A multilevel fuzzy assessment of solar energy project risks using Matlab-Simulink

Dr Li HongXia[1] and Bouba Oumarou Aboubakar [2]
[1]School of management, Xi'an University of Science and Technology, Xi'an, China,
[2]PhD Candidate, Safety school, Xi'an University of Science and Technology, Xi'an, China,

ABSTRACT: *On a project entity, risks are everywhere. In ensuring that projects are completed by the scheduled date and within the given costs, risk associates and project managers play an important role. A comprehensive management of risks is important to properly check a high risk project due to uncertainty and flexibility. The aim of this paper is to design an approach that uses a fuzzy decision making system for a solar energy project risk assessment. The algorithm developed in this paper is based upon fuzzy logic, giving it the ability to solve step by step unclear problems and split them into small and easy to understand issues. A fuzzy risk calculation system is designed and implemented using the MATLAB Fuzzy Logic toolbox. The model developed is quite proactive to the major different risks that can be found on a PV project platform and could be used as data for upcoming projects. We used data from lesson learnt on a project in Morocco, to apply the method.*

KEYWORDS: *Fuzzy logic, Project risk management, Risk calculation, solar energy, fuzzy decision making.*

I. INTRODUCTION

Numerous solar energy projects have been started around the world to reduce gas emissions, especially in Africa, where the population is set to double by 2050 and its energy needs will grow even faster. Providing full electricity access to all Africans will require at least a doubling of total electricity production by 2030 from current levels. Then the need to replace fossil fuels has engendered a sense of urgency in seeking energy resolutions. The continent has about 36 macro-solar projects. China by contrast lured $67.7 billion in investment and the U.S. $44.2 billion. [1] The nature of construction has made it a challenging regime to handle risks, e.g. constant change on building environment, direct exposure to hazardous sources, high pressure on demanding schedules and costs, and increasing complexity on construction techniques [2] .Project managers, due to different issues are under pressure to generate results from these ongoing projects. As investments in solar energy continue to grow, and as PV comprises a larger portion of the energy mix, it is becoming increasingly important for stakeholders across the industry to understand the particular risks associated with PV and the most effective means of managing them. On the basis that constructing mega projects will always induce risks, effective RM can help to deliver projects to meet the triple constraints (cost, schedule and specification), and avoid painful and expensive firefighting [3].

Different approaches have been created to assess the various types of risk. Researchers have used stochastic methods for dealing with duration risk or cost risk, while risk has been perceived as a synonym for variability of expected duration or estimated cost. Objective probability has been adopted as it suited such a perception. However, appropriate data for such approaches are rarely available [4].Hybrid techniques include Human Error Analysis Techniques, Fault-tree Analysis, Event Tree Analysis etc. [5].These methods are used to manage risks but present very high rate of uncertainty. Gradually, researchers have concluded that human factors, personal experience, intuition and judgment need to be considered. To show this, fuzzy logic systems was introduced as a solution for handling subjective assessments. The models such as fuzzy logic and neural networks might do a better job in understanding and assessing certain risks, such as operational risk. The use of fuzzy is to describe the risk factors and fuzzy-based decision techniques to help incorporate inherent imprecision, uncertainties and subjectivity of available data, as well as to propagate these attributes throughout a model, yield more realistic results. Therefore, it may be beneficial to build and implement more appropriate operational risk models for solar projects using a newer approach such as fuzzy logic.

The goal of this research is to design, implement and apply a fuzzy evaluation and decision making model that can be used in solar energy projects risk assessment. This research makes two main contributions: First, it introduces a model for solar energy risk assessment method based on a combination of fuzzy inference early project risk identification, risk prioritization, and the preparation for a risk control plan based on project

risk level results. Second, it implements the method into the matlab fuzzy logic toolbox and applies the model on a real PV project.

II. MODEL DESIGN OF THE RISK ASSESSMENT METHOD

The risk estimation process consists of seven stages, namely, establishment of a risk assessment team, preparatory step, risk Identification, risk classification and breakdown structure, basic risk level measurement, fuzzy inference step, overall risk appreciation step, records and report step. An overview of these six stages of system development is shown in Figure1.
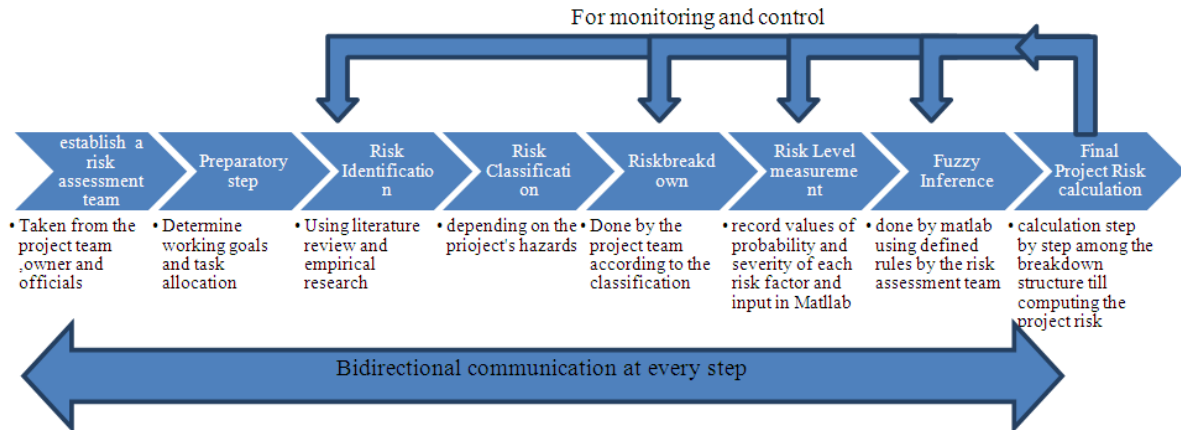

Figure1: Adopted risk Assessment method

Step 1: Establish a risk assessment group: this working team should be carefully selected. They must all be experts and have a high degree of knowledge and previous experience in similar projects. They must be selected from the project entity, the contractor and even government representatives.

Step 2: Preparatory Step: In this step, the risk assessment group undertakes the review of risk data and information and determination of risk criteria. The problem is defined, the situation understood and a general presentation and introduction of the work to be done will be performed. The decision problem will be formulated and each of the risk assessment team members will be allocated tasks.

Step 3: Risk identification: The objective of this part is to identify probable basic hazards that can influence a PV project. Using 'what ifs' and using the risk data base, a little empirical research will be done, focusing on identifying the potential risk factors that can be sorted out of a solar energy project. A questionnaire has to be sent to experts in the domain, experts that have experience both from the project, contractors and government. Data was collected through primary and secondary sources via questionnaire and previous research, government reports, and technical documents respectively. Secondary data was used when getting the primary data was impossible. We made checklist about the entire hazards that we Identified through our data and asked interviewers to rate them according to the risk model we developed (i.e. high risk, medium risk, low risk, no risk, and don't know).

Respondents from almost all over the world were sent an e-mail requesting their help in the survey questionnaire, along with a simple, two-page format listing the questions for which input was sought and an explanatory note. An online questionnaire has also been established to gather all the data needed from targeted respondents (companies, researchers, experts).Telephone interviews and in-person interviews were then conducted, with some respondents also filling out and returning the survey formats.

It took us nearly two months to collect all data, out of the 52 questionnaires conducted, 48 interviews were used for the analysis. The mean number of experience of the respondents was 8.7years and 54% were expert project managers and engineers, 12% were PhD and scholars, the rest were company's managers. At the end we could collect 31 major hazards that we used for the case study and the later points of this research.

Step 4: Risk classification: Since this step is essential in the decision-making process, risk classification, will be done in an iterative way. In the first iteration the team will elaborate a list of risks, grouped by concepts associated with the different steps of the project. Some classifications are focused on the risks nature and their magnitude [6] or on the risks origin [7].Other proposals use a hierarchical structure of risks like [7] [8] [9] [13] to classify risks according to their origin and to the location of the risk impact in the project. The risks, in turn, will be grouped into nine specific categories: policy risks (P), economic risks (E), social risks (S), Finance risks (F), technical risks (I), time delay risks (T), client risks (C), sub-contractors risks (SC) and project site risks (PS).

In the second iteration, the risks will be put into two categories internal (I, F, C, T, SC, PS) and external risks (E, S, P).In the next iteration the internal risks will be divided into Global (I, F, C, T) and Local (SC, PS) risks.

Step 5: Construction of a risk brake down structure: The hierarchical risk analysis can be carried out from levels 3 and 4, and then progressed up to level 2 and finally the hierarchical structure can be sorted out. On the basis of their experience and qualification, the risk assessment group identifies the risks and constructs a risk hierarchy [10].In this model the main goal of the problem is placed at the top vertex: to evaluate the project risk and give the most convenient advices to the control crew. Several techniques can be used to generate a breakdown structure of influential factors regarding a risk, such as Brainstorming, Checklist, ''What if?'', and Failure Mode and Effect Analysis [11]. At the bottom of the hierarchy, lie the basic risk factors. Once the hierarchy is established the overall project risk breakdown will be clear for the risk assessment team, the next step will be the quantification of the basics risks, which will be used in the proper assessment.

Step 6: Risk factors measurement: If the probability of a high-impact event increases, there should be no debate as to what that means for the project. This step is not just about getting the probability or consequence of the risk factors on the project, but also identifies how it could affect each element of the structure. This is a very crucial step as it reviews and allocates numbers that could just be trusted on the experience of experts. This is why the use of fuzzy logic is imperative. Probability and consequence are fuzzified because of their uncertain or linguistic representation, as shown in figure 2. Furthermore, the risk management and risk level calculation statements are represented in the form of if premises then conclusion rule forms, and the risk factor calculation or output decision is made.
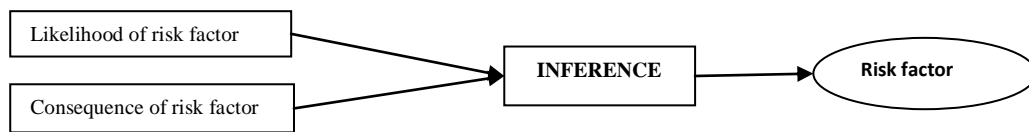

Figure 2: risk factor measurement

Step7: Fuzzy Inference Step: In the fuzzy inference phase, a conversion of the aggregated values of risks levels and into matching fuzzy sets will be performed by the help of Matlab/Simulink and previous literature[11][12][15][21]to[25]. This step will be done for all basic risk factors and then step by step following the breakdown structure until finding the final value of the project risk.

Determine the membership functions: This is usually done after getting advices from experts. In this model, as presented and figure 3 we will use simple triangular functions and not more than seven membership functions (from VERY LOW to VERY HIGH levels) will be used, otherwise there is no improvement about the final result. **a) Determine the Inference rules:** Using "if then rules" the rules for all membership functions should be sated in the Simulink platform. Each of the fuzzy logic system cannot have more than 12 rules to define the knowledge base. **b) Input the calculated value:** In this phase, an access to a risk data base will be the most important point, because the fuzzy interface model will need the probability and consequence values. The decision maker is mostly asked to input the values defined earlier in the fuzzy controller for the Fuzzification. **c) Fuzzification Interface:** The Fuzzification part measures the values of the input variables on their membership functions to determine the degree of truth for each rule premise. This phase will be automatically realized by the Matlab, and prepares the result for going through the inference rules. **d) Fuzzy inference:** The Algebraic Product was selected to combine the result of the above aggregation with the Potentiating factors. The rationale behind this selection is that there is an identical contribution of both terms to the risk level. **e) Defuzzification Interface:** There are several methods proposed for Defuzzification process. In this risk assessment framework, standard MATLAB functions 'defuzz' based on the cancroids method.

Table 1: triangular values chosen [12]

Linguistic variable	Triangular fuzzy numbers
Very low (VL)	(0.0.01)
Low (L)	(0.0.1.3)
Medium low (ML)	(0.10.3.0.5)
Medium HIGH(MH)	(0.5.0.7.09)
Medium high (ML)	(0.5.0.7.09)
High (H)	(0.7.0.9.1)
Very High(VH)	(0.9.1.1)

Step 8: Final risk level: In this step, the decision team will appreciate the final value of the project risk, and give some explanations about it. The final risk level is the last appreciations of risk that will be used appreciate the project's state or future, starting from sample risk factors through a strong fuzzy inference, that value will be used in the following decision making. This step will be one of the most important steps, because the assessment team will give convenient recommendations about the final risk level, whether to accept it or send it to the project risk control team for modifications. The final result of risk assessment provides the project management team with reliable data for risk respond decision making. The output variable is either accepted and finds some insurance measures about it, or rejected and has to go back to the steps of assessment through improvements from the risk monitoring and control.

1. Implementation of the method on a solar project using Matlab-Simulink

This section includes an example of applying the model on a real solar energy project in Morocco, financed by the African Development bank. Procedural steps of the risk assessment module have been highlighted below. For the calculation steps of the evaluation (steps 6 and 7), we have decided to realize it using MATLAB SIMULINK.

Project basic information

The project is an autonomous investment operation executed under an electricity production PPP that will be supported by the Bank, CTF and other donors (AFD, EIB, World Bank, KFW and EU/NIF). The total project cost net of taxes and customs duties is estimated at EUR 1,752.04 million. The project will be implemented on the Ouarzazate solar complex (3000 ha) whose land, is situated 10 km from Ouarzazate town along National Highway No. 10 which leads to Errachidia. The project beneficiaries will be the Moroccan population, Moroccan businesses and all productive sectors.

STEP 1: Establish a risk assessment group: Six experts with high qualification in solar energy projects and power plant projects were selected to form the risk assessment group. The risk evaluation team is formed by a civil engineer from the local government in charge of energy, an electrical engineer, a business development director, an agent from the mayor's office, a solar analyst and a project manager. The team may undertake the risk assessment by using the proposed approach.

STEP 2: Preparatory Step: In this step, the risk assessment team prepared all relative work which will help to compute the exact value of the risk and try to manage it in a much convenient way. The state commitment to ensure the financial balance of the Moroccan Solar Program, which includes the current project, is crucial to the financial viability of the entity. The main problem of the risk assessment is then to make sure the right value of the risk is computed and effective measures are undertaken to reduce these risks to a minimum value, such that the agreements will be satisfied. The duration of any task, the responsibility and completion is also dedicated by every expert to the team members. The use of experienced data on previous projects realized by the bank in Africa, previous research on the risk management field made for this research and previous reports on solar energy risks have been a great help in the understanding of the steps to follow in this evaluation.

STEP 3: Risk identification: It must be noted that all hazards were reported; including those eliminated any situation where a machine could cause injury or other significant loss under different circumstances. Using previous literature on risk identification in the field [2], [4], [11] to [17], we listed some hazards, and performed an empirical study to rate or propose a hazard that could come up. A checklist was sent to experts as explained previously working on 8 different projects cumulating 300 years of experience and returned for use. After this process, 31 risk factors or hazards were identified.

Variable	Identified risks	explanations	consequence
R1	Changes on startup	Legislative changes in the obtaining of the plant Startup	Schedule
R2	Bureaucracy	Rigid Bureaucracy and paper work in the country	Schedule
R3	Lack of conformity with Normalizations	IEC 62446 ,IEC 60364-1,IEC	Legal and safety
R4	Changes on electricity prices	whether there is any risk that the prices vary during the plant construction	Revenue
R5	Changes on VAT	Increase of VAT of more than 2% in	TAX

		the construction period	
R6	Natural Environmental Risks	Natural disasters	Security safety
R7	social disapproval	Assessment of the risk of social disapproval	conformity
R8	Procurement risks	Inadequate procurement planning	Schedule
R9	Impact of Technological Progress	on following technological changes during the project	Schedule
R10	Accident-related loss	Mishaps or failures during the construction and operation phases	Security safety
R11	Reliability Risk	What are the component	Revenue

		failure/reliability	
R12	Productivity rate of the panel manufacturer	What is the production availability	Revenue
R13	Unplanned maintenance	Going on maintenance work without any accurate plan	Schedule
R14	Performance risk	Efficiency on monitoring the power plant construction	Schedule
R15	Organizational Structure	Lack of conformity in the organization of the project team	Schedule
R16	Monitoring and Evaluation of Project	Misevaluation of the project variables	Revenue
R17	Accuracy of Market Forecast	Deviations between the calculated and the actual value of the market	Revenue
R18	Market Operational Capabilities	Up to which price the market is ready to buy the KWh	Revenue
R19	Expecting Project Profitability	Mistake in the project profitability calculation	Revenue
R20	Environmental constraints/prohibitions	What is known and what might not be known about the site?	Conformity
R21	Infrastructure constraints	water, geotechnical, and infrastructure conditions	Conformity
R22	Commitment honor risk	the possibility that private developers	Revenue

		may not be able to honor their commitments	
R23	solar radiation risk	extreme weather conditions	Revenue
R24	Insurance risk	Changes in insurance costs could make project uneconomic	Revenue
R25	Cost estimation risk	Misjudged cost estimation	Revenue
R26	Off-Taker Risk	On financing the gap between the kWh purchase price paid and the selling price	Revenue
R27	delays in legal agreements	Possible Delays in signatures and paper work	Schedule
R28	delays in constructions and operations of the power plant	Possible delays due to any mistake or failure on project	Schedule
R29	Late payment	Late payment of the loan by the client	Schedule
R30	Reference by subcontractors	Lack of reference to all the subcontractors about project financial situation	Revenue
R31	Relation with the third party	Weak relation between the client and the Bank	Schedule

Table 2: Identified sources of hazards for the selected project.

STEP 4: Risk classification: As a result of the study that we made previously on this part, the risk classification was then just to choose and classify the identified hazards into the different risk categories and subcategories proposed. The risk classification framework as shown in the following table helps in the formulation of ways of accessing risks to solar energy projects.

Risk subsection	factors variables	Frequency of risk factor
International policies	R3	1
National policies	R1,R2	2
microeconomics factors	R5	1
macroeconomics factors	R4	1
social risks	R6,R7	2
Project site risks	R20,R21	2
subcontractors risks	R22	1
maintenance /operation risks	R11,R12,R13	3
PM risks	R14,R15,R16	3
construction risks	R8,R9,R10	3
cost risks	R23,R24,R25,R26	4
market risks	R17,R18,R19	3
client risks	R29,R30,R31	3
time delay risks	R27,R28	2

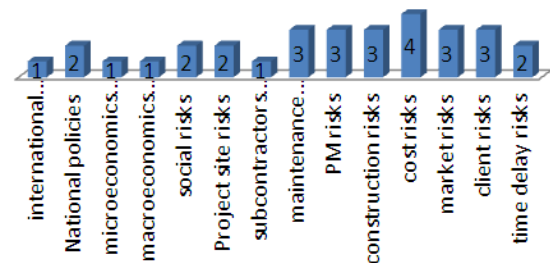Table 3: Risk classification

Figure 2: risk subsection histogram

STEP 5: Construction of a risk breakdown structure: using the list of classified risks, by conformity to the model developed, the following risk breakdown structure has been developed.
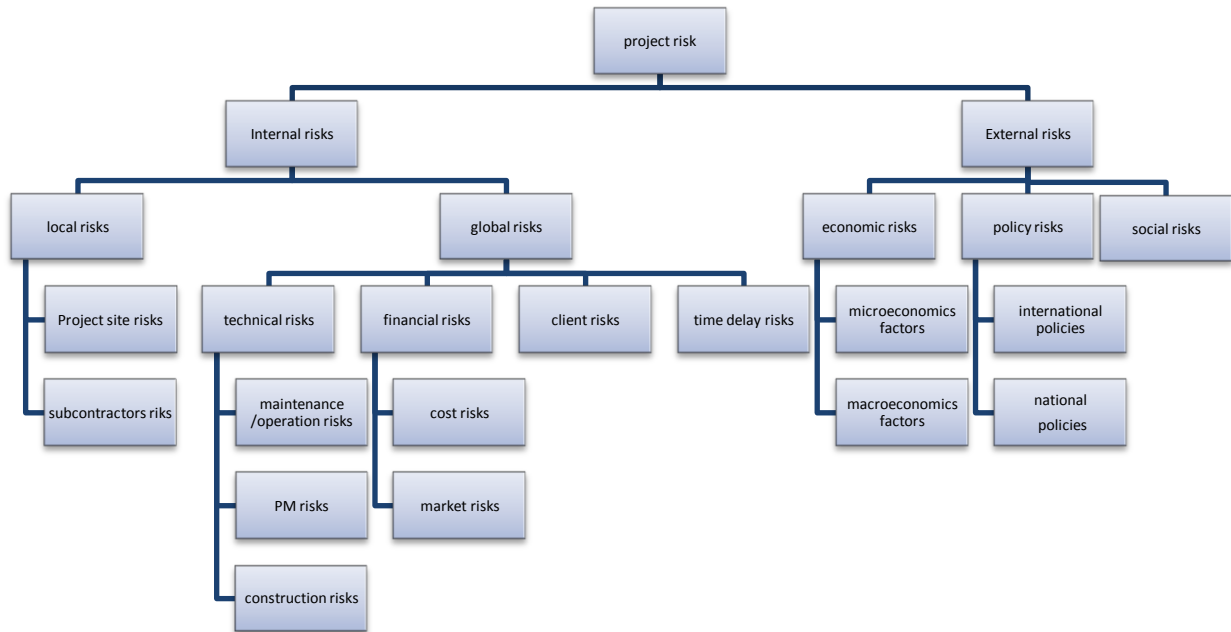
Figure 3: risk breakdown

Based on the working environment, and literature [2][4][5][19], the risk assessment group constructs a hierarchy as shown in figure above, which consists of all sections described earlier. Each section has number of major risk factors.

THE MATLAB TOOLS FOR THE STEPS 6, 7

STEP 6: Risk level measurement: In this step, according to the model developed, the Matlab simulink suite is used to measure the risks, factor by factor. For each risk factor, after a brief discussion and a vote among the project team members, numerical values are allocated to prepare the fuzzy study. After giving the probability and severity of each risk factor the average values were recorded and assembled in the risk register provided below; using Matlab and the table, the risk assessment team will find the risk factor level. In the table, the risks that identified are clearly classified level by level and category by category.

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5 (risk factors)	Probability (%)	Severity (%)	Risk Phase
FINAL RISK LEVEL	Internal risks	local risks	Project site risks	/////	R20	5	10	mature
					R21	30	7	mature
			subcontractors risks	/////	R22	85	50	close
		global risks	Technical risks	maintenance /operation risks	R11	3	30	mature
					R12	10	10	mature
					R13	50	15	mature
				PM risks	R14	90	15	mature
					R15	10	5	mature
					R16	8	10	mature
				construction risks	R8	55	15	mature
					R9	20	5	mature
					R10	1	3	mature
			financial risks	cost risks	R23	30	3	plan
					R24	50	2	plan
					R25	5	15	plan
					R26	80	30	plan
				market risks	R17	25	20	plan
					R18	20	15	close
					R19	2	25	close
			client risks	/////	R29	75	2	close
					R30	80	2	plan
					R31	20	7	plan
			time delay risks	/////	R27	20	2	mature
					R28	70	5	mature
		/////		microeconomics factors	R5	90	2	plan

	External risks		economic risks	macroeconomics factors	R4	10	15	plan
			policy risks	international policies	R3	5	10	plan
				national policies	R1	50	2	plan
					R2	80	5	plan
			social risks		R6	1	50	mature
					R7	3	2	mature

Table 4: Risk register

According to the model, every value of probability and severity will be input by the decision maker into a fuzzy logic model. For this step, as designed for the research, seven triangular membership functions are allocated both for the probability and the severity taking values(in percentage).The Fuzzification and inference process are respectively "MIN MAX" and mandani methods as provided by the Matlab library. The result for a single risk factor calculation is given in the figure below. For example, if it is given to us to calculate the risk factor level for the risk R20.Its probability is 5% and its severity is 10%.As we can see from the figure 5.16, the assessed risk factor level for R20: environment constraints and prohibition is 18.7%.As the assessment will continue, this value will be used for further evaluation.
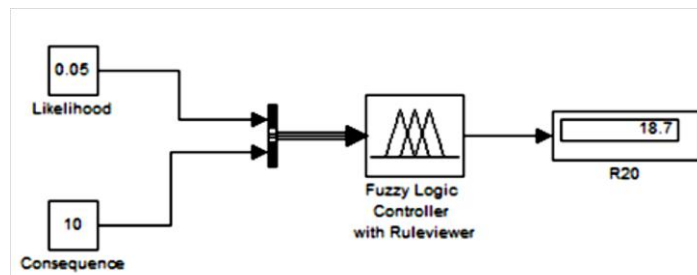

Figure 4: risk factor level calculation for R20

For the calculation of the risk factor, we used five membership functions to describe the value of the likelihood or the severity. The input parameters are represented on the unit universe [0,1] for probability and [0,100] for severity with triangular membership functions describing the linguistic variables .
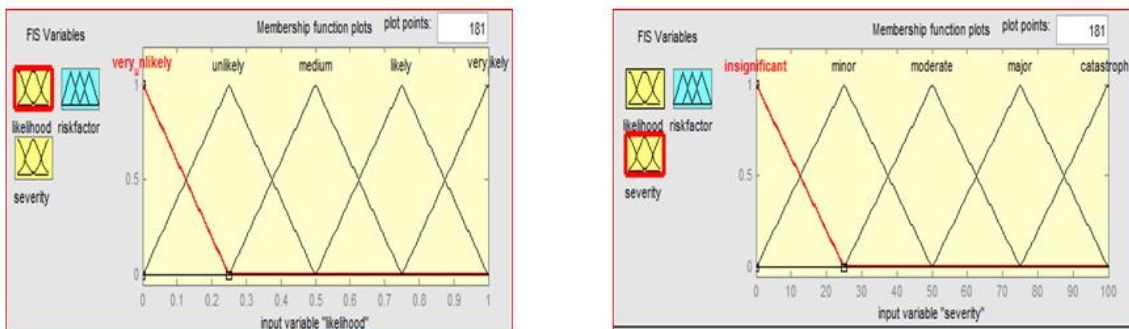

Figure 5: Membership functions for the variables "likelihood" and "severity"

For the output variable which is the risk factor, we designed seven membership functions to make sure that the result will cover all the possibilities that will come from the input variables.
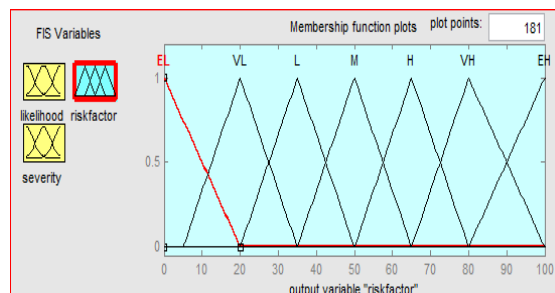

Figure 6: Membership functions for the output "risk factor"

After every risk factor level is computed for the 31 identified risks, it will be interesting in the decision to make, to know which of the risk subcategories is dominant among the ones identified previously. For the Ouarzazate project, we can clearly see from table 4 that the most sensitive risk subcategories are mostly cost and market risks, or management and technical risk. While taking a decision, the project manager should have a good care of these points. Low effect risk (the ones considered as not risky at all) had been ignored by the project team, to simplify the calculations, and reduce the complexity of the model, so no evaluation will be conducted for these risk in this thesis.

STEP 7: Fuzzy Inference Step: In this step, all the mathematical computations are done; the Matlab suite will operate all the calculations needed to make his task easier. What the project manager did in this step was just to follow the opinions given by the project team (experts).The experts that have been selected to operate the risk management have given the following advices.
1. Use the maximum number of membership functions to cover all the values of the risk factors that have been calculated.
2. Take a good attention on the financial risks that appeared to be the most sensitive part.
3. For the inference rules just draw a logic table and follow all the process of identifying rules.
    Membership functions: As mentioned in previously, according to previous research and expert advices, all the membership functions that will be used in the decision making are triangular. For the risk levels in intermediate level of the hierarchy, the input parameters are represented on the unit universe [0,100] with seven triangular membership functions describing the linguistic variables. The risk assessment team have agreed that seven levels of linguistic terms to describe the variables as extremely low (EL), very low (VL), Low (L), medium (M), high (H), very high (VH) and extremely high (EL).The definitions of the membership functions for a Fuzzy logic controller with two entries is given by the figure bellow.
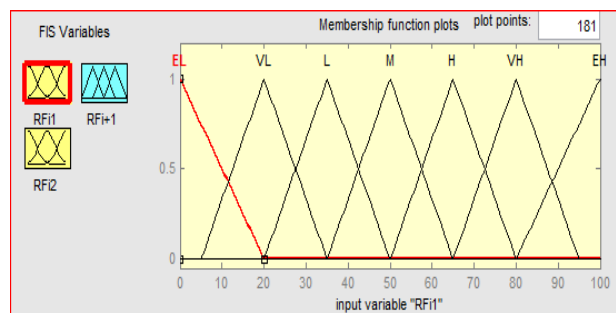

Figure 7: membership functions for a fuzzy bloc with two entries

For the output variable, the membership functions have the same distribution as the input variable but the last triangular function goes up to100, to give a wide range for the "very high" and reduce all the uncertainties.
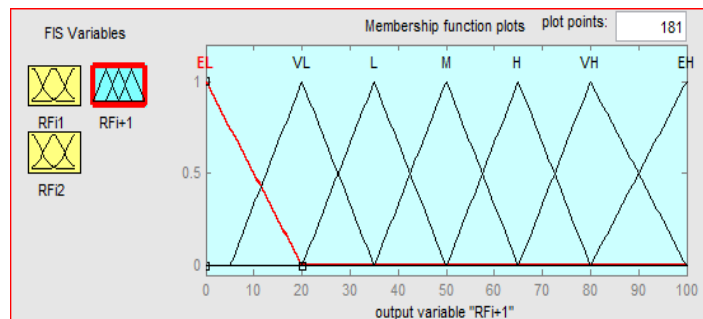

Figure 8: The seven membership functions for a given risk level output

Inference rules: The inference rules defined for each fuzzy component is exactly as advised by the experts. All possibilities of the logic truth table linking the inputs and output are listed in the rule editor. The logic truth table gives us a result of 25 rules (five membership functions for each input).We repeated the same process for the fuzzy components using three and for inputs.

1. If (RFi1 is EL) and (RFi2 is EL) then (RFi+1 is EL) (1)	11. If (RFi1 is L) and (RFi2 is EL) then (RFi+1 is L) (1)
2. If (RFi1 is EL) and (RFi2 is VL) then (RFi+1 is VL) (1)	12. If (RFi1 is L) and (RFi2 is VL) then (RFi+1 is M) (1)
3. If (RFi1 is EL) and (RFi2 is L) then (RFi+1 is L) (1)	13. If (RFi1 is L) and (RFi2 is L) then (RFi+1 is M) (1)
4. If (RFi1 is EL) and (RFi2 is M) then (RFi+1 is M) (1)	14. If (RFi1 is L) and (RFi2 is M) then (RFi+1 is H) (1)
5. If (RFi1 is EL) and (RFi2 is critical) then (RFi+1 is M) (1)	15. If (RFi1 is L) and (RFi2 is critical) then (RFi+1 is H) (1)
6. If (RFi1 is VL) and (RFi2 is EL) then (RFi+1 is VL) (1)	16. If (RFi1 is M) and (RFi2 is EL) then (RFi+1 is M) (1)
7. If (RFi1 is VL) and (RFi2 is VL) then (RFi+1 is L) (1)	17. If (RFi1 is M) and (RFi2 is VL) then (RFi+1 is M) (1)
8. If (RFi1 is VL) and (RFi2 is L) then (RFi+1 is M) (1)	18. If (RFi1 is M) and (RFi2 is L) then (RFi+1 is H) (1)
9. If (RFi1 is VL) and (RFi2 is M) then (RFi+1 is M) (1)	19. If (RFi1 is M) and (RFi2 is M) then (RFi+1 is M) (1)
10. If (RFi1 is VL) and (RFi2 is critical) then (RFi+1 is H) (1)	20. If (RFi1 is M) and (RFi2 is critical) then (RFi+1 is VH) (1)
	21. If (RFi1 is EH) and (RFi2 is EL) then (RFi+1 is M) (1)
	22. If (RFi1 is EH) and (RFi2 is VL) then (RFi+1 is H) (1)
	23. If (RFi1 is EH) and (RFi2 is L) then (RFi+1 is H) (1)
	24. If (RFi1 is EH) and (RFi2 is M) then (RFi+1 is VH) (1)
	25. If (RFi1 is EH) and (RFi2 is critical) then (RFi+1 is EH) (1)

Table 5: Fuzzy rules for a risk bloc of two inputs

Input the calculated value: The input of every calculated value of risk from a given level I to a higher level i+1 is done automatically by the SIMULINK suite. A simple link is mentioned to show the linkage between all the parts of the simulation.
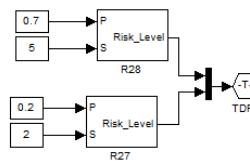

Figure 9: Input of the time delay risks into the next step

In this example shown in figure 9, the TDR is a label allowed by the Matlab suite that will take directly the value calculated from the previous levels of the hierarchy, and transfer it to the next level. The figure below shows how the TDR is reused for computing the global risks and internal risks respectively.
Fuzzification Interface This step is also done in background by the Matlab suite, for every entry in a given fuzzy component, the input is always a crisp numerical value limited to the universe of discourse of the input variable and the output is a fuzzy degree of membership in the qualifying linguistic set Fuzzification of the input amounts to either a table lookup or a function evaluation.
Fuzzy inference: the fuzzy inference method used by the Matlab suite is mandani method this "min max aggregation". So for all the fuzzy components calculating risks, this method is definitely used.
Defuzzification Interface: As we explained earlier, Matlab toolbox uses the centroid method explained by the equation for Defuzzification and find out the actual value of the risks for every fuzzy component.
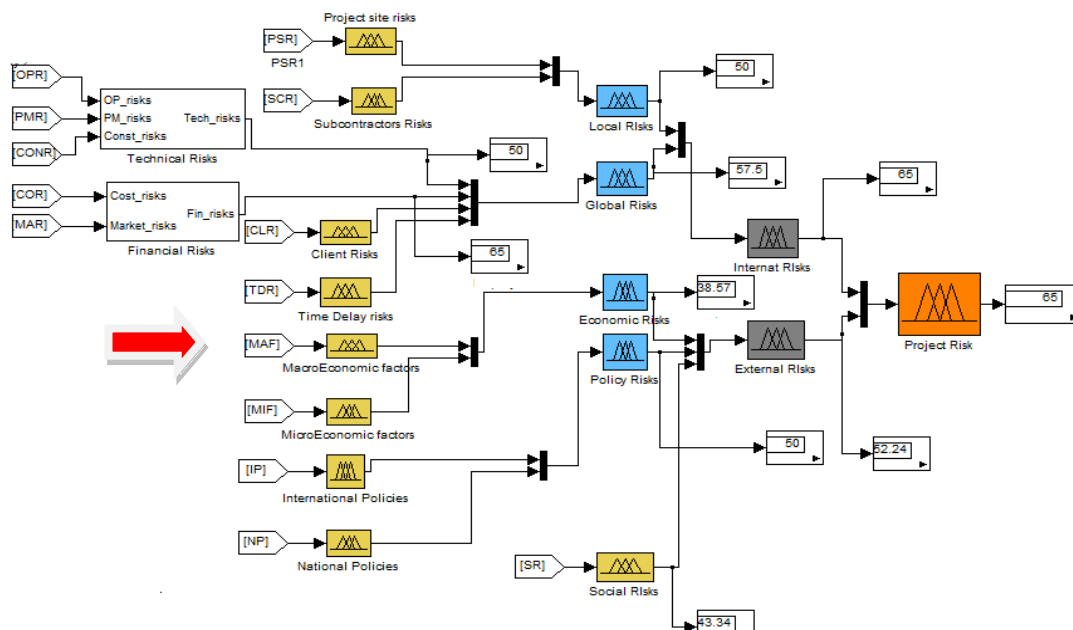

Figure 10: Final risk level

STEP 8: Final risk level and Interpretation: this step is about the calculation of the final risk level for all the project, and explanations needed for the project manager to take a decision.

Final risk level .While reviewing the assessment process, the final result is found by assessing step by step every level of risk so that the final value will be given to the decision maker. This result provides the risk management project team with valuable information for risk control or response decision making. The figure bellow shows the calculation of the final value of the risk, using SIMULINK. We evaluate the effectiveness of this final risk level calculation using a fuzzy analysis method in back; we can clearly see the result we got in percentage for the Ouarzazate solar project is 65(High level risk for the total risk as decided by the project team). The system output variable gives the complex assessment of the final project risk from identified hazards relevant to the Ouarzazate solar plant. For the final decision making the complex assessment is taken as criteria to evaluate the level of the project Risk using the parameters proposed in the design of the model. These data demonstrate that project management team must be paid special attention to the composition of the financial risks and with all the activities and hazards going through. The technical risks have also to be considered because at this level, although the 50% risk level is Medium but it might generate more added values on the upper levels.

Decision on the project risk value at time T: As described in the previously, the acceptance evaluation of the project risk and the advices to take while undertaking the project. The value of the final risk of the Ouarzazate project will then be taken and put into a new fuzzy assessment to define whether to accept or not this risk.
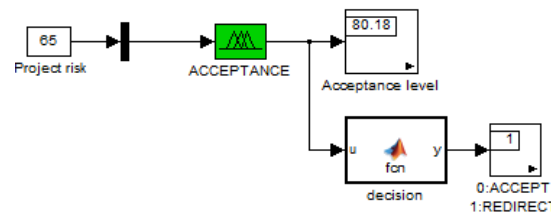

Figure 11: Acceptance scheme

We can clearly see that the final value of the project risk is at the limit of acceptance, but the project team should redirect this value to the project control team, and they can follow and review the given risk categories.

III. DISCUSSION AND VALIDATION

As we have seen clearly, the two most critical parts in the Ouarzazate project are the technical incentives and financial directions, before the startup of the company which leads to a final project risk rate at 65%; the project team should review all the factors that are included in this two risk categories. In particular, suitable planning, supervision and quality assurance activities are critical at all stages of the PV plant in order to minimize the risk of damages and outages, optimize the use of warranties, avoid dilution of resources and ultimately optimize the overall performance of the PV plant should be performed. After computing the final risk level, the project manager has the opportunity to create an interactive report in a chart, all the main risks on his evaluation form, which will lead him directly to the right decision upon the risk control. After categorizing and computing risks levels, the project team decides the controls that could mitigate the risk. The decision for what regulations are needed lies with the project manager. The team's conclusions as to what risks exist and what controls needed are provided along with a related action craft for control implementation.

We used a small sensitivity compilation at each level to compare our results with the old probability model. As our model is assuming the project is somehow risky, the mean values model is a on some points in accordance with the problems that could be found on field, this might be a problem on the execution part, where the project team might need some qualified field agents to reduce all these uncertainties. On the other side, as our design might be a little bit severe than the probabilistic model or maybe a little bit expensive, as the project will go on, the project team can set up a recovering plan, and with less experience needed all the time on field.
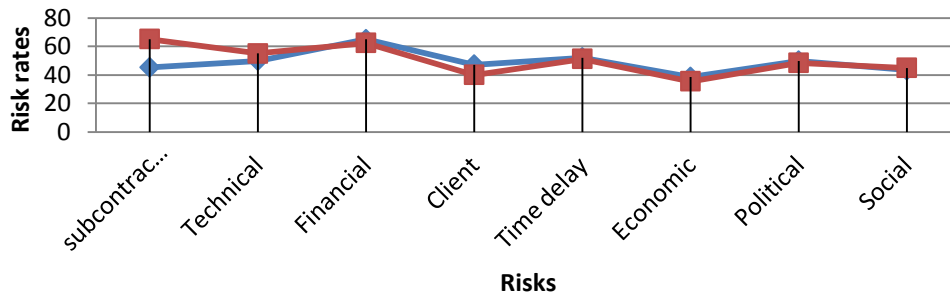
Figure 12: models comparison analysis

The red line represents the project team's probabilistic model results, whereas the blue line represents our serat model results for the project risks for every category. We can see from the analysis that instead of the subcontractors and technical risks, all the way long the serat design is over the mean values model. This is to say that in these cases, our model might be more secure, and less 'risky 'for the project team.

Validation

The validity of the model is presented in table below using one-sample t-test with the help of experts and field project managers and companies mostly from Africa. We designed some few questions about the application of this model if it could be assembled with computer software, and received answers about its application. Due to the level of uncertainty and the focused region for the validation, the significant levels of the test are 5 %. With the help of experts' knowledge and through a standard questionnaire we will show the validity of the model by testing the model's variables. Respondent were asked to choose the appropriate number to indicate the level of your agreement or disagreement with the following statements about our methodology and user interface.

(Strongly agree=5, Agree=4, neither agree or disagree=3, Disagree=2, strongly Disagree=1)

Questions	1	2	3	4	5	Mean frequency
The model can support project managers in assessing solar energy risks	0	0	2	2	5	0.77
The risk breakdown structure is clear for risk Identification	0	0	3	2	4	0.66
The use of fuzzy logic and linguistic variables in an improvement for risk assessment	0	0	1	2	6	0.88
We've already applied such a method in our projects	0	7	0	2	0	0.22
I find the User interface easy to use	0	1	3	1	4	0.55
I find User interface is flexible to interact with	0	1	3	0	5	0.55
It seems learning to operate the system would be easy for managers	0	2	3	0	4	0.44
My interaction with the model would be clear and understandable	0	0	3	0	6	0.66
We will be willing to apply this method in our organization, I think that the method is innovative	0	0	2	1	6	0.77

Table 6: model validity results

The mean here represents the average frequency level of agreements, as we defined earlier, the companies that responded YES to any of these questions. The observed mean frequency is 0.67, with a standard deviation of 0.24.We need to prove that In this case: **Null hypothesis:** The expected frequency mean of agreement with our designed assessment tool is less than five. **Alternative hypothesis:** the expected frequency mean of agreement with our designed assessment tool is more than five (claim).The t-score is made a relative score by dividing the difference between the sample mean and m by the standard error of the mean. The critical t-value (for n=9 and 95% level of significance) can be found directly from the t distribution table (t0=2.306). To compute the expected t value, we can use the basic formula of finding the t-value.

$$t = \frac{\bar{x}-\mu}{s\sqrt{n}} \quad \mu \text{ Is the expected mean}$$

With n=9,$\mu = 0.5$, $\bar{x} = 0.67$, s=0.24, we get t=0.236

Since the calculated value is less than the critical t-value, we have enough evidence to support the alternative hypothesis which claim that our expected mean is more than 0.5, which means that our mean is actually acceptable and we can say with 95% level of confidence that the designed model can be used in a real project. As we can clearly show that our designed model is acceptable, the respondents also gave us some advices that we need to take in consideration to improve our future work.

IV. CONCLUSIONS AND FORWARDS

In response to the problems that led us to our present work, the research described in this paper introduces and uses a proactive method for solar risk evaluation. This modest research work proposes a different way of taking project risk assessment to face risks associated with the PV projects in the various situations in which the information to analyze risks is uncertain, incomplete or non-obtainable. The model allows members in the risk assessment team to give their advices by means of linguistic terms instead of mathematical computations. Since linguistic terms are not operable, to deal with complexity. In order to make easier the application of this model to problems with a large number of risks, a hierarchical analytic process method has been used to assess the weight of risks using the fuzzy functions that have been developed. The risk pair-wise comparative judgements are generally not consistent. To make all the calculation part easier for us, MATLAB and Simulink have been used to express all the logical fuzzy values and express in a more cognitive way.

The method provides a clear and effective algorithm for modelling risk assessment problems involving surrealistic evaluations of the members in the risk assessment group. The developed methodology is applicable to the general fuzzy risk assessment problem where a ranking of risks is required. The difficulties faced while realizing this research, and the advices of experts from our model we can be used as the basis for next exciting research in this topic area of fuzzy logic risk assessment and risk management that may include:

- *Continuing the research with more fuzzy functions and inputs thus link the overall system with a neural network, and teach the system how to deal with any project.*
- *Improving the model into a programmable desktop tool and refer it to a better data base and make it as a complete online application.*
- *The validation of the model with more calibration and improvement can be done by validating the model using additional industrial and public data sets.*
- *Linking the model system with the other areas of project management.*

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