Risk Assessment and Distribution in Small Hydro Power Projects: A Fuzzy Approach

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ISBN: 978-81-924713-8-9

The paper identifies and asses investment related risk of small hydro power project in Uttarakhand state of India using Fuzzy Logic approach The result of this research is displaying various investment related risk factors their relative importance and risk index for small hydro power projects in operation stage An optimum risk distribution for investors is developed using optimum portfolio theory Apart from stochastic variables there are some external variables that are not stochastic by nature also influence on investment decision Such variables are identified based on literature reviews expert interviews and relative importance of these factors are evaluated and ranked.

Key words: Risk Assessment; small hydro power projects; Fuzzy Logic Approach, optimum portfolio**.**

1. Introduction

With the fast growing economy and population, there has been a huge increase in energy demand in India. India ranks sixth in the world in total energy consumption (planning commision report., 2013). The rapid increase in use of energy has created a problem by defining a significant gap between energy production and consumption (Utilization, 2010). Global declining of non-renewable energy brings future uncertainty in the energy supply to meet with an increase energy demand in India.(IEA, 2011) To combat with future uncertainty in energy India has to meet with increased production of energy. However, given the raise of sustainable development concerns, there is the need to think about alternative sources of energy production, with a particular emphasis on renewable energy sources (RES) as India has a large amount of, supply of renewable energy resources; (Rana, 2003). Apart from the need to meet the increased energy consumption, there are several reasons for the growth of RES interest (Mckinsey, 2010), namely: the increase in fuel prices; the concern about protecting the environment of the impact of nefarious power generation through non-renewable sources (e.g., coal and oil); and the desire to reduce dependence on traditional energy sources (e.g. thermal). It is, therefore, imperative to develop new solutions for sustainable energy production combining economic development with environmental sustainability.(Pillai & Banerjee, 2009)

The remainder of the paper is organized as follows. Section 2 presents a brief description of the electricity sources in Uttarakhand of India, with particular emphasis on small hydropower. Section 3 describes investment project evaluation and investment appraisal. Section 4 assesses the main sources of risk underlying the type of investment under analysis and optimum portfolio distribution. In section 5 the results of the risk analysis are presented with discussion. Finally, section 6 drawn the main conclusions of the paper and highlights future avenues of research.

1.1 Uttarakhand Electricity Sector

Uttaranchal Jal Vidyut Nigam Limited (UJVNL) is hydro power generation body of uttarakhand state. Its major function is to develop and promote new hydropower projects with the purpose of harnessing more potential of hydro power. (confederation of Indian Industry(CII), 2012.)In Uttarakhand estimated capacity of SHP projects is approximate 1478 MW. The harnessed capacity of SHP's are 8.7% while total harnessed capacity of state is 10.25% as per 10th Five Year Plan.(Planning commision, 2011)

2. SHP Project Investment Evaluation

Most of the investment decisions are made by tariff calculation technique in Uttrakhand SHP investment project (DPR, 2005). But in tariff calculation technique, the cash flow model is not made risk adjusted. However, in few projects (Galogi, Mohammadpur & Pathri) are also evaluated and supported by standard financial indicators such as Net present value (NPV); internal rate of Return (IRR); profitability Index (PI) & payback period (PBP). Literature shows risk adjustment is ignored for investment decisions..

Globally the small hydro power projects consider many factors that create a possibility of cost overrun. As (Wiemann, 2011b) shows if running hour per hour is increased how electricity production cost is also increased. One of the river-type small hydropower plants in Uttarakhand, the cost of civil works increased because of unpredicted approval delays, river flow and geological structure, (Joshi, 2007). In another example, the policies have ruled against hydroelectric power plants in 3 completed cases in Uttarakhand, issuing a stay of execution decision or canceling the construction altogether because of the environmental issues.(Girmay, 2006). (Fig 1.1)

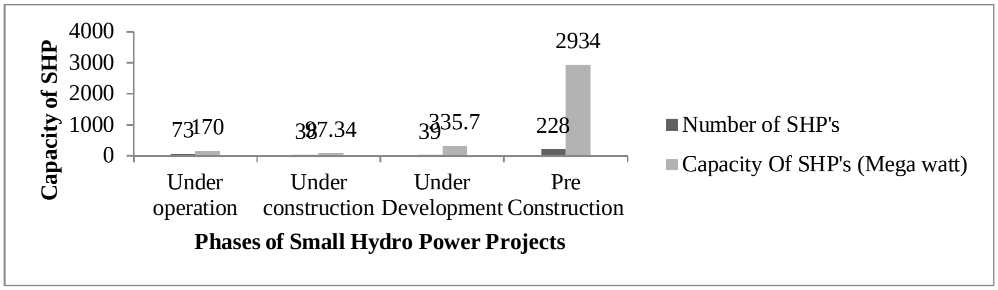

Figure 2.1 *SHP's Capacity Addition for Small Hydro Electric Power Sector*

Similarly there are a lot of factors which create risk for small hydro power project. small hydropower plant investment involves risks due to a number of factors such as technical, market, financial, environmental, socio-economic, policies and various subcategories lie under these.(Júnior & Reid, 2010); (S. M. H. Hosseini, Forouzbakhsh, & Rahimpoor, 2005); (Madlener & Ediger, 2004); (Fleten & Heggedal, 2009). These factors have influences on cost and revenue.

Investors wishing to invest in renewable energy must be aware of all the risks to consider their effect on profitability. (Jayant Sathaye (USA), Oswaldo Lucon (Brazil), 2012). The investors benefit will be increased if more and more risks were identified in the beginning and if truly assessed so risk management would work well. (Júnior & Reid, 2010).

(Lundmark & Pettersson, (2002.); (Zhang et al., 2010a), (Kucukali, 2011)(Wiemann, 2011b) and (Arid, 2000) explain major investment risks in small hydropower sector as price, market, climate, technology, regulatory, environmental, socio-economic, interest rate, (S. A. Hosseini, 2011) who used different investment decision making approaches to quantify and asses the risk in small hydropower project. (Zhang et al., 2010b) and (Chan, Chan, Asce, & Yeung, 2009) used various techniques, like deterministic, probabilistic, stochastic and strategic for risk assessment in small hydropower project (Gains et al., 2002) applied Monte Carlo simulation as a stochastic approach in for parametric risk analysis, he found as one of the best methods. For analyzing non- parametric risk fuzzy logic based approach was found to be popular in the investment decision field (Kucukali, 2011).

2.1 Risk Assessment Process

A complete risk assessment procedure is likely to consist of five steps (Shang & Hossen, 2013):

1. Identification of the risk that is to be analyzed
2. A qualitative description of the problem and the risk – why it might occur, what you can do to reduce the risk, probability of the occurrence etc.
3. A quantitative analysis of the risk and the associated risk management options that is available to determine or find an optimal strategy for controlling and hereby solving the risk problem
4. Implementing the approved risk management strategy

The essence of the traditional risk analysis approach is to give the decision-maker a mean by which he can look ahead to the totality of any future outcome. The advantage of using any risk analysis approach is the possibility of differentiating the feature of risk information in terms of outcome criteria such as Net Present Value (NPV), the Internal rate of Return (IRR) or the Benefit/Cost rate (B/C-Rate) by probability distributions (Deng, Su, Jiang, Xu, & Xu, 2010).

Risk assessment in this project consists of two basic steps:

2.2 Sample Size

Questionnaire surveys usually involve only a proportion, or sample, of the population in which the researcher is interested (Veal 1997). In this paper, questionnaire has been prepared consulting experts of Hydro power area and sends to all technical, managerial, operational people and investors of UJVNL, researchers who are doing research in the same area and those who are directly or indirectly related with investment in small hydro power plants, 60 responses are considered. Two operational stage SHP's are considered for classifying the risk index of project. Those are Pathri also near Haridwar & KaldiGad in Rudraprayag.

2.3 Risk Identification

There are ten risk factors were identified in construction stage and nine in operation stage of SHP's based on the expert interviews and literature review and categorize them into quantitative and qualitative/subjective factor. The risk factors and their emphasis are given in Table 2.1 operation stage.

2.4 Risk Analysis for factors using Fuzzy Logic

Identified risks are individually analyzed as to their potential probability and consequence (Pejovic et.al.; 2007). The subjective risks were analyzed by relative importance based on the evaluation are listed in Table 1. The relative importance of operational stage small hydro power projects are shown in fig.2.1. In order to determine the relative importance of the risk factors, a survey was conducted with the experts from Uttarakhand Jal Vidyut Nigam Ltd. (UJVNL) and investors who have experienced in the construction of river-type small hydropower project. The participants were asked to grade the importance of the risk factors regarding their importance and seriousness of concern. They weigh the risk factors using a scale between 1-5, where 1 represents "Very low risk" and 5 "very high risk".

Table 2.1 *Risk Factors Responses Underlying*

Risk Factor	score 1 (very Low)	score 2 (Medium)	score 3 (High)	score 4 (very High)	score 5 (Extreme)
Operational Delay	No Breakdown occurs in power plant and no impact	Breakdown occurs once in a year but manageable	Breakdown occurs Twice in a year creates cost overrun	Breakdown occurs 2-4 times in a year creates high cost overrun	Breakdown occurs frequently and cost overrun exceed severely
Generation	Electricity generated more than average capacity	Electricity generated +- 5% than average capacity	Electricity generated +- 10%to 20% than average capacity	Electricity generated +- 20-40%% than average capacity	Electricity generated less than 50% of average capacity
Electricity Price	price fluctuates once in 10 year	price fluctuate every 5 year	price fluctuate within 2-4 years	price fluctuation once in a year	price fluctuation 3 times in a year
Operation & Maintenance cost	Operation and maintenance c ost is 1-2% of capital cost	Operation and maintenance c ost is 2-5% of capital cost	Operation and maintenance c ost is 5%-10% of capital cost	Operation and maintenance cost is 10%-20% of capital cost	Operation and maintenance cost is more than 20%of capital cost
Inflation	No inflation increment	No revision in one year	Revised twice in a year	Revised two to three times in a year	inflation changes frequently
Interest Rate	Fixed interest rate	No revision in one year	Revised twice in a year	Revised two to three times in a year	Inflation changes frequently
River Flow	river flow uniform throughout the year	river flow is monsoonal but under controlled	river flow is monsoonal but partly controlled	river flow is monsoonal but damage controller available	river flow is very high so damage power project
Tax Rate	No changes in tax	No revision in one year	Revised twice in a year	Revised two to three times in a year	Tax changes frequently
Terrorism	terrorism risk index of the state is very low	terrorism risk index of the state is low	terrorism risk index of the state is Moderate	terrorism risk index of the state is High	terrorism risk index of the state is very High

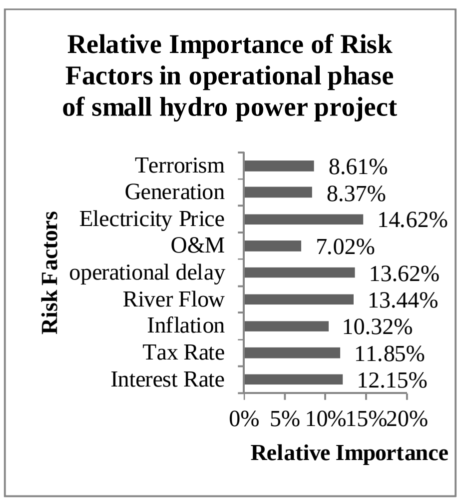

Figure 2.1 *Relative Importances of Risk Factors*

In calculation of the weights of parameters, the number of ticks against each parameter attributes in the expert's interview were counted. 1 to 5 attributes were taken into consideration in the calculation of overall weighted averages **(WA)** of parameters using fuzzy theory triangular method to promote precise preferences. Each factor has a significant rating **(r_i)** that demonstrates the importance of the factor compared to other. Weights of factors were obtained by multiplying overall weighted averages **(WA)** with significance rating **(r_i)** and were normalized. Normalized final weights **(w_r)** were used in the fuzzy logic application. The Assessment fuzzy matrix **(*AF*)** was obtained by taking product of input matrices (*I*) with Rating fuzzy matrix (R*F*) of the parameter,

$$AF_j = I_j \times RF_j \quad \text{(j= 1 to 10 and 9 respectively)} \qquad (2.1)$$

Where, j is the row number of the fuzzy assessment matrices. The membership degree matrix **(*MD*)** was obtained by multiplying relative weight of parameters **(w_r)** with assessment fuzzy matrix **(*AF*)** and summing the columns resulting in a one row matrix;

$$\boldsymbol{MD = w * AF} \tag{2.2}$$

A risk index computed using decision parameter computation was agreed upon from several scenarios considering membership degree versus attributes curves and formulation of Risk Index **(RI)** was given as

$$\boldsymbol{RI = \frac{1*A_{12}+2*A_{23}+3*A_{34}+4*A_{45}}{A_T}} \tag{2.3}$$

Where the area under the curve between the attributes i and j is named $\mathbf{A_{ij}}$ with: **i =1, 2, 3, 4, 5** and **j = 2, 3, 4, 5.** the total area under the curve is $\mathbf{A_T}$. This enabled a Risk Index **(*RI*)** value to be calculated, establishing a 5 grade evaluation system: Low risk having **RI** values less than 0.6, medium risk between 0.6 and 1.9; High risk, between 1.9 and 3.2; very high risk, between 3.2 and 4.4; extreme risk 4.4 and above. The risk scale index represents the minimum and maximum values calculated by Eq. (2.3).

2.5 Optimum portfolio selection in SHP

The process of constructing an investor portfolio can be viewed as a sequence of two steps: (1) selecting the composition of one's portfolio of risky alternatives in this case operational or construction phases and (2) deciding how much to invest in risky project. An investor decide to allocate investment funds between the two projects after knowing its expected return and degree of risk (Tongtao & Cunbin, 2014), so a fundamental part of the capital allocation problem is to characterize the risk–return trade-off for this portfolio. The theme of portfolio allows to quantify investors' personal trade-offs between portfolio risk and expected return using weighting function,(Salling, 2005).

The risk and return of two projects are shown in table 3. A construction phase, denoted using con, and an operational phase using op. for estimation of expected return and risk of portfolio the weights of each alternative is required. A proportion denoted by $\boldsymbol{\omega_{pat}}$ is invested in the Project1 and the remainder for Projects2, **1-** $\boldsymbol{\omega_{pat}}$, Symbolized $\boldsymbol{\omega_{kal}}$. The rate of return on this portfolio, R_p, will be computed using equation 2.4.

$$\boldsymbol{R_p = \omega_{Pat} R_{Pat} + \omega_{kal} R_{kal}} \tag{2.4}$$

Where **Rpat** is the rate of return on the pathri project and $\boldsymbol{R_{kal}}$ *is* the rate of return on the kaldigad project.

The variance of the two-alternative portfolio is computed using equation 5.

$$\boldsymbol{\sigma_p{}^2 = \omega^2{}_{pat}\ \sigma^2{}_{pat} + \omega^2{}_{kal}\ \sigma^2{}_{kal} + 2\omega_{pat}\omega_{kal}cov(R_{pat}, R_{kal})} \tag{2.5}$$

Though in both equation 4 & 5 weights are required so randomly weights values are varied between 0 to 100% for generating optimum portfolio. The optimum portfolio is the need for investors so minimum variance portfolio is created via estimation of optimum weights using equation 2.6 & 2.7.

$$\boldsymbol{\omega_{pat} = \frac{\sigma_{pat}}{\sigma_{pat} + \sigma_{kal}}} \tag{2.6}$$

$$\boldsymbol{\omega_{kal} = 1 - \omega_{pat}} \tag{2.7}$$

Optimum portfolio thus created using above estimated weights at different correlation values varies between +1 to -1.

3. Results

3.1 Determination of Fuzzy Score of risk factors

Two types of small hydro power projects of uttarakhand are taken one is under construction stage and other is under operational stage. 9 and 10 risk factors were identified based on literature survey, expert opinion and questionnaire survey.

For construction and operational phase each 9 & 10 risk factors , a 1x5 input matrix was developed, each column corresponding scores 1- 5. If the score for a parameter is 2 the input matrix (*I*) for the parameter is:

$$I = |0 \quad 1 \quad 0 \quad 0 \quad 0| \tag{8}$$

Each parameter has a grading fuzzy matrix. The grading fuzzy matrices were developed considering the degree of error a scoring observer may cause due to subjectivity and bias in the assessment process.

$$GF = score \begin{bmatrix} 1 & 0.5 & 0 & 0 & 0 \\ 0 & 1 & 0.3 & 0 & 0 \\ 0 & 0.2 & 1 & 0.2 & 0 \\ 0 & 0 & 0.5 & 1 & 0 \\ 0 & 0 & 0 & 0.3 & 1 \end{bmatrix} \tag{9}$$

Under operational stage risk index is calculated using fuzzy logic approach shown in table 3.1.

Table 3.1 *Risk Index Assessment for Operational stage SHP's*

Risk Index assessment for operational stage small hydro power project																			
Assessment Parameters	**% Relative importance**	**Score**	**Input Matrix(I)**					**AF=I * RF**	**Fuzzy Grading Matrix**					**MD=**	**Fuzzy Assessment Matrix**				
															Membership Degree				
									1	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
Interest Rate	12.15%	4	0	0	0	1	0		0	0	0	0.2	1		0.0000	0.0000	0.0000	0.0243	0.1215
Tax Rate	11.85%	4	0	0	0	1	0		0	0	0.2	1	0.4		0.0000	0.0000	0.0237	0.1185	0.0474
Inflation	10.32%	4	0	0	0	1	0		0	0	0	0.2	1		0.0000	0.0000	0.0000	0.0206	0.1032
River Flow	13.44%	4	0	0	0	1	0		0	0	0	1	0		0.0000	0.0000	0.0000	0.1344	0.0000
operational delay	13.62%	1	1	0	0	0	0		1	0	0	0	0		0.1362	0.0000	0.0000	0.0000	0.0000
O&M	7.02%	4	0	0	0	1	0		0	0	0.4	1	0		0.0000	0.0000	0.0281	0.0702	0.0000
Electricity Price	14.62%	5	0	0	0	0	1		0	0	0	0.2	1		0.0000	0.0000	0.0000	0.0292	0.1462
Generation	8.37%	5	0	0	0	0	1		0	0	0	0	1		0.0000	0.0000	0.0000	0.0000	0.0837
Terrorism	8.61%	1	1	0	0	0	0		1	0.2	0	0	0		0.0861	0.0172	0.0000	0.0000	0.0000
Risk Index(RI) Operational															0.0260	0.0015	0.0048	0.0464	0.0594
															0.0137	0.0031	0.0256	0.0529	0.0953
															A12	A23	A34	A45	AT
															0.3084				
															3.2342				

The risk index **(RI)** for pathri small hydro power project comes out to be 3.2342 and for kaldigad power project comes out to be 2.8581 which categories both the stages with very high risk.

3.2 Risk Distribution using Optimum Portfolio Theory

In order to create an optimum portfolio, optimum weights for both stages are estimated using Equation 2.3 & 2.4. Capital investment proportion for construction stage computed as 53.14% and for operation 46.86%. These weights are varied randomly between 0 to 100% for both the stages shown in table 4 and 11 different scenarios are generated. Scenario 7 shows the optimum portfolio corresponding to above estimated weights. (Table 3.3)

Table 3.2 *Risk and Return Summary for Two Operational Stage SHP's*

Expected Return (Pathri)	18.83%	Expected Return (kaldiigad)	11.13%
Estimated risk using Fuzzy Logic (Pathri)	57.04%	Estimated risk using fuzzy logic (kaldigad)	64.68%
Correlation	-1 to +1		

Table 3.3 *Scenarios for Optimum Portfolio*

Scenario's	**W_{op}**	**W_{con}**	**Expected Return (E(Rp))**	**σpcor1**	**σpcor0.75**	**σpcor0.5**	**σpcor0.25**	**σpcor0**	**σpcor-1**
scenario 1	1	0	18.83%	57.04%	57.04%	57.04%	57.04%	57.04%	57.04%
scenario 2	0.9	0.1	18.06%	57.80%	51.74%	54.86%	53.32%	51.74%	44.87%
scenario 3	0.8	0.2	17.29%	58.57%	47.43%	53.29%	50.45%	47.43%	32.70%
scenario 4	0.7	0.3	16.52%	59.33%	44.39%	52.40%	48.56%	44.39%	20.52%
scenario 5	0.6	0.4	15.75%	60.10%	42.90%	52.21%	47.78%	42.90%	8.35%
scenario 6	0.5	0.5	14.98%	60.86%	43.12%	52.74%	48.17%	43.12%	3.82%
optimum Scenario	**0.514492754**	**0.4854**	15.09%	60.62%	42.86%	52.50%	47.92%	42.86%	0.00%
scenario 7	0.4	0.6	14.21%	61.62%	45.02%	53.96%	49.69%	45.02%	15.99%
scenario 8	0.3	0.7	13.44%	62.39%	48.40%	55.83%	52.25%	48.40%	28.16%
scenario 9	0.2	0.8	12.67%	63.15%	52.99%	58.29%	55.70%	52.99%	40.34%
scenario 10	0.1	0.9	11.90%	63.92%	58.49%	61.26%	59.89%	58.49%	52.51%
scenario 11	0	1	**11.13%**	**64.68%**	**64.68%**	**64.68%**	**64.68%**	**64.68%**	**64.68%**

The expected return of optimum portfolio comes out as 15.09% and risk value varies between 0 to 60.62% with correlation values -1 and +1 respectively, Shown in table 4. Although getting 0% risk is a speculation but with reference to each portfolio minimum risk is achieved (Fig. 3.1). While checking the significance of estimated weights several other scenarios are created via changing risk and return values of projects, the variation is within the range of 5% which is not high significant, so these weights are considered to be the optimum distribution of capital investment by investors between alternatives

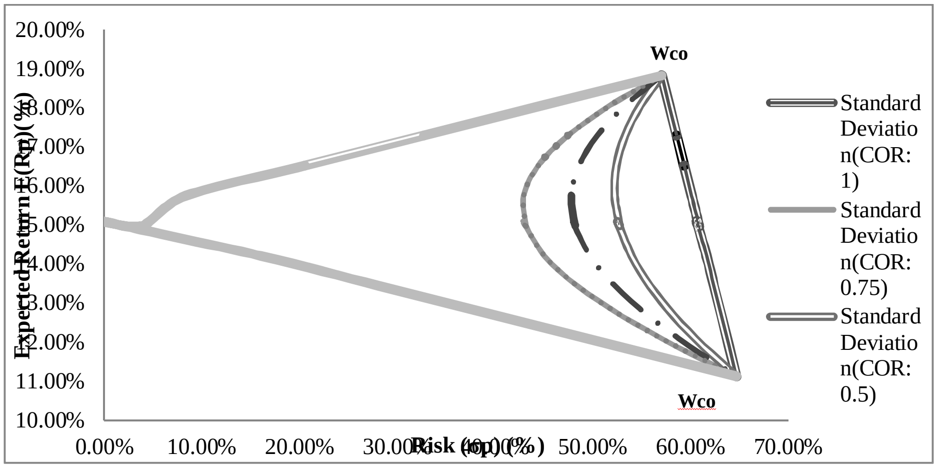

Figure 3.1 *Optimum Portfolios for SHP's Investors*

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4. Discussion

Fuzzy logic works strategically, which deals both parametric and non-parametric risk factors and further quantify risk. The linguistic risk factors as Terrorism, clearances, operational delay, Geology, and parametric risk factors as construction budget, operational and maintenance cost, interest rate, tax rate are not grouped together and quantified so far. This paper in this series gives a new dimension of quantifying risk using above mentioned risk categories together that is quite unique in this area.

Assessed risk applied on portfolio theory which is the useful application for investors. Investor's capital distribution is decided based on optimum portfolio theory which suggest them if they invest in appropriate proportion in two different operational & construction project so their investment will give optimum risk and return outcome.

5. Conclusion

Risks associated with SHP investment are identified. These risk items serve as a checklist that cover possible investment risks associated with SHP in constructional and operational phases which are not addressed so far globally. In construction phase most prominent risk factor come out as geology, relocation & climate and in operational phase the leading factors are electricity price, operation delay & river flow. It is also concluded that operational stage small hydro power projects are under more risk as compare to construction phase. Risk managers or investment decision makers can be informed and be able to recognize the risks associated with SHP investments. The optimum portfolio standard line also has no variation more than 4% while choosing other projects so this model satisfies the results.

An overall risk index can be used as early indicators of project problems or potential difficulties. Evaluators can keep track to evaluate the current risk level with the progress of investments.

Moreover, it was assumed that the ''weighting'' assigned by each evaluator in the risk evaluation was the same, but the relative importance placed on certain factors by individual decision makers and experts could be widely different. Further research is needed to develop different ''weightings'' for different evaluators

Also, for simplification, the membership functions were evenly distributed by triangular fuzzy numbers. Various membership functions need to be estimated to be as realistic as possible.

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