach for benefit evaluation in investment IT in modern enterprises [6].

- a) In fuzzy logic, the truth of any statement becomes a matter of degree. This is useful as because the exact equation of the return on investment in IT and the expenditure incurred in IT cannot me made with the standard economic models.
- b) Fuzzy logic is tolerant of imprecise data, which is true for the figures obtained for return on IT investment in organizations.
- c) What makes fuzzy nice is the “naturalness” of its approach avoiding far-reaching complexity.

5 Approach to Fuzzy Logic Solution?

Fuzzy Logic is a matter of mapping inputs to the appropriate outputs. Between the input and the output there may be assumed a fuzzy inference engine (black box) that does the work. The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated in parallel, and the order of the rules is unimportant.

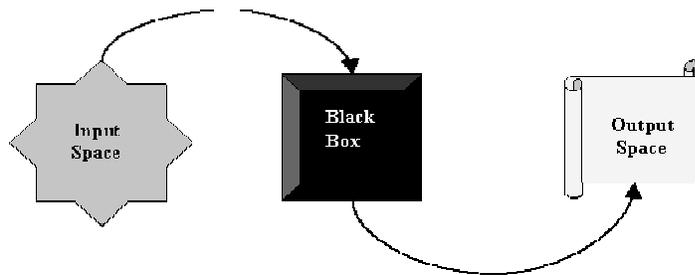


Fig. 2. A Fuzzy Solution Map of Input vs. Output space.

5.1 Determination of the Input Space

The cost incurred in IT constitutes the Input space. While we consider the cost side, the cost of the technology has to be given the major point of concern. On the cost side, with the introduction of the new technology in IT, some cost is added to the existing one. To the organization it is the price of the technology. The cost is added in the following way:

- Fixed Cost: One-time investments in assets, such as computer hardware, software, networks etc. R&D is considered as lumpy investment, where it is difficult to guess the time horizon for which the investment has to be made to have a suitable return.
- Variable Cost: Recurring expenditure on skilled manpower, support services etc.

For an organization that has production capacity at manufacturing units and also runs sales branches at various locations, the total IT investment for the organization can be segregated on the basis of:-

- IT Investment in Plant
- IT Investment in Branch
- IT Investment in Head Office (HO)

These may be treated in the Input Space indicating all possible investments in IT.

5.2 Determination of the Output Space

The return from IT, as reflected in revenue, operational efficiency etc. in the organization, may be classified in the Output Space. This is discussed below:

- a) Factor related to the revenue aspect of the organization (that is the factors that might enhance the revenue, thanks to the IT intervention).
- b) Factors that would reduce the cost so that the efficiency is increased (the major elements could be the reduction in Transaction Cost).

Some of the examples may be Customer Service, Product Quality, Resource Utilization, Stockroom Inventories, Cost accounting controls, Work in Progress (WIP) inventories & Manufacturing lead times, Material Cost, Warehousing etc.

As outlined above, there are several avenues to judge the return, typically decided by the highest management level of the organization based on the organization mission and business goals. However for the present purpose of modeling, the following areas are considered to build the fuzzy logic framework:

- Manager Salary (MgrSalary)
- Labour Wages (LabWages)
- Raw Material Inventory (RMInv)
- Customer Receivables (CustRcv)

5.3 Using MATLAB Fuzzy Logic Toolbox to Model the Scenario

The problem can be adequately mapped into the MATLAB Fuzzy Logic toolbox (shown below) representing the elements related to the input and output spaces.

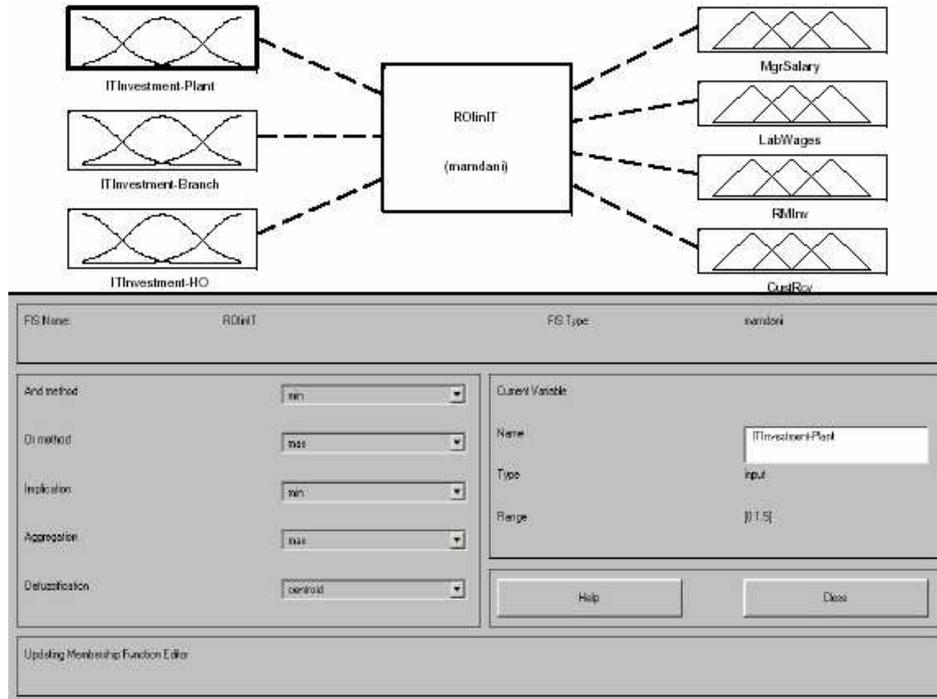


Fig. 3. Solution Map of Input vs. Output space in MATLAB.

5.4 Using Neural Network Techniques to Determine the Membership Function

For the current purpose IT investment have been categorized into three categories – high, medium and low in the input space. Likewise, returns in the output space are also categorized as high, medium and low. Since a Fuzzy scenario is dealt with, the degree of relationship of each member of the input and output space to the category (high, medium, low) has to be ascertained through a membership function. A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) in between 0 and 1.

This may be achieved by using Neural Network Techniques.

- A set of Training Data is used to train the network.
- Error Back-Propagation and consecutive iteration to determine the MF of the input
- The Checking Data is used to validate the neural network model

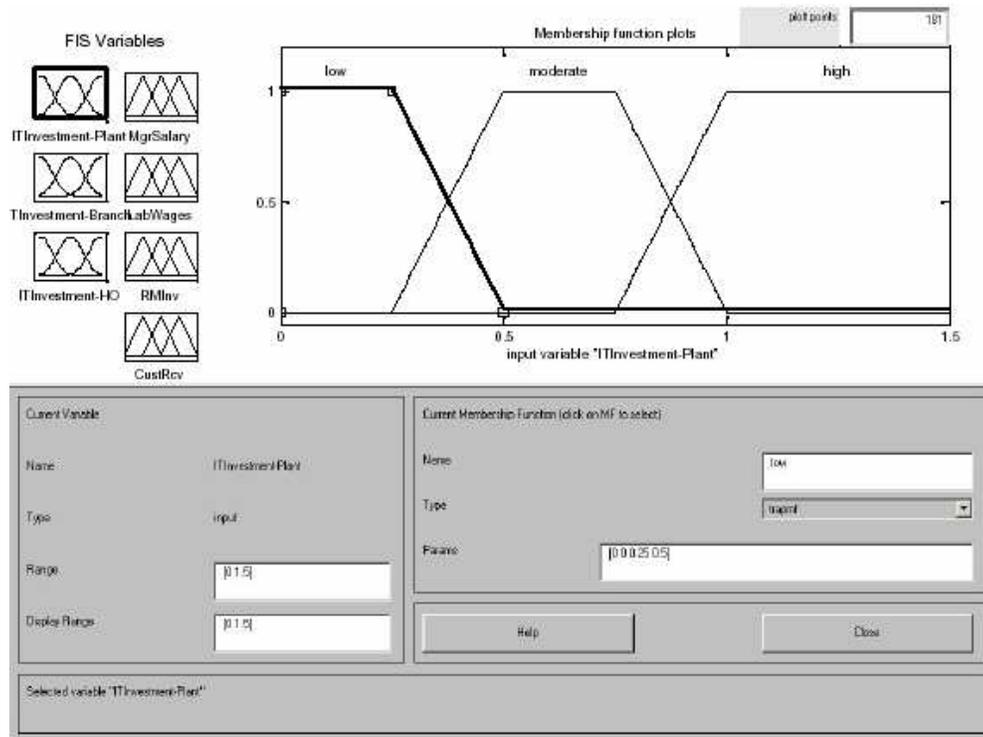


Fig. 4. Membership Function Plots in MATLAB.

5.5 Using the Rule Editor to Model the Data

Constructing rules using the graphical Rule Editor interface is fairly self evident. Based on the descriptions of the input and output variables, the Rule Editor allows to construct the rule statements automatically, by clicking on and selecting one item in each input variable box, one item in each output box, and one connection item. Choosing none as one of the variable qualities will exclude that variable from a given rule. A representative set of rules is framed as follows:-

- a) Manager Salary (MgrSalary) => expected to go up with higher IT investment
- b) Labour Wages (LabWages) => expected to come down with higher IT investment
- c) Raw Material Inventory (RMInv) => expected to reduce with higher IT investment, especially in manufacturing units.

- d) Customer Receivables (CustRcv) => expected to reduce with higher IT investment, especially in Sales Branch and Head Office.

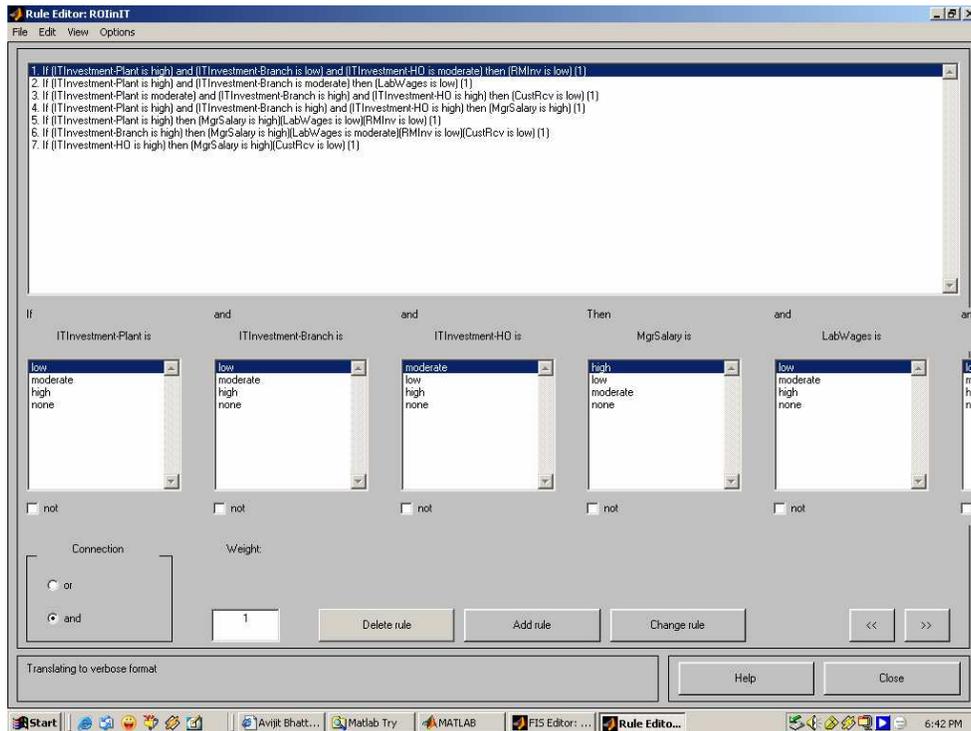


Fig. 4. Modeling the Data using MATLAB Rule Editor

5.6 Using MATLAB Fuzzy Logic Toolbox to Analyze the Data

As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable should be naturally a single number for carrying out analysis and subsequent decision. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set. The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. The method adopted here is centroid calculation (which returns the center of area under the curve).

The Input values can be entered manually or can be adjusted these input values by clicking anywhere on any of the three plots for each input. This will move the red vertical index line horizontally. This line can also just be clicked and dragged in order to change the input values. When the line is released, (or after manually specifying

the input), a new calculation is performed, and the whole fuzzy inference process take place. A yellow (or light grey) patch of color under the actual membership function curve is used to make the fuzzy membership value visually apparent. Each of the characterizations of the variables is specified with respect to the input index line in this manner. The aggregation occurs down the output columns (4, 5, 6, 7), and the resultant aggregate plot is shown in the single plot to be found in the lower right corner of the plot field. The defuzzified output value is shown by the thick line passing through the aggregate fuzzy set.

The defuzzified output is, as a matter of fact, are the crisp output values obtained in modeling the input space data mapped with the output space through the Fuzzy Inference Engine. Thus the input space data (investment) may be suitably tuned to achieve the desired values in the output space (return).

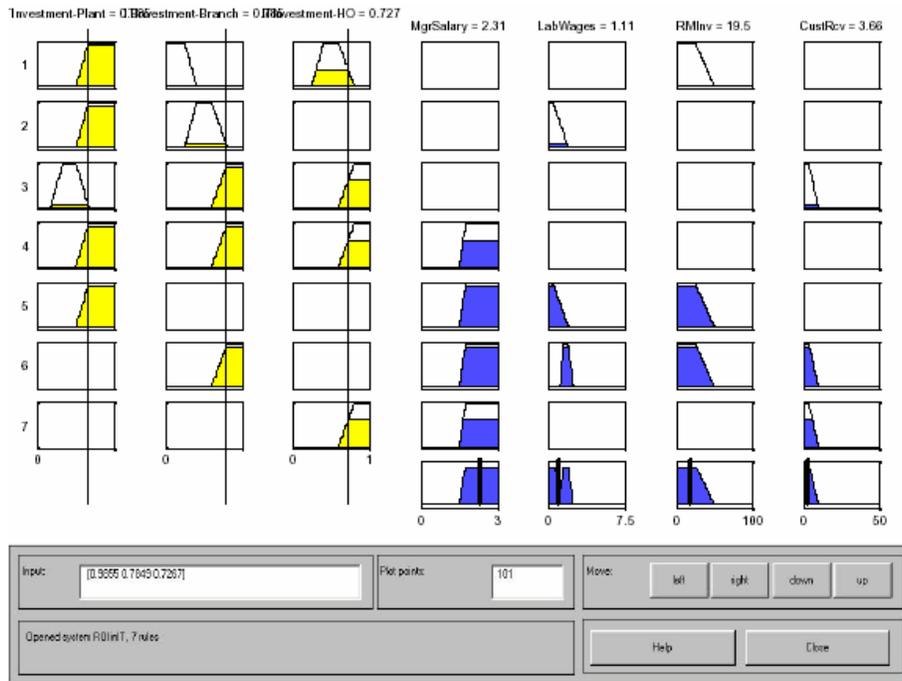


Fig. 5. Analyzing the Data using MATLAB

6 Conclusion

The conventional models (e.g. NPV, IRR) of evaluating the benefits of investment in IT is prone to some shortcomings owing to the nature of investment pattern in IT and

also because the returns obtained, that are attributable to IT investment can not be proportionately demarcated. Hence a fuzzy logic framework has been evolved to handle this situation and subsequently through a defuzzification process a mechanism of analysis of the return may be carried out wherefrom the scope of implementing a predictive decision rule for future investment exists.

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