A Fuzzy Approach to Risk Assessment in Construction Industry

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Introduction

1. Risk is an uncertain event that may have a positive or negative impact on the project.
2. Or it can be defined as "a situation where there exists no knowledge of its outcomes."
3. Risk management is a systematic process of Identifying, Analyzing, and Responding to Project risk.

Objective of the study

1. To identify and classify the various risks associated with a construction project.
2. To do the quantitative analysis of the risks associated with the construction industry.
3. To develop a decision making model for risk analysis in construction projects by using soft computing technique.
4. To study the risk management steps involved in the construction projects.
5. Total Project Risk Evaluation based on specific inputs and output by using Fuzzy Logic (i.e membership function and natural language computation).

Motivation of the study

1. Construction projects take place in a complex and challenging environment.
2. High levels of risk are associated with this industry.
3. A reliable way to analyze the associated risks is vital to make success.
4. Construction project managers can predict the overall risk of the project before start the implementation
5. An overall risk index can be used as early indicators of project problems or potential difficulties by using fuzzy logic.
6. Fuzzy logic used along with a soft computing technique makes the analysis of risk less time consuming, quick and easy.

Scope of the study

1. The scope of the project is to the use of fuzzy logic as a support of evaluation of total project risk by using fuzzy logic toolbox of MATLAB software.
2. Fuzzy logic is using pretty much the same tools as probability theory. But it's using them to trying to capture a very different idea. Fuzzy logic is all about degrees of truth - about *fuzziness* and *partial* or *relative* truths.
3. Probability theory deals with bivalent logic and says nothing about how to reason about things that aren't entirely true or false.

Literature Review

AUTHOR	YEAR	FINDINGS
Zadeh	1965	Formulated Fuzzy logic to model vagueness and to solve ill-defined and complicated problems because of ambiguous, incomplete, vague, and imprecise information that characterize the real-world system
Lorterapong and Moselhi	1996	Presented a new network scheduling method based on FST to estimate the durations of construction activities

Kumar et al.	2000	developed a methodology to incorporate linguistic variables into workable mathematical propositions for the assessment of working capital using Fuzzy Set Theory after considering the uncertainty associated with many of the project resource variables.
Knight and Fayek	2002	used fuzzy logic to predict potential cost overruns on engineering design projects. By doing so, it assists in assessing the amount of possible risk on a project and the likelihood of making a profit on the job.
Choi et al.	2004	presented a risk assessment methodology for underground construction projects, in which they developed a formalized procedure to evaluate the risks.

		The main tool of the proposed risk assessment methodology is the risk analysis software which was built upon an uncertainty model based on fuzzy set.
Sánchez et al	2005	developed a fuzzy set-based approach for representing and synthesizing information about the various kinds of variables involved in the evaluation of a project's value in the context of construction in civil engineering
Morote and Vila	2011	presented a risk assessment methodology based on the Fuzzy Sets Theory, which is an effective tool to deal with subjective judgement and on the Analytic Hierarchy Process (AHP), which is used to structure a large number of risks.

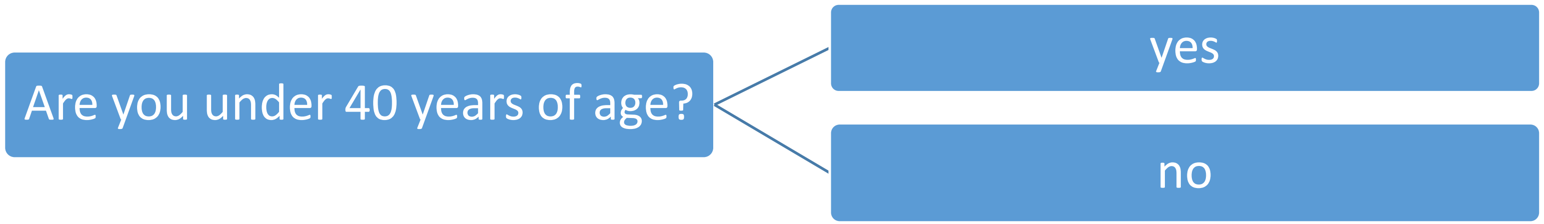
Ingle, *etal.*	2011	reported the methodology to solve risk analysis problems. Fuzzy logic was used since it is a tool capable of modeling complex and uncertain or vague data using simple terminology such as IFTHEN statements.
Ossama et al	2013	proposed a process of risk assessment is about risk quantification and determining appropriate controls. The issue under this study is the application of Fuzzy Logic to develop a Fuzzy Model to enhance the risk assessment process.
Singh et al	2017	Stated that risk management in a project encompases the identification of the influencing factors which would negatively impact the cost schedule or quality objectives of the project.

Basics of Fuzzy Logic and Fuzzy set theory

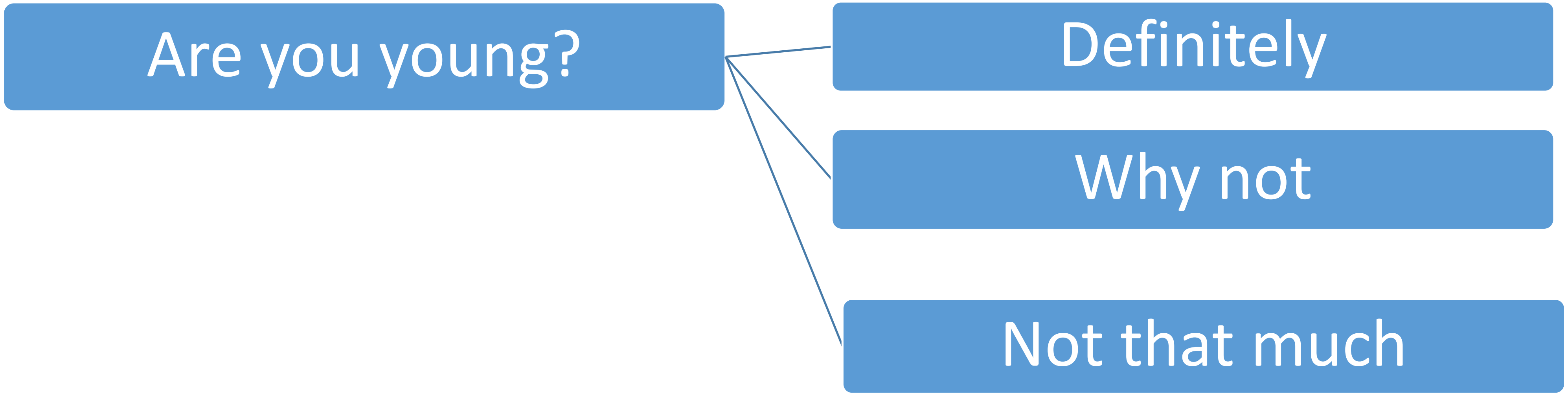
1. In classical set theory (bivalued logic), an individual object is either a member or a non-member of a set. However, in reality, due to insufficient knowledge or imprecise data, it is not always clear whether an object belongs to a set or not. (Crisp Set)
2. fuzzy set theory allows an object belonging to multiple exclusive sets in the reasoning framework. For each set, there is a degree of truth that an object belongs to a fuzzy set. (Fuzzy Set)

Bivalent logic Vs Fuzzy Logic

1. Bi-valued logic can only have two possible values as 0/1, yes/no, right/wrong etc.
2. Fuzzy logic can be multivalued. It can have relative values like yes, why not, not so much, not that much etc.
3. Crisp concept



- Fuzzy concept



Membership Function

1. The difference between traditional set and fuzzy set theory lies in the degree of membership which elements may possess in a set.
2. Traditional set theory indictates that an element is either a member of a set or it is not; it’s membership values are defined as 1 or 0.
3. In fuzzy set theory this membership value can take any real value from 0 to 1 and this value defines the degree of membership of a given set.

Mathematical representation of fuzzy logic

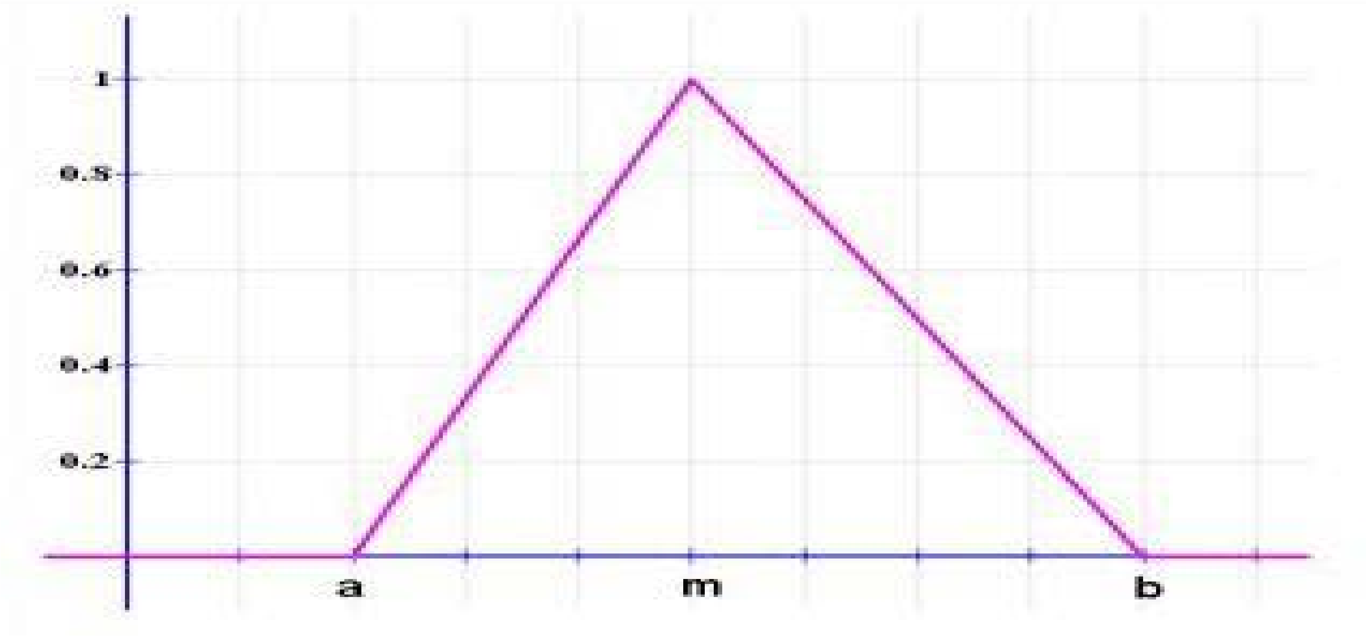
Fuzzy sets can generally be expressed mathematically as follows:

$$A = [x / \mu A(x)]$$

A = fuzzy set, $\mu A(x)$ = a membership value between zero and one, and x = an element of universe X. In order to make it simple, x can be defined as a scale element between zero and ten, which is figured out as the degree, from lower to higher, of uncertainty.

Triangular function

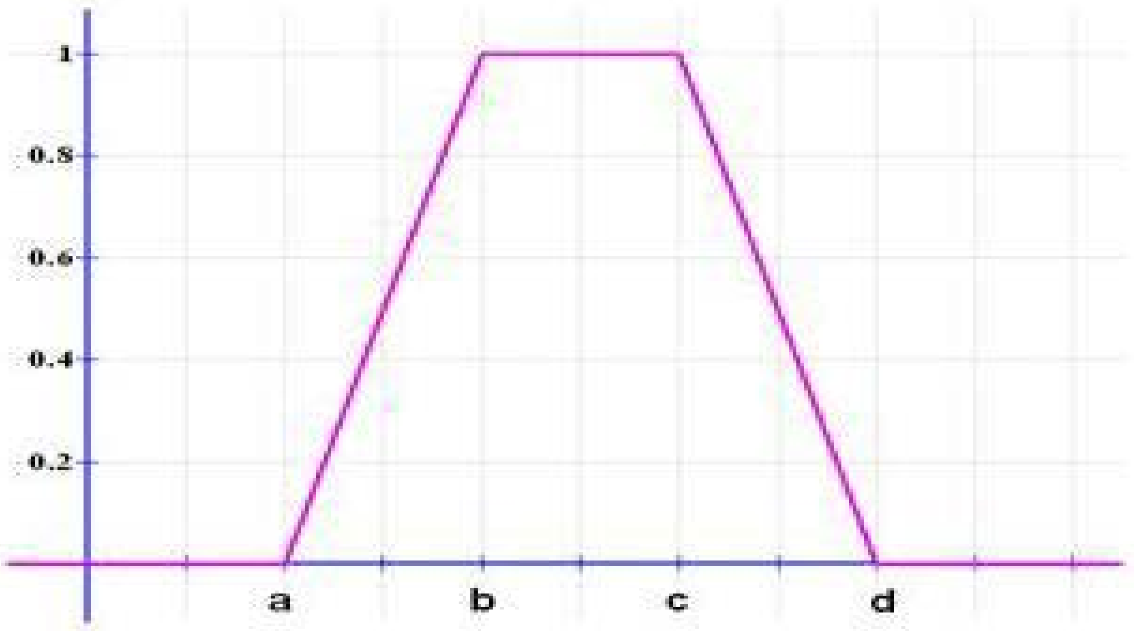
1. Defined by a lower limit a, an upper limit b, and a value m, where a < m.



$$\mu A(\mathrm{x}) = \begin{cases} 0 & x \le a \\ (x-a)(m-a) & a < x \le m \\ (b-x)(b-m) & a < x \le m \\ 0 & x \ge b \end{cases}$$

Trapezoidal function:

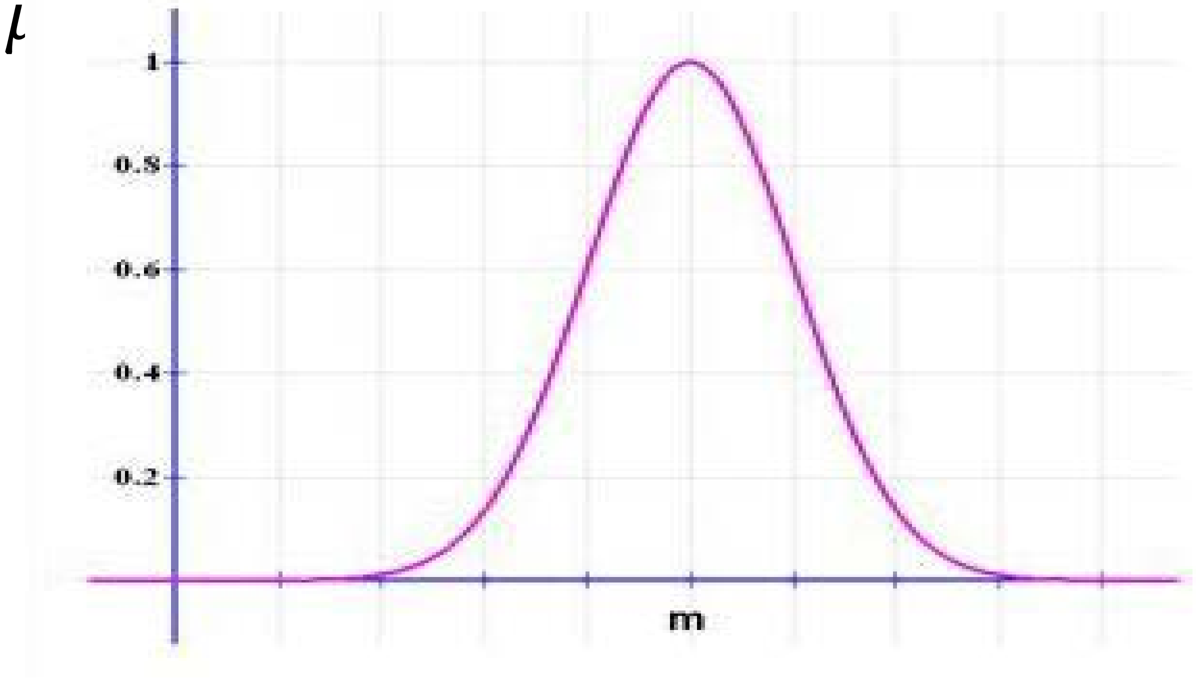
1. Defined by a lower limit a, an upper limit d, a lower support limit b, and an upper support limit c, where a < b < c < d.



$$\mu A(\mathrm{x}) = \begin{cases} 0 & (x<a) \; or \; (x>d) \\ (x-a)(b-a) & a \le x \le b \\ 1 & b \le x \le c \\ (d-x)(d-c) & c \le x \le d \end{cases}$$

Gaussian function:

1. Defined by a central value m and a standard deviation k > 0. The smaller k is, the narrower the “bell” is.



Fuzzy Set Operations

1. **Fuzzy Union**: The union of two fuzzy sets is the maximum of each element (MAX) from the sets.
2. Eg: A={1, 0.2, 0.7}

    B={0.2, 0.45, 0.50}

    A∪B={MAX(1,0.2), MAX(0.2,0.45), MAX(0.7,0.50)}

    ={ 1, 0.45, 0.7}

Fuzzy Intersection: The intersection of two fuzzy sets is the minimum of each element (MIN) from the sets.

Eg: A={1, 0.2, 0.7}

B={0.2, 0.45, 0.50}

A∪B={MIN(1,0.2), MIN(0.2,0.45), MIN(0.7,0.50)}

={ 0.2, 0.2, 0.50}

-

Inference Rules

- With logical operations on fuzzy sets, inference rules can be built to establish the relationship among different variables.
- fuzzy inference rule is called the max-min inference rule.
- 1. *If A and B, then C.*
- The maximum degree of truth for C is the lesser of the degree of truth for A and that for B.

- 2. If A or B, then C.
- The maximum degree of truth for C is the greater of the degree of truth for A and that for B.
- 3. If not A, then C.
- The maximum degree of truth for C is one deducted by the degree of truth for A.

Defuzzification

1. Defuzzification is the process of estimating the value of the dependent variable based on the resulting fuzzy set after applying the fuzzy inference rule.
2. Translating the membership degree of fuzzy sets into a particular choice or real value.
3. A process that converts fuzzy terms to conventional expressions quantified by real-valued functions.

Methodology

- **Risks associated with the construction industry can be broadly categorized into:**

a. Technical risks:

- Inadequate site investigation
- Incomplete design
- Appropriateness of specifications
- Uncertainty over the source and availability of materials.

b. Logistical risks:

- Availability of sufficient transportation facilities
- Availability of resources-particularly construction equipment spare parts, fuel and labor.

c. Management related risks:

- Uncertain productivity of resources
- Industrial relations problems.

d. Environmental risks:

- Weather and seasonal implications
- Natural disasters

e. Financial risks:

- Availability and fluctuation in foreign exchange
- Delays in Payment
- Inflation
- Local taxes
- Repatriation of funds

f. Socio-political risks:

- Constraints on the availability and employment of expatriate staff
- Customs and import restrictions and procedures
- Difficulties in disposing of plant and equipment
- Insistence on use of local firms and agents

Determination of Risk

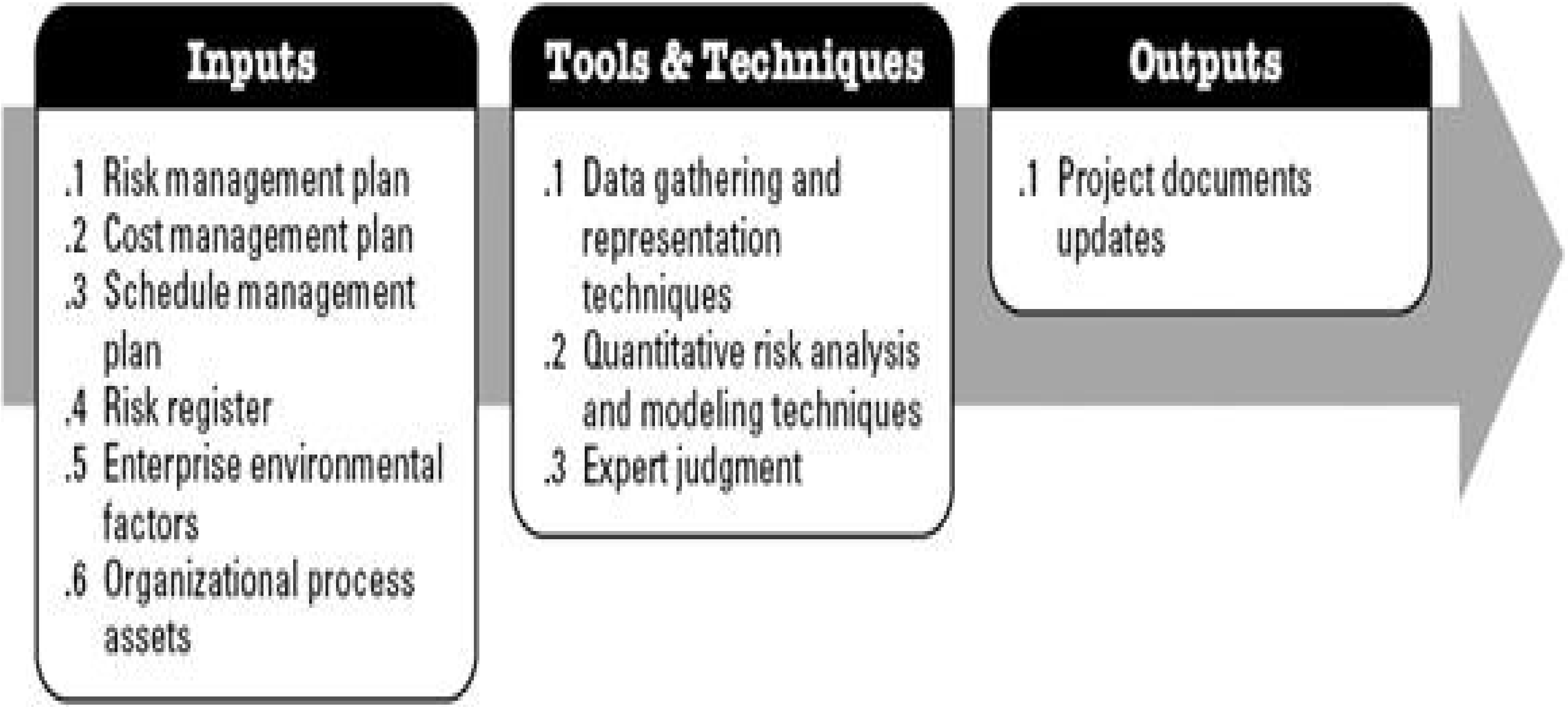
- Qualitative Risk Analysis :

The qualitative approach relies on judgments and it uses criteria to determine outcome.

- Quantitative Risk Analysis :

The quantitative analysis relies on statistics to calculate the probability of occurrence of risk and the impact of the risk on the project.

Quantitative Analysis



Methods used in Quantitative Analysis

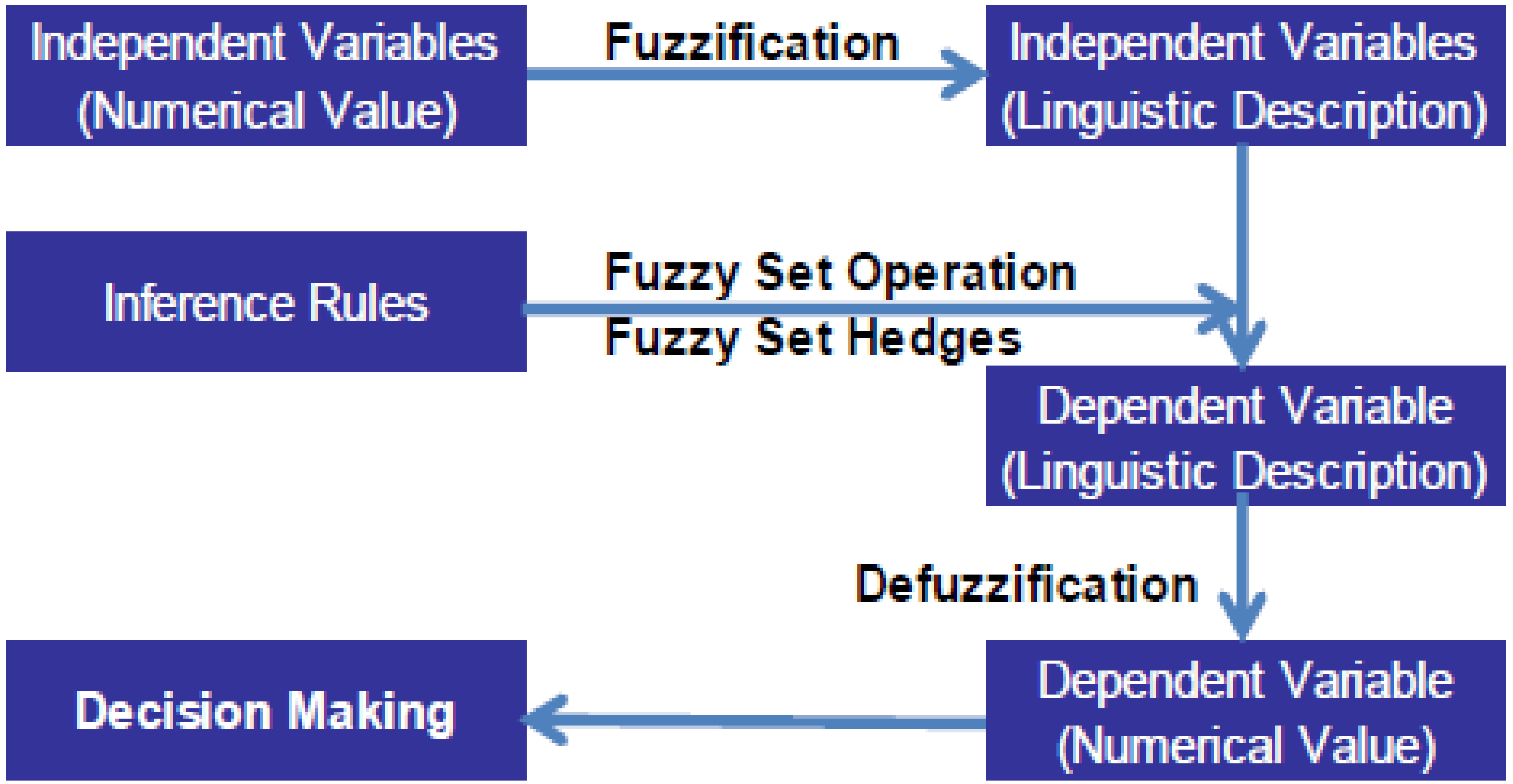
- Expected Value Methods
- Probability Distribution Methods
- Mathematical Modelling
  - Fuzzy logic
  - Artificial Neural Networks
- Interdependency Models
- Empirical Methods

1. The proposed methodology develops a decision making model by using fuzzy logic.
2. The advantage of the fuzzy model is the ability to transform the input variables, The Number of Sub-Risks (NSR) and The Total Value of Sub-Risks (TVSR) to linguistic variables, which helps in the evaluation of the Total Value of Project Risk (TVPR) which is the output variable.
3. With this approach it is possible to simulate the risk value and uncertainty that are always associated with real projects.

Fuzzy Logic System

- **Step 1.** Input variables are selected as the key determinants or indicators of the output variable.
- **Step 2.** Fuzzy sets are created for both input and output variables. Instead of using the numerical value, fuzzy sets in terms of human language are used to describe a variable. The degree of truth that each variable belongs to a certain fuzzy set is specified by the membership function.

- **Step 3.** Inference rules are built in the system. A fuzzy hedge may be used to tweak the membership function according to the description of the inference rules.
- **Step 4.** The output fuzzy set of the output variable is generated based on the input variables and the inference rules. After defuzzification, a numerical value may be used to represent the output fuzzy set.
- **Step 5.** The result is then used for informed decision-making.


Independent Variables
(Numerical Value)
Fuzzification
Independent Variables
(Linguistic Description)
Inference Rules
Fuzzy Set Operation
Fuzzy Set Hedges
Dependent Variable
(Linguistic Description)
Defuzzification
Decision Making
Dependent Variable
(Numerical Value)

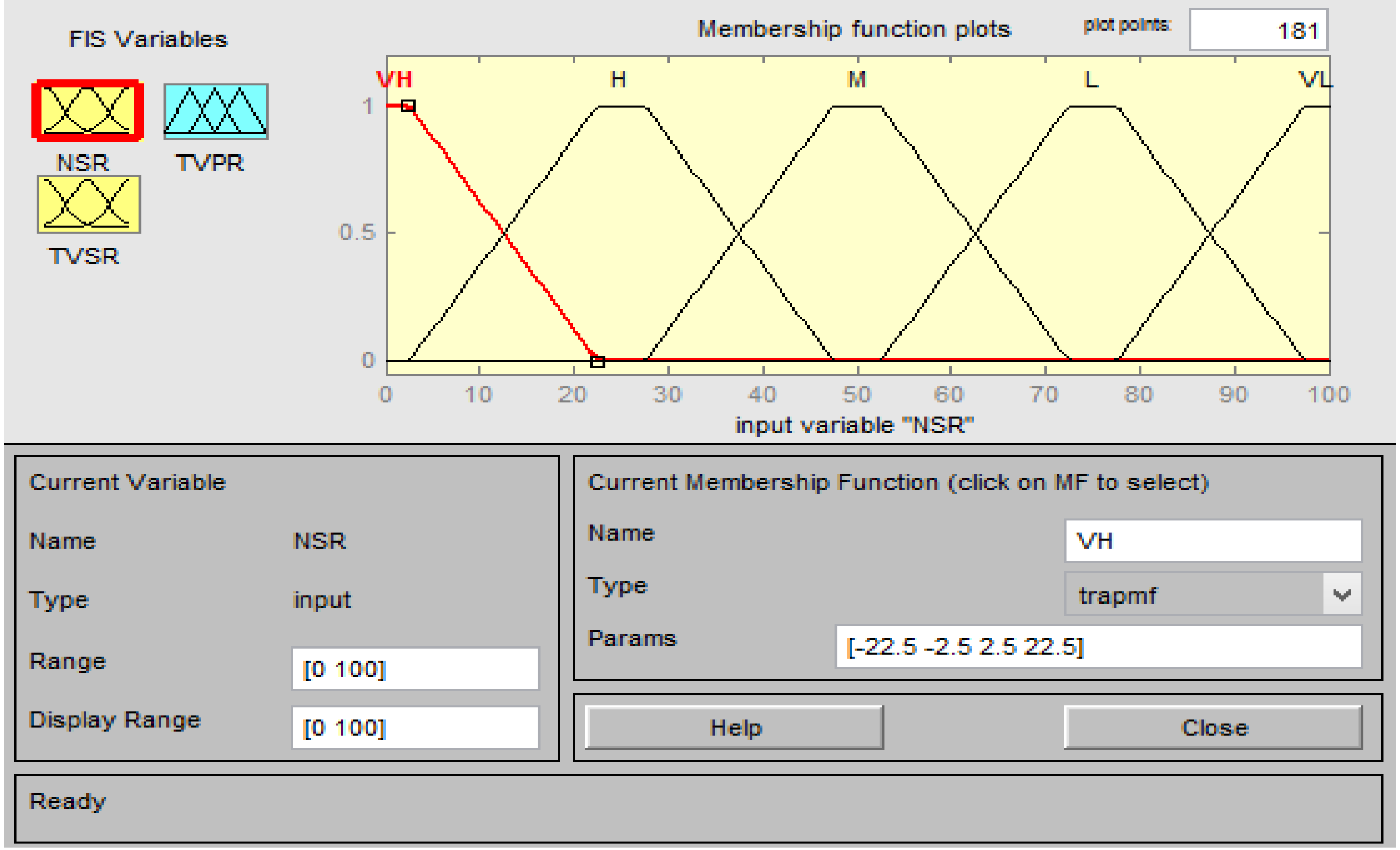
Results and Discussions

1. The developed decision-making fuzzy model system consists of two input variables with five attributes.
2. The input variables are No. of Sub-Risk (NSR) and Total Value of Sub-Risk (TVSR).
3. The five attributes are Very High (VH), High (H), Medium (M), Low (L), Very Low (VL).
4. And the output variable is Total Value of Project Risk (TVPR) with the same attributes as above. Table shows the likelihood of each attribute.
5. The use of fuzzy logic is a particular advantage in decision-making processes where description by algorithms is extremely difficult and criteria are multiplied.

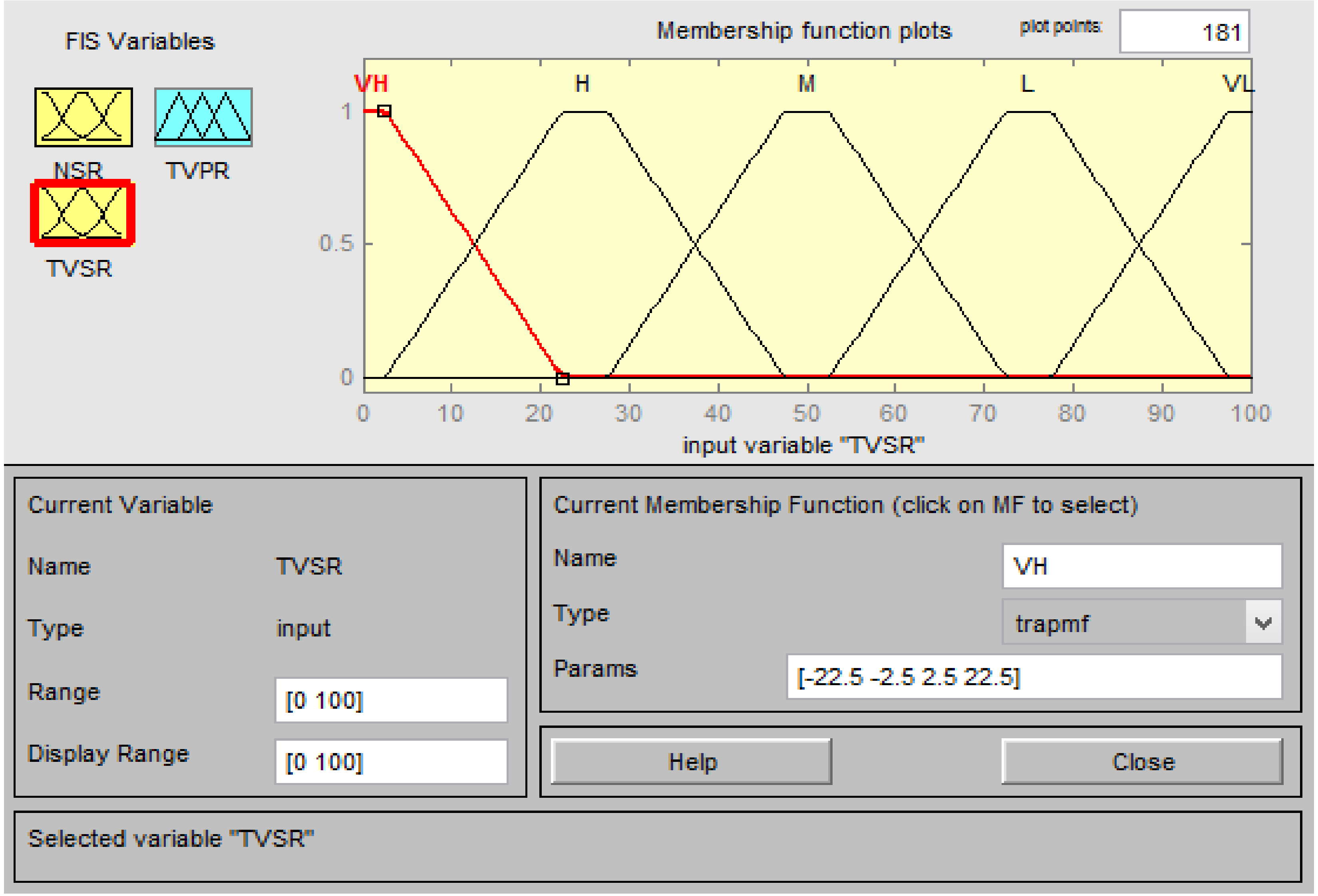
Customizable standard terms for quantifying likelihood

Likelihood	Description
Very High	Expected To Occur With An Absolute Certainty
High	Expected To Occur
Medium	Likely To Occur
Low	Unlikely To Occur
Very Low	Almost No Possibilty Of Occurenece

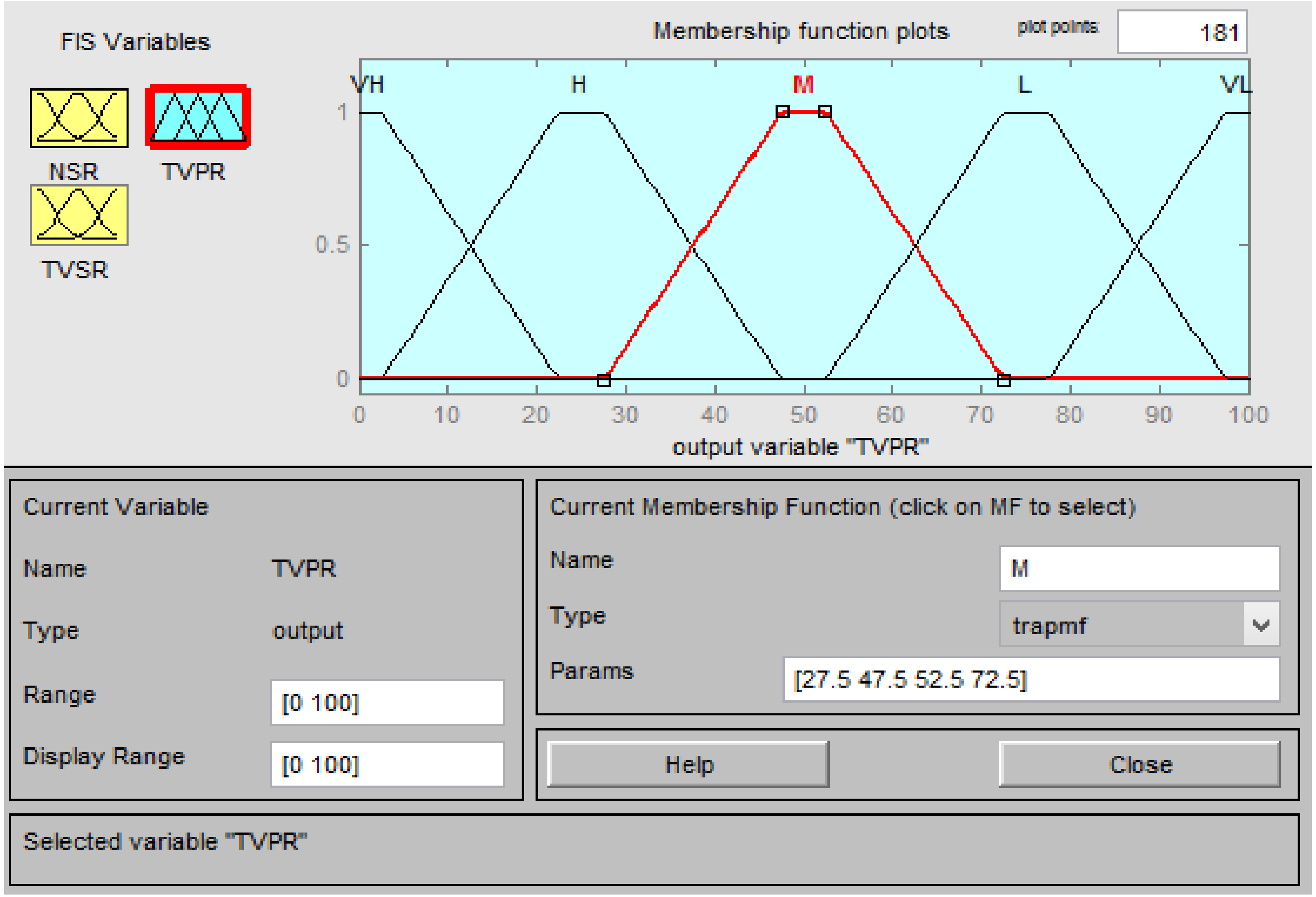
Membership Function of input variable



Membership Function of input variable



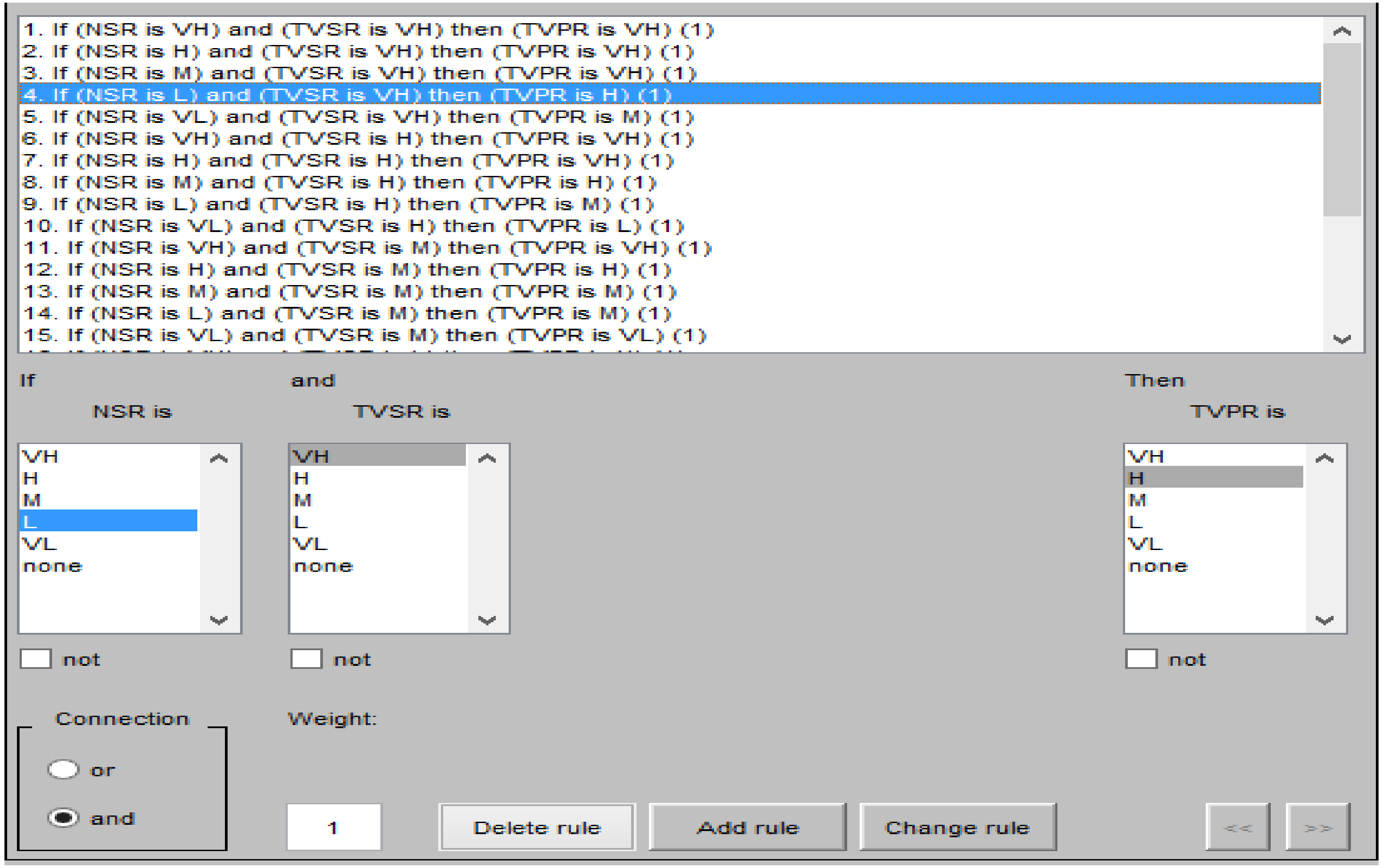
Membership Function of output variable



Fuzzy Inference Rule Combination

NSR	TVSR	NSR	TVSR	NSR	TVSR	NSR	TVSR	NSR	TVSR
1	1	2	1	3	1	4	1	5	1
TVPR=VH		TVPR=VH		TVPR=VH		TVPR=H		TVPR=M	
1	2	2	2	3	2	4	2	5	2
TVPR=VH		TVPR=VH		TVPR=H		TVPR=M		TVPR=L	
1	3	2	3	3	3	4	3	5	3
TVPR=VH		TVPR=H		TVPR=M		TVPR=M		TVPR=VL	
1	4	2	4	3	4	4	4	5	4
TVPR=H		TVPR=M		TVPR=M		TVPR=VL		TVPR=VL	
1	5	2	5	3	5	4	5	5	5
TVPR=M		TVPR=M		TVPR=VL		TVPR=VL		TVPR=VL	

Rule Block


1. If (NSR is VH) and (TVSR is VH) then (TVPR is VH) (1)
2. If (NSR is H) and (TVSR is VH) then (TVPR is VH) (1)
3. If (NSR is M) and (TVSR is VH) then (TVPR is VH) (1)
4. If (NSR is L) and (TVSR is VH) then (TVPR is H) (1)
5. If (NSR is VL) and (TVSR is VH) then (TVPR is M) (1)
6. If (NSR is VH) and (TVSR is H) then (TVPR is VH) (1)
7. If (NSR is H) and (TVSR is H) then (TVPR is VH) (1)
8. If (NSR is M) and (TVSR is H) then (TVPR is H) (1)
9. If (NSR is L) and (TVSR is H) then (TVPR is M) (1)
10. If (NSR is VL) and (TVSR is H) then (TVPR is L) (1)
11. If (NSR is VH) and (TVSR is M) then (TVPR is VH) (1)
12. If (NSR is H) and (TVSR is M) then (TVPR is H) (1)
13. If (NSR is M) and (TVSR is M) then (TVPR is M) (1)
14. If (NSR is L) and (TVSR is M) then (TVPR is M) (1)
15. If (NSR is VL) and (TVSR is M) then (TVPR is VL) (1)
If
NSR is
VH
H
M
L
VL
none
not
and
TVSR is
VH
H
M
L
VL
none
not
Then
TVPR is
VH
H
M
L
VL
none
not
Connection
or
and
Weight:
1
Delete rule
Add rule
Change rule
<<
>>

Executable File

```
BTVPR = readfis('rules');
dataBTVPR = input('enter the input data in the form (the number of Sub-risk; the total value of sub risks): ');
evaluationBTVPR= evalfis( dataBTVPR, BTVPR)
if evaluationBTVPR<20 'very high value of total project risk'
elseif evaluationBTVPR<40 'high value of total project risk'
elseif evaluationBTVPR<60 'middle value of total project risk'
elseif evaluationBTVPR<80 'low value of total project risk'
else 'very low value of total project risk'
end
fuzzy(BTVPR)
mfedit(BTVPR)
ruledit(BTVPR)
surfview(BTVPR)
ruleview(BTVPR)
```

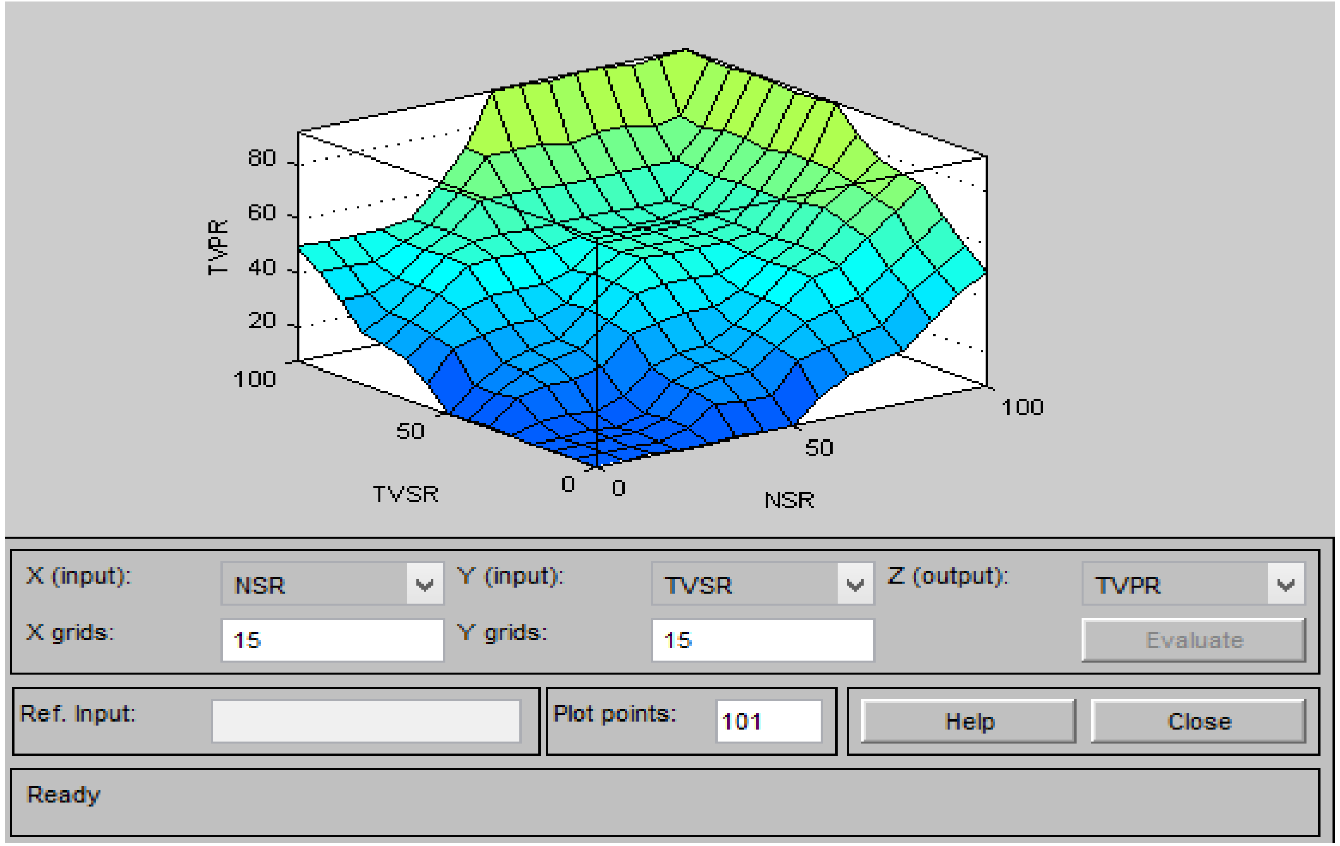
ommand Window

```
>> mfile
enter the input data in the form (the number of Sub-risk; the total value of sub risks): [0;0]

evaluationBTVPR =

    7.2885


ans =

very high value of total project risk
```

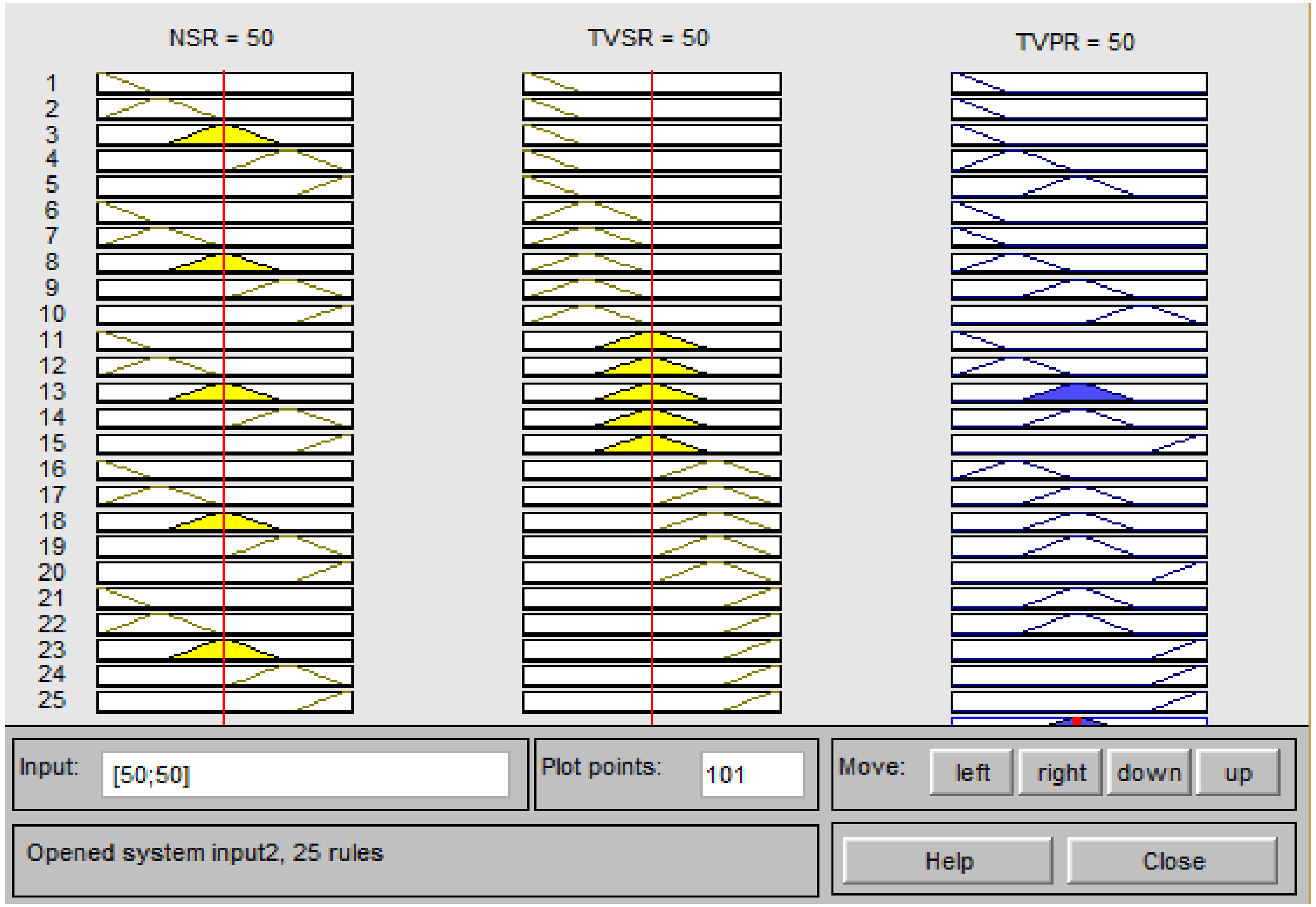
Customizable standard terms for severity quantification

Severity	Range Of Output Variable
Very High	<20
High	20-40
Medium	40-60
Low	60-80
Very Low	>80

Correlation between variables



Rule Viewer


NSR = 50
TVSR = 50
TVPR = 50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Input:
[50;50]
Plot points:
101
Move:
left
right
down
up
Opened system input2, 25 rules
Help
Close

Summary and Conclusions

1. The fuzzy decision-making model of evaluation of total project risk is only one of possible options how to use fuzzy logic for support of decision-making.
2. This work presented a fuzzy model, based on the RIPRAN method, specifically on the phase: risk assessment.
3. The advantage of fuzzy sets in comparison with the classical set theory is its ability to record inaccurate (vague) concepts that project managers use natural language in the design and implementation of projects.

3. The advantage of this fuzzy model is the ability to transform the input variables The Number of Sub-Risks (NSR) and The Total Value of Sub-Risk (TVSR) to linguistic variables, as well linguistic evaluated The Total Value Project Risk (TVPR) – output variable.
4. The fuzzy model has a lot of benefits for users (project managers and others). Some of them are: speed up the decision-making in risk management, automatization and standardization of risk analysis process, effective project management etc.
5. If the fuzzy model is tuned, it is possible to use it in practice. To implement the fuzzy model in MATLAB an executable file called M-File is created. M-file is used to enter the input values and automatically evaluate the total risk of the project.

Future Scope

1. Although the computations involved in the model of the fuzzy risk analysis are tedious if performed manually, it is an easy task and the time for risk analysis can be significantly reduced. It becomes easier if a software is used.
2. The proposed fuzzy risk analysis provides an effective, systematic and more natural way to analyze the associated risks.
3. Evaluators can just adjust the parameters of the input and output variable and run the M-file to get the total value project risk.
4. There are some limitations in this work. For example, the membership functions were distributed by trapezoidal fuzzy numbers. Various membership functions need to be estimated to be as realistic as possible.

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List of Publications

1. “Fuzzy Approach to Risk Assessment in Construction Industry: A Review”, International Conference on Construction, Real Estate, Infrastructure and Projects(CRIP) Management-ICCRIP-2017 by NICMAR, Pune. (Paper Communicated)

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