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Risk in solar parks: a parametric approach of comparing AHP and TOPSIS methods

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Abstract

Renewable energy sector projects like development and implementation of solar power plants are crucial in the present era to suffice the target for generation of green and clean energy. Just like any complex infrastructure projects, the solar power projects face risks and uncertainties throughout its many phases. The risk assessment for projects remains a multi-variable problem as a lot depends on human expertise. The present work identifies the risks involved in its various phases and employs two methodologies of risk analysis while comparing between the two. It has been observed that the TOPSIS approach produces more coherent interpretation than the AHP approach. This is the first study where TOPSIS approach is employed for the case of risk assessment of solar park and then subsequently compared with the AHP analysis of the same. It has been inferred that for niche and isolated projects AHP is more suitable however for more general and multiple source data TOPSIS is the superior approach. The risk assessment is broken down into 5 phases and it has been observed that based on the risk indexing of those phases, the project authorities cannot afford to ignore any of the phases.

Keywords: Solar Parks; Feasibility Study; Risk Management; TOPSIS; AHP

1.0 Introduction

Complex multidisciplinary infrastructure projects suffer huge risks starting from the inception of the idea to its feasibility, design, development, implementation and operation [1]. If these risks are not properly addressed by the project authorities and mitigated priory by adequate mitigation measures, then the project runs the likelihood of collapses due to time and cost over- run. Risk analysis thereby becomes a crucial activity to be carried out by the project authorities during the feasibility phase of the project. Risk analysis determines the severity of the risk in a quantitative manner by formulating risk maps. Based on the scale of risk maps which indicate low, medium, high, very high and critical risk zones, the corresponding mitigation measures can be adopted. [1] Carried out risk analysis of a complex infrastructure project like construction of elevated corridor for metro rail operations through Expected Value Method (EVM) which was later implemented by [2], [3, 4] carried out risk analysis and developed risk index through Fuzzy Analytical Hierarchy Process (FAHP) for an elevated corridor metro rail project in India. Risk identification, risk analysis and development of risk mitigation measures are the three basic steps for carrying out the risk management process [2]. Risk analysis can be carried out through various Multi Criteria Decision Making (MCDM) methods. [5] Introduced the fuzzy set theory within MCDM which was used by many researchers working in decision making.

In the risk analysis concept, identifying and assessing risk variables is an important step that should be conducted by a project manager to get an early warning about the possible risk variable using statistics that can occur in the project. Many techniques exist in order to quantify and assess such risk variables into formulating decision making parameters. Other approach is applying fuzzy logic as an algorithm to capture the disguises of perceptible perceptions combined with the Technique for Order Preference by Similarities to Ideal Solution (TOPSIS) method. Furthermore the evaluation of the risk priority number is based on fuzzy TOPSIS to the ideal solution to solve multi criteria problems.

In the recent years, intensive research and development has been carried out in the area of Project Risk Management (PRM) [1, 3, 4]. It is widely recognized as one of the most critical procedures & capability areas in the field of project management. The construction industry, perhaps more than the rest, has been plagued by risk, resulting in poor performance with enhanced costs and time delays. Every part of project life cycle is subject to risks, which have to be treated adequately to stay in control of the project and to achieve its goals in an optimal way[6] formulated the probabilistic infrastructure risk analysis model, presenting a holistic approach for modeling the water distributions infrastructure systems dynamics. Further work of [7] presents the application part of such risk analysis model by characterizing the water system along the parameters of function, structure, component, state, and vulnerability, while keeping in view of other political, temporal and economic perspectives. Expected and extreme risks are evaluated using probability, while efficient alternatives are generated and presented in a multi-objective framework. The methodological framework can be easily applied to other critical infrastructure elements and networks. (Author?) [8] Defines vulnerability as a measure of any system susceptibility to threat scenarios while demonstrating that vulnerability is a condition of the system which can be quantified using the Infrastructure Vulnerability Assessment Model (I-VAM). Such a model requires establishing value functions and weights to various protection parameters of the system. Additionally the un- certainty in measurements is taken into account by suitable simulations along with expert's feedback depending on the particular field, eventually providing a vulnerability density function (Ω).

[9] carried out risk assessment primarily for construction industry and concluded that in construction industry things do not always turn as planned and thereby detailed risk management is must. [10] Suggested in developing methodologies which can put risk management into practice. Furthermore, [11] claimed that all the undertaken risk management practices focuses on project uncertainty. However, project risks are all about project cost and unscheduled uncertainties [2]. Thereby, the risk management unarguably should be focused on project uncertainty and complexity management.

Recent trends in the construction industry indicate continued use of alter- native procurement methods such as design-build, construction management, build-operate-transfer, and privatization [12]. Increased use of these evolving methods produces higher levels of uncertainty with respect to long term performance and portability. The uncertainties inherent in implementing new procurement methods necessitate investigation of enhanced methods of pre- project planning and analysis. This aspect is particularly true for revenue de- pendent projects such as toll tax on roads/highways. Enhanced risk analysis tools provide improved information for pre-project decision making and performance outcome. One such risk analysis method is the Monte Carlo [12] for revenue dependent infrastructure projects. Mathematical analysis is limited for some studies available in the literature due to constraints in data about the overall reliability of a system. This issues leads to shifting the domain to input set of parameters from expert knowledge in the field. Thus, a lot of crucial parameters that are identified before they are put to any mathematical modeling or simulation are provided by the field experts or by statistically obtained opinion about the inherent parameters. This problem usually continues due to the lack of hard quantifiable data in most of the cases as shown by [13] leading to the use of probabilistic risk analysis.

The emergence of information technology has transformed the situation from one characterized by little data to one characterized by data over-abundance [13]. Critical infrastructure systems such as electric power distribution systems, transportation systems, water supply systems, and natural gas supply systems are important examples of problems characterized by data over-abundance. There are often substantial amounts of information collected and archived about the behavior of these systems over time. Yet it can be very difficult to effectively utilize these large data sets for risk assessment due to the long list of variables and trickier limitation to assigning weight age values to these parameters. One of the unforeseen and unpredictable parameters in the risk assessment of any infrastructure system comes from natural disasters, the impact and the scale of which is very unpredictable depending upon the kind of infrastructure in consideration. Other industrial risk and contingencies can be well designed and streamlined through a well-structured organization and management system. Sometimes, the terrorist activities due to their unforeseen nature are clubbed along the natural disasters and are sometimes considered as a separate parameter in the risk management studies [14, 15]. Compared to other infrastructure industries, construction industry is subjected to greater risk due to its unique features in various project phases like planning, investigation, collection of data, feasibility, design and development, implementation and execution as well as operation & maintenance. Many complex mega infrastructure projects like setting up of solar park, power projects, refineries, construction of elevated and underground corridors for metro rail, etc. have experienced large variations in cost & scheduling leading to enormous load on manpower, longer delays in the execution & commissioning of these projects.

In most of the cases, the economic viability itself ends up being questioned due to delay in project completion on account of various risks encountered during implementation stage. It is a well-established fact that due to increase in project size & complexity, higher levels of risk & uncertainty are inevitable. Hence, a systematic process of risk analysis is imperative to classify, identify and analyze these risks, for the corresponding formulation of risk response strategies [16].

Substantial work has be carried out in risk assessment and management of the same [17, 18]. [19] studied the relationship between management support for risk management processes and the reported project success extensively complimenting with the identification of shortcomings and possible improvement opportunities.

[1] argues that one needs to identify the various stages of projects such that, the entire work of project implementation from concept to commissioning can be divided appropriately in different phases such that, broad activities can be grouped under each phase and sub activities may be defined which in turn portray the risk associated for those broad and sub activities. Same has been employed in the present work where an attempt is made to explore the relationship between broad and sub activity risks under each phases of project related solar power plant. Development of questionnaires for risk rating using Saaty Scale, probability of risk occurrence & impact of risk for assessment of risk severity, risk index & risk ranking are carried out. For this, three projects located in three different parts of India have been considered. To achieve the above mentioned objectives, two research frameworks have been employed using Modified Analytic Hierarchy Process (MAHP) and TOPSIS.

As solar parks are still either rare or under development & installation, can be considered to be in the cocoon phase, not much literature is available on the risk assessment or risk management or such solar parks yet. As discussed earlier that for other infrastructure projects, risk management is studied both in detailed in theory and in application. However, these learning are not specifically applied to the risk management of solar parks except a few isolated studies here and there which are discussed later. One such relevant work is by [20] who studied the Analytic Network Process (ANP) and applied the same to the selection of photovoltaic (PV) solar power projects. These projects follow a long management and execution process from plant site selection to plant start- up. As a consequence, there are many risks of time delays and even of project stoppage. These risk and vulnerabilities are only hurdles in terms of economic aspect or efficiency consideration. This study identified 50 project execution delay and/or stoppage risks in order to invest based on risk minimization. The main conclusion of this study is that unlike the other models used in the literature, the single network model can manage all the information of the real- world problem and thus it is the decision analysis model. The strengths and weaknesses of ANP as a multi-criteria decision analysis tool are also described in their work. In the further works of [21], the criteria for accepting or rejecting any proposals for such an investment based on risk priorities. [22] extended the research in all forms of renewable energy, wind, water and solar power in their work. Cost effectiveness studies of solar power can be found in literature [23, 24, 25]. A preliminary case study of solar parks has earlier been carried out in our earlier works showing the role of vigilance in design and construction [26]. Adding to the previous work and understanding, an attempt is put forward in applying the known approaches of risk management on solar power parks and commenting on the better approach to deal with multi criteria decision making and substantial crucial parameters. The primary objective of this work is to compare the two approach and determine their merits and demerits over one other by identifying and evaluating the risks and uncertainties associated with a complex project like solar power plant installation in India.

2.0 Methodology

The methodology is primary data research, where the data pertaining to risks associated with the different activities of the solar power plant has been collected from solar power plants at three locations in India namely Rajasthan, Gujarat and Karnataka respectively. The identified risks pertained to the activities with respect to health, safety, environment, quality, site selection, investigation, planning, approvals, design, resources and maintenance of solar parks. The identified risks were categorized and grouped into 5 phases as following

1. Feasibility Study
2. Survey, investigation, master plan & concept report
3. Detailed Design & Specifications - Civil, Structural, Electrical, Scada & Transmission Line
4. Vendor Selection, Procurement, Construction & Commissioning
5. Operation & Maintenance

Further details of each phase with broad categories are depicted in Table-1, 2,3,4,5.

2.1 Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally extensively By [27] as a method to deliver a tioscales from paired comparisons. The input can be obtained from actual measurement such as price, weight etc.

or from subjective opinion such as satisfaction feelings and preference in a quantitative magnitude scale. The limitations of this approach are a little in consistency as inputs from human judgment is relatively constrained. The ratio scales are derived from the principal Eigen vectors and the consistency indexes derived from the principal Eigen value.

Table 1: Broad Risks Identified under Phase-1

No	Activities with Risks
a	Letter of Intent (LOI)
b	Acceptance and Kick of Meeting & Finalization of the Scope and Deliverables.
c	Risks in Site location
d	Reconnaissance Survey of Site
e	Collection of Data
f	Inception Report Preparation (IR) & Submission
g	Review and Approval IR
h	Preparation & Submission of Draft Feasibility Report (DFR)
i	Presentation and Discussion
j	Approval of DFR
k	Submission of Final DFR

Table 2: Broad Risks Identified under Phase-2

No	Activities with Risks
a	Resource Mobilization & Establishing camp & site office.
b	Delay of Site Land Handover
c	Topographical Survey
d	Land Acquisition Risks
e	Environmental Risks
f	Resettlement and Rehabilitation Risks
g	Geo-tech Investigations
h	Data Analysis
i	Master Plan & Concept Report
j	Approval of Master Plan & Concept Report

Table 3: Broad Risks Identified under Phase-3

No	Activities with Risks
a	Revision in Master Plan
b	Risk in DPR Preparation
c	Design of Civil Works
d	Design of Structural Works
e	Design of Electrical, SCADA& Transmission Line Works
f	Preparation & Submission of Draft Detailed Project Report (DDPR) including Tender Documents
g	Approval of DDPR& Tender documents
h	Submission of Final DPR & Tender documents

Table 4: Broad Risks Identified under Phase-4

No	Activities with Risks
a	Invitation of Tender & Award of Work
b	Letter of Intent (LOI) to Contractor
c	Acceptance and Kick of Meeting & Finalization of the Scope
d	Financial Closure Risks
e	Permit and Approval Risks
f	Civil Works Construction & Quality
g	Mechanical & Electrical Works & Quality
h	Safety

Table 5: Broad Risks Identified under Phase-5

No	Activities with Risks
a	Operation
b	Maintenance

The data analysis of the quantitative output of the qualitative attribute survey for each attribute of quality, risk assessment can be obtained using MAHP data analysis tool which is a multi-criteria decision making tool used to obtain ranks and outputs. Initially, a questionnaire is formulated to obtain the responses per tainting to "Probability of occurrence of risk" and "Impact" which is filled up by industry experts of a sample space of 200.These values range from 0to1 where 0 indicates nil probability of occurrence of a risk and impact while 1 indicates very high probability of occurrence of a risk and impact. For computational simplicity, the risk rating values obtained from questionnaire survey have been converted into "Saaty Scale" (1to5) where1 denotes least importance and 5 represent highest importance. Additionally, a level of risk non-singular matrix is created for each item of the chosen subgroup (elements of row1 are divided by weights of respective column to that of row and soon). Probability weight based non-singular matrix is created for each item of the chosen subgroup. This process is repeated for all the three solar park sunder study in this case with the Saaty scales for each of the phases in terms of broad activities and sub-activities separately. Another constraint to this process is that it cannot differentiate between the better solar parks or can make any quantitative assertion among the case studies. The level of risk weights and probability weights are normalized. Normalized value= $\left\{II_{i=1}^{j=1,\ldots\ldots,n} a_a\right\}\frac{1}{n}$, where n is the number of it emsunder the chosen subgroup.

The severity of the identification risks can be computed by the equation of EVM methodology: Risk Severity=Risk likelihood or probability of occurrence X Impact which lies from 0-1 demarcated by categories of flow (0-0.1), medium (0.11-0.2), high (0.21-0.3), very high (0.31-0.5), critical (0.51-0.7) and very critical (0.71-1).

In order to estimate the risk index and risk ranking, normalized weights have been estimated based on the total weights calculated for each phase. These normalized weights have been multiplied with risk severity to estimate the risk index which side noted as Risk Index=Risk Severity X Normalized Weights (Wn).

2.2 TOPSIS

The identified risks we reanalyzed with a Multi Criteria Decision Making (MCDM) technique termed as Fuzzy TOPSIS. TOP SIS is a multi-criteria decision analysis method, which was originally developed by [28] with further developments by [29]. TOPS Isis based on the concept that the chosen alternative should have the shortest geo metric distance from the Positive Ideal Solution (PIS) and the longest geo metric distance from the Negative Ideal Solution (NIS). It is a method of compensatory aggregation that compares a set of alternatives by identify in weights for each criterion. As the parameters or criteria are often of in congruous dimensions in multi-criteria problems it may create problems in evaluation. So, to avoid this problem a need o fuzzy system is necessary. Using fuzzy numbers in TOPSIS for criteria analysis the evaluation becomes simpler. Hence, Fuzzy TOPSIS is simple, realistic form of modeling and compensatory method which includes or excludes alternative solutions based on hard cut-off. It is important to note that for all the development phases of each solar parks the Saaty data used in the AHP is the input to the TOPSIS method where it is converted to the corresponding fuzzy numbers (whereSaatynumber1correspondstofuzzy (1,1,3), 2 corresponds to (1,3,5), 3 corresponds to (3,5,7), 4c corresponds to (5,7,9) and 5 corresponds to (7,7,9) respectively). In this approach the saaty numbers are converted into fuzzy number sets for the same parameters for different solar park. Then the mixed data set $\bar{x}_{ij}$ is created to combine the inputs from all sources of Rajasthan, Gujarat and Karnataka, where

$$\bar{x}_{ij}=\left(\min(a_{ij}^{k}),\frac{1}{k}\sum_{k=1}^{3} b_{ij}^{k}, max(c_{ij}^{k})\right).$$

The matrix $\bar{x}_{ij}$ is further converted to $r_{ij}=\left(\frac{a_j^-}{c_{ij}},\frac{a_j^-}{b_{ij}},\frac{a_j^-}{a_{ij}}\right)$

where $a_j^- = \min(a_{ij})$ as risk is only a cost criteria and not a beneficial one thus analysis is preferred using the lower values. Moreover the weight age values (w_j) are obtained from the experts just like the saaty value and further converted into fuzzy numbers. Then, the matrix $V_{ij} = r_{ij} * w_j$ is obtained. Henceforth,

$A^{+} = \max(V_{ij3})$ and $A^{-} = \min(V_{ij1})$ are evaluated obtained. These new variables help in obtaining the distance parameters which are denoted as

$$d^{+}= \sqrt{\frac{1}{3}\sum(V_{ij}-A^{*})^{2}} \text{ and } d^{-}= \sqrt{\frac{1}{3}\sum(V_{ij}-A^{-})^{2}}.$$

Finally, the closeness coefficient is calculated using

$CC_i = \frac{d^-}{d^* + d^-}$. The higher the CCi value higher the ranking.

3.0 Results & Discussions

3.1 AHP results

The outcome of the analysis towards assessment of risk index for each project as obtained from the analysis as explained in the methodology section are finally tabulated in Table- 11, 12, 13, 14. The gist of conclusions can be summarized as

a) Project in Rajasthan:

Highest risk is observed in Phase-2 i.e. SURVEY, INVESTIGATION, MASTER PLAN & CONCEPT REPORT Stage of the project on both Broad Activities as well as Sub Activities.

b) Project in Gujarat:

Highest risk is observed inPhase-4 i.e. VENDOR SELECTION, PROCUREMENT, CONSTRUCTION AND COMMISSIONING Stage of the projection both Broad Activities as well as Sub Activities.

c) Project in Karnataka:

Highest risk is observed in Phase-2i.e. SURVEY, INVESTIGATION, MASTERPLAN & CONCEPT REPORT Stage of the project based on Sub Activities and Phase 1 i.e. FEASIBILITY STUDY based on Broad Activities.

3.2 TOPSIS results

The analysis and interpretation of data obtained using the TOPSIS method is tabulated inTable-15 where the higher value of C Cede notes higher risk factors and its thereby rankings in terms of risk, higher number denoting higher risk.

It can be seen that if the analysis is performed based on broader activities then phase-3 is the highest in terms of risk. Similarly, inference can also be drawn from looking at the analysis is done with sub-activities where the data shows that phase-5 has the maximum risk. This is in accordance that phase-5 deals with sub-activities with bigger natural hazards and uncertainties. How- ever, if the lowest risk is observed that conclusion remains the same whether broad activities or sub-activities are looked into Based on broad activities phase-1 is at the lowest most risk as it involves post project maintenance which grebes with the general understanding. With respect to sub-activities as well, Phase-1 shows the least most risk. In general, phase-3 shows relatively higher amount of risk from both the broad activities and sub-activities analysis. This contradicts with the AHP results were in two of the solar parks phase-2 was found to have greatest risk rankings. However in TOPSIS analysis, phase-2 stays third in terms of both broad and sub-activities showing medium level of risk involved. The advantage of this analysis is that it takes into account all the solar park locations at once and provides a more generic and reliable understanding of the risk on the whole. Where as in AHP the solar parks can only be studied separately. In other words there is no way to inculcate the data from Rajasthan Gujarat and Karnataka all in one go for the AHP analysis. The TOPSIS approach combines the fuzzy numbers from all solar parks in the first step in formulating the X ij and thereby generalizes the parametric fuzzy numbers o of all the identified variables of all solar parks into a single chart. A sample calculation of Phase-5 is shown in Table-16.

Table 6: Sub Activity Risks Identified underPhase-1

No	ActivitieswithRisks
1	Delay in Issue of LOI
2	Wrong Details of Contract
3	Delay in responding to Wrong details by Client
4	Delay in Acceptance of LOI
5	Delay in conducting Kick of Meeting
6	Gaps in scope of work
7	Improper objectives Scope & Deliverables finalisation
8	Proximity to International border
9	Proximity to wild life sanctuary

No	**ActivitieswithRisks**
10	Presence of forest land
11	Proximity to eco sensitive zone
12	Proximity to Historical monuments,Place of worship etc.
13	Presence of sensitive lands within the project boundary
14	Highly undulating androcky terrain.
15	Presence of Built-up Close to Project
16	Access to Site
17	Ground Water Table
18	Impact on Environment
19	Social Impact
20	Availability of Land
21	Permission from Government
22	Presence of low laying area.
23	Identification of Different Site for Reconnaissance
24	Wrongly Identification of Site Boundary & Orientation
25	Missing of Key Data during Reconnaissance survey
26	Improper Data Collection
27	Inadequate Data Collection
28	Misinterpretation the Scope of Work
29	Defining of Unrealistic Approach & Methodology
30	Insufficient Time Allocation for Investigation & Design
31	Delay in Submission of IR
32	Review by non-technical professional
33	Delay in review & forwarding the observations
34	Delay in approval of IR
35	Improper Approach & Methodology for Feasibility Report
36	Insufficient Survey & Investigation
37	Mistakes in Conducting Survey & investigations
38	Hydraulic andhydrological Investigations
39	Recommendation of Foundation Type
40	Poor Interpretation of Data
41	Wrong Planning of Master Plan
42	Presence of Utilities
43	Raw Material Sources
44	Preliminary Design
45	Drawings & Documentation
46	Mistake in Quantity Calculations
47	Adopting Wrong Schedule of Rates for Estimation
48	Delay in Preparation of Draft Feasibility Report
49	Delay in Submission of Draft Feasibility Report
50	Presenting Wrong Details about Project
51	Discussions of un-related points during presentation
52	Authenticity of Clients Observations & Incorporation in Report
53	Review by non-technical professional
54	Delay in review & forwarding the observations
55	Delay in approval of DFR
56	Delay in Receiving Comments/ Observation of Draft DFR
57	Delay in Attending the Comments/ Observation of Draft DFR
58	Delay in Submission of Final Feasibility Report

Table 7: Sub activity Risks Identified under Phase-2

No	Activities with Risks
1	Access to project office is improper
2	Delay in Marking of site
3	Delay in construction of project office
4	Lack of Conducive environment in the office
5	Lack of basic amenities and infrastructure
6	Delay due to all permits and procedures are in place before any work commence
7	Delay in setup of project site office, Lay down area and site establishment
8	Delay in Site Land handover
9	Delay in Taking over of the site
10	Delay in Survey &Investigation
11	Delay in Detailed Project Report (DPR)
12	Delay in Construction
13	Joint boundary demarcation
14	Delay due to Wrong Identification of Site
15	Delay due to Site Handing over for work
16	Mistake in Establishing Horizontal &vertical Control points
17	Deployment of unqualified surveyors
18	Deployment of poorly calibrated equipments
19	Not connecting to national grid such(GTS) and Mean Sea Level
20	Wrong project boundary Identification
21	Omission of major topographical details
22	Elevation of land is not properly done through survey or equipments
23	Political interference
24	Faulty Revenue Survey
25	Delay in finalizing temporary rehabilitation schemes
26	Public interference for changing the Site
27	Interference of environmental activists
28	Delay due to inter department a issues
29	Delay in construction of diversion roads for existing traffic
30	Cost of Compensation
31	Problems with the physical possession of land
32	Deforestation
33	Reduction in Intensity of Rainfall
34	Ecological Imbalance
35	Increase in Surrounding Area temperature
36	Resettlement site not accepted by affected parties
37	Resettlement site very costly
38	Litigation by affected parties or Litigation in the Site Identified for R&R
39	Resistance and agitation by political parties
40	Delay in Final is action of Site and Locations of Investigations
41	Delay in Deployment of Required Machineries
42	Deployment of unqualified Personnel for Investigation
43	Improper/Inadequate/Insufficient Investigation
44	Collection of sample sand testing
45	Poor interpretation of data
46	In adequate foundation design recommendations
47	Missing of Soil Resistivity Data
48	Poor assessment of catchment area and historical floods
49	Deficient Hydrological Report

No	Activities with Risks
50	Computation of Finished Grade Level for the plant
51	Wrong QA& QC Report
52	Finalization of Route for Transmission Lines
53	Processing of the data and preparation of base maps in different layers.
54	Establishment of the documentation
55	Preparation of Engineering documents in line with project requirement
56	Delay in Finalization of Master Plan &Concepts
57	Lack of Involvement of Skilled Professional
58	Misunderstanding of Data Analysis
59	Preparation & Submission of Master Plan & Concept Report for Approval
60	Presenting Wrong Details about Project
61	Discussions of un-related points during presentation
62	Authenticity of Clients Observations &on Master Plan & Concept Report
63	Review by non-technical professional
64	Delay in review &forwarding the observations
65	Delay in approval of Master Plan & Concept Report

Table 8: Sub activity Risks identified underPhase-3

No	Activities with Risks
1	Minor Level Modification in Master Plan
2	Medium Level Modification in Master Plan
3	Large Level Modification in Master Plan
4	Delay in Finalization due to extent of Revision
5	Delay in approval of Revised Master Plan
6	Wrongly identification of Works
7	Lack of Coordination among different teams
8	Inadequate data &information
9	Un economical Design
10	Defective Design
11	In complete Detailing
12	Missing of Design & Specifications for Works
13	Improper Design of Site Leveling &Grading Plan
14	Identification of Type of Fencing/ Compound
15	Discarding importance of Roads, Drainage &Cross Drainage Structures
16	Faulty Design of Structure Foundation for the Module Mounting
17	Location &Size of Control room
18	Location &Size of Security/Guardroom
19	Source & Raw water storage including distribution
20	Design of Module Mounting structure
21	Design of Control Room
22	Design of Maintenance Staff Accommodation
23	Design of Security Cabins
24	Design of Main entrance Gate
25	Array layout including optimization
26	Cable Trenches

No	Activities with Risks
27	Switch Yard
28	Ear thing Layout
29	Overall SLD
30	HV System SLD
31	Overall PV array layout
32	Area power Ear thing &Grounding layout
33	SCADASLD
34	Substation
35	Auxiliary power
36	Transmission line
37	Site Lighting
38	Building Lighting
39	Lightening arrestor
40	Improper Approach &Methodology
41	Improper Use of Survey &Investigation Data
42	Delay in submission of drawings by detailed design consultant Civil Works
43	Delay in submission of drawings by detailed design consultant Structure Works
44	Delay in submission of drawings by detailed design consultant Electrical Works
45	Adopting Wrong Schedule of Rates for Estimation
46	Lack of accuracy in internal detailed estimate
47	Deficiency in Drawings
48	Short comings in internal detailed estimate/provisions
49	Delay in Preparation of DDPR &Tender documents
50	Delay in Submission of DDPR & Tender documents
51	Review by non-technical professional
52	Delay in review &forwarding the observations
53	Delay in approval of DDPR & Tender documents
54	Delay in Receiving Comments/Observation of Draft DPR& Tender documents
55	Delay in Attending the Comments/Observation of Draft DPR &Tender documents
56	Delay in Submission of Final Detailed Project Report &Tender documents

Table 9: Sub activity Risks Identified underPhase-4

No	Activities with Risks
1	Delay in preparation and approval of tender document
2	Two packet system (Technical and financial evaluation)is not implemented
3	Delay in issuing NIT(Notice Inviting Tender)
4	Delay in Pre-Bid Meeting
5	Delay in Response to the Queries of Bidders
6	Postponement of Tender Submission Date
7	Variations by the client
8	Improper evaluation of Tender Documents of Bidders
9	Delay in Award of Contract to Successful Bidder
10	Delay in Issue of LOI to Contractor
11	Wrong Details of Contract
12	Delay in responding to Wrong details by Client

No	Activities with Risks
13	Delay in Acceptance of LOI by Contractor
14	Delay in conducting Kick of Meeting
15	Improper objectives Scope & Deliverables finalization
16	Delay in mobilization of resources by contractor
17	Project not bankable
18	Lenders not comfortable with project viability
19	Adverse investment climate
20	Delay in contractual clearances
21	Delay in projects specific orders and approvals
22	Delay in clearance from environment a land forest departments
23	Delay in the approval of relocation of major utilities (telecom cables, electrical cables, storm water drains, sewer lines).
24	Un suitable construction programmed planning (e.g. Sequence of activities is not properly planned)affecting workings chem. and quality of work.
25	Delay in Labor induction by doctor and safety officer.
26	Delay inperforms100%pre –checks and pre-inspection before the GEC do the official checks and inspections.
27	Delay in submission of GFC drawingsby contractor.
28	Delay in granting approval of drawings.
29	Drawing bullet in system is not implemented onsite for drawing progress/Implementation tracking.
30	Longer Lead for Constriction Materials.
31	Delay in Supply of Materials from Vendors
32	Increase in Cost of Materials(Steel, Cement)
33	Risks of minor/major accidents during Work
34	In effective control and management
35	Delay in Start of Construction Activity
36	Defect in Level Carrying for Site Work
37	Defects in Foundations for Module Mounting structure
38	Defective works in Other Civil Works
39	Improper Drainage Facility
40	In adequate program scheduling
41	Variation of construction programs
42	Lack of coordination between project participants
43	Incomplete approval and other documents
44	Poor construction plan
45	Insufficient experience and skill in construction works
46	Unstable supply of critical construction materials
47	List of Approved materials/brands and vendors is not prepared
48	Defects in Module Mounting structure
49	Improper Erection/Mounting of modules
50	Defect in Area Power Ear thing & Grounding Layout
51	Defect in Cables &Trenches
52	Defects in Overall SLD &HV System SLD
53	Defective Switch Yard
54	Delay in Implementation of SCADA

No	Activities with Risks
55	Substation
56	Auxiliary power
57	Transmission line
58	Yard Lighting
59	Building Lighting
60	Lightening arrestor
61	Main entrance Gate
62	Security/Guardroom
63	Raw water storage including distribution and connection
64	String extension cabling
65	Module Connector
66	Combiner Box
67	ICB to inverter cabling
68	PCU
69	Data logger along with PC
70	Weather Stn-Pyrano, Anemo & Temp sensor
71	Earthing System/Lighting System
72	Documentation, Department approvals, Statutory clearance
73	Testing &Pre-commissioning
74	Staffing, SOP & tTraining
75	Safety of Workers during Construction
76	Safety of Machineries
77	Safety of Plant after Construction

Table 10: Sub activity Risks Identified underPhase-5

No	Activities with Risks
1	Reduction in Power Generation due to Variation in Solar Energy
2	Defect in the Solar Panels
3	High Rainfall
4	High Wind Causing Dust cover on Panels
5	Fire Hazards
6	Robbery of Equipment
7	Unskilled Operational Staff
8	Delay in Supply of Materials for Maintenance
9	Poor Maintenance by Operating Staff
10	Non Availability of Spare parts
11	Scarcity of Water
12	Delay in attending the break-down in operation

Table 11: Risk Severity of Broad Activities Risk Factors Quality Parameters (EVM Methodology)

No	Risk Description of Task	Project in Rajasthan		Project in Gujarat		Project in Karnataka	
		Severity Risk	Severity (Qualitative)	Severity Risk	Severity (Qualitative)	Severity Risk	Severity (Qualitative)
1	PHASE-1 :FEASIBILITY STUDY	0.39	Very High	0.25	High	0.39	Very High
2	PHASE-2 : SURVEY, INVESTIGATION, MASTER PLAN&CON-CEPT REPORT	0.56	Critical	0.30	High	0.33	Very High
3	PHASE-3 : DETAILED DESIGN AND SPECIFICATIONS -CIVIL, STRUCTURAL, ELECTRICAL, SCADAAND TRANSMISSIONLINE	0.30	High	0.39	Very High	0.30	High
4	PHASE-4 : VENDOR SELECTION, PROCUREMENT,CON-STRUCTION AND COMMISSIONING	0.33	Very High	0.42	Very High	0.23	High
5	PHASE-5 : OPERATION &MAINTENANCE OF SOLAR PLANTS	0.10	Low	0.09	Low	0.07	Low

Table 12: Risk Severity of Sub Activities Risk Factors Quality Parameters (EVM Methodology)

No	Risk Description of Task	Project in Rajasthan		Project in Gujarat		Project in Karnataka	
		Severity Risk	Severity (Qualitative)	Severity Risk	Severity (Qualitative)	Severity Risk	Severity (Qualitative)
1	PHASE-1 :FEASIBILITY STUDY	0.39	Very High	0.25	High	0.39	Very High
2	PHASE-2 : SURVEY, INVESTIGATION, MASTER PLAN&CON-CEPT REPORT	0.56	Critical	0.30	High	0.33	Very High
3	PHASE-3 : DETAILED DESIGN AND SPECIFICATIONS -CIVIL, STRUCTURAL, ELECTRICAL, SCADAAND TRANSMISSIONLINE	0.30	High	0.39	Very High	0.30	High
4	PHASE-4 : VENDOR SELECTION, PROCUREMENT,CON-STRUCTION AND COMMISSIONING	0.33	Very High	0.42	Very High	0.23	High
5	PHASE-5 : OPERATION &MAINTENANCE OF SOLAR PLANTS	0.10	Low	0.09	Low	0.07	Low

Table 13: Final Risk Index for factors Associated with Broad Activities Risk Quality Parameters

No	Risk Description of Task	Project in Rajasthan		Project in Gujarat		Project in Karnataka	
		Final Rank Index	Risk Ranking	Final Rank Index	Risk Ranking	Final Rank Index	Risk Ranking
1	PHASE-1 :FEASIBILITY STUDY	0.108	2	0.070	4	0.105	1
2	PHASE-2 : SURVEY, INVESTIGATION, MASTER PLAN&CONCEPT REPORT	0.1531	1	0.0826	2	0.0935	2
3	PHASE-3 : DETAILED DESIGN AND SPECIFICATIONS -CIVIL, STRUCTURAL, ELECTRICAL, SCADAAND TRANSMISSIONLINE	0.060	4	0.077	3	0.059	3
4	PHASE-4 : VENDOR SELECTION, PROCUREMENT,-CONSTRUCTION AND COMMISSIONING	0.0663	3	0.0834	1	0.0464	4
5	PHASE-5 : OPERATION &MAINTENANCE OF SOLAR PLANTS	0.005	5	0.004	5	0.003	5

Table 14: Final Risk Index for factors Associated with Sub-Activities Risk Quality Parameters

No	Risk Description of Task	Project in Rajasthan		Project in Gujarat		Project in Karnataka	
		Final Rank Index	Risk Ranking	Final Rank Index	Risk Ranking	Final Rank Index	Risk Ranking
1	PHASE-1 :FEASIBILITY STUDY	0.084	3	0.054	4	0.086	2
2	PHASE-2 : SURVEY, INVESTIGATION, MASTER PLAN&CONCEPT REPORT	0.138	1	0.074	3	0.088	1
3	PHASE-3 : DETAILED DESIGN AND SPECIFICATIONS -CIVIL, STRUCTURAL, ELECTRICAL, SCADAAND TRANSMISSIONLINE	0.063	4	0.080	2	0.060	4
4	PHASE-4 : VENDOR SELECTION, PROCUREMENT,CONSTRUCTION AND COMMISSIONING	0.093	2	0.121	1	0.061	3
5	PHASE-5 : OPERATION &MAINTENANCE OF SOLAR PLANTS	0.004	5	0.004	5	0.003	5

Table 15: FinalRiskIndexforRiskQualityParametersforvariousphasesusingTOPSIS method (decimal values rounded off)

No	Phase no	CCi based on broad activities	Ranking index	CCi based on Sub activities	Ranking index
1	PHASE-1 : FEASIBILITY STUDY	0.099	5	0.16	5
2	PHASE-2 : SURVEY, INVESTIGATION, MASTER PLAN & CONCEPT REPORT	0.18	3	0.20	3
3	PHASE-3 : DETAILED DESIGN AND SPECIFICATIONS - CIVIL, STRUCTURAL, ELECTRICAL, SCADA AND TRANSMISSION LINE	0.29	1	0.23	2
4	PHASE-4 : VENDOR SELECTION, PROCUREMENT, CON-STRUCTION AND COMMISSIONING	0.23	2	0.18	4
5	PHASE-5 : OPERATION & MAINTENANCE OF SOLAR PLANTS	0.14	4	0.42	1

Table16: Sample TOPSIS calculation forphase-5 (decimal values rounded off)

No	Activities with risk	Rajasthan	Gujarat	Karnataka	Xij			Rij			Wj			Vij			d+ (FPIS)	d− (FNIS)	Cci
a	Operation	5,7,9	5,7,9	3,5,7	3	6.33	9	0.11	0.16	0.33	1	3	5	0.11	0.47	1.67	3.34	0.95	0.22
1	Reduction in Power Generation due to Variation in Solar Energy	7,7,9	3,5,7	3,5,7	3	5.67	9	0.11	0.18	0.33	1	3	5	0.11	0.53	1.67	3.33	0.96	0.22
2	Defect in the Solar Panels	7,7,9	7,7,9	7,7,9	7	7.00	9	0.11	0.14	0.14	1	3	5	0.11	0.43	0.71	4.29	0.00	0.00
3	High Rainfall	3,5,7	3,5,7	3,5,7	3	5.00	7	0.14	0.20	0.33	1	3	5	0.14	0.60	1.67	3.33	0.97	0.23
4	High Wind Causing Dust cover on Panels	3,5,7	3,5,7	3,5,7	3	5.00	7	0.14	0.20	0.33	1	3	5	0.14	0.60	1.67	3.33	0.97	0.23
5	Fire Hazards	3,5,7	7,7,9	1,3,5	1	5.00	9	0.11	0.20	1.00	1	3	5	0.11	0.60	5.00	0.00	4.29	1.00
6	Robbery of Equipment	5,7,9	7,7,9	1,3,5	1	5.67	9	0.11	0.18	1.00	1	3	5	0.11	0.53	5.00	0.07	4.29	0.98
7	Unskilled Operational Staff	5,7,9	5,7,9	5,7,9	5	7.00	9	0.11	0.14	0.20	1	3	5	0.11	0.43	1.00	4.00	0.29	0.07
8	Delay in Supply of Materials for Maintenance	3,5,7	5,7,9	1,3,5	1	5.00	9	0.11	0.20	1.00	1	3	5	0.11	0.60	5.00	0.00	4.29	1.00
b	Maintenance	5,7,9	5,7,9	5,7,9	5	7.00	9	0.11	0.14	0.2	1	3	5	0.11	0.43	1.00	4.00	0.29	0.07
9	Poor Maintenance by Operating Staff	7,7,9	7,7,9	3,5,7	3	6.33	9	0.11	0.16	0.33	1	3	5	0.11	0.47	1.67	3.34	0.95	0.22
10	Non Availability of Spare parts	5,7,9	3,5,7	5,7,9	3	6.33	9	0.11	0.16	0.33	1	3	5	0.11	0.47	1.67	3.34	0.95	0.22
11	Scarcity of Water	5,7,9	3,5,7	7,7,9	3	6.33	9	0.11	0.16	0.33	1	3	5	0.11	0.47	1.67	3.34	0.95	0.22
12	Delay in attending the breakdown in operation	5,7,9	5,7,9	1,3,5	1	5.67	9	0.11	0.18	1.00	1	3	5	0.11	0.53	5.00	0.07	4.29	0.98
													A+	0.11	0.60	5.00			
													A−	0.11	0.43	0.71			

4.0 Conclusions

After careful scrutiny of the results from AHP and TOPSIS analysis the following conclusions are drawn. TOPSIS has substantial advantages over the conventional AHP process in terms that it can evaluate the data using fuzzy numbers from various decision makers or sources. In this case, TOPSIS approach combines the input of the solar parks from Rajasthan, Gujarat and Karnataka and combines them with the same activities and sub-activities and provides an ensemble interpretation of the parameters. The results of maximum and minimum risk phase are more coherent in TOPSIS than in AHP. AHP concludes Phase-2 or Phase-4 as the highest risk depending upon the solar park. This in coherency is not well appreciated where the quality of results lie on external factors. The highest risk phase should be independent of the geo graphical location as the parameters in the study are same for any solar park. However, TOPSIS clearly shows both the phase2 and 4 to be of medium risk. It is very evident from the comparison and the analysis that TOPSIS is a more refined approach in such study of various solar power parks using the same identified parameters.

Furthermore, AHP is limited to the study of each solar park separately and there exist no way to interpret one with respect to another. Asset can be seen the results of AHP of each solar park are shown separately and the most critical case varies case to case which may not be the true representation of the actual problem under consideration. Moreover, for standalone projects or niche markets of study AHP is better suited in the abs hence of other related projects that can provide the same range of identifiable parameter across the board.

Phase-3 shows the maximum risk in terms of both the broad and sub activities for TOPSIS approach. However the lowest risks belong to Phase-1 for both the broad and sub-activities. This can be justified as the execution phase and the operation & maintenance phases have the maximum amount of uncertainties. The comparison between the two approaches how that they different their conclusions by a substantial margin.

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