Markov Analysis as a Tool for Developing a Model for Risk Management: A Case Study Based on Electrical Transmission Line Installation Projects

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ABSTRACT

The study develops a model for risk assessment by the use of Markov analysis combined with the Delphi approach for expert opinion, the paper gives a methodology under which the various risk factors are firstly collected then they are applied for Markov analysis, the Markov analysis returns the probability of occurrence of that particular risk factor, this probability is then used to calculate the R_{value}, *a model is then given which is used to calculate the final impact value for each risk, which will be used in risk deciding risk mitigation plan.*

Keywords: *Risk Management, Markov Analysis, Electrical Transmission Line Installation Project and Risk Assessment.*

INTRODUCTION

The risk management process for any industry is dependent on the risk assessment and this process is in particularly cumbersome when the project involves a severe amount of civil work and is riddled with deadlines and day to day operational problems like an electrical transmission line installation projects.

In this study we have developed a model in which we can assess the probability of risk occurrences for an electrical transmission line installation project with the help of probability, the model developed gives us the risks involved in a transmission line installation project along with the use of other factors that influence these risks are also studied and included in the analysis, an electrical transmission line installation project is very highly sensitive in case of risk management and every such project is unique in itself hence the need for historical data is more but such data is very scarce and hence we have developed a system which can predict risk level with minimal usage of historical data, but the main problem that had been encountered is that if historical data is less we have to tend towards probabilistic approach but such an approach is also bounded by the need for a huge amount of data and involves non practical assumptions and conditions.

On giving an insight we found that both qualitative and quantitative risk assessment methods are discussed by many authors (Chen et al., 2011; Thevendran and Mawdesley, 2004; Olaru et al., 2014) in which basically risk factor based approach is used, on the other hand many authors (Ping

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and Li, 2010; Erickson and Evaristo, 2006; Wu et al. 2008) have made a more generalized study for risk assessment which is not based on any specific industry. The need for better risk assessment is always present since both qualitative and quantitative assessment methods discussed by many authors are heavily dependent on historical data, so what we have analyzed here is that Markov analysis can be used in order to have a specific probability of risk occurrence to be decided, the main advantage that has emerged in our study is that we need very less amount of data to forecast the risk occurrence level, further the study takes turn and calculates the impact level of various risks involved and on combining the probability and impact we can have a system which is very helpful in deciding the risk level and hence the risk mitigation plan for an electrical transmission line installation project.

Risk management in power sector is one such topic which is always given priority since the cost involved in the project is very high and even a small amount of risk can cause dramatic loss for the project(Geraldi, et al., 2008), moreover with the increase in the development process of the country we have even more electrical transmission line installation projects underway, so in order to have dedicated system for risk assessment in such projects we have developed a model which needs very less amount of historical data and works on both quantitative and non quantitative techniques to decide upon the level of the risk. This study deals with a model for risk assessment of electrical transmission line installation projects which will be helpful in optimizing the risk management process for the whole of the project.

The study stresses on the identification of risk factors involved in an electrical transmission line installation project, then these risk factors are discussed by experts and finally the experts employ probability of transition matrix for being used as seed value in Markov analysis, the analysis returns the final probability of risk occurrence for each risk factor. Then $_{Rvalue}$ is calculated by multiplying it with the impact value of each risk factor, this impact value is generated by the use of mathematical modeling. Hence finally the R_{value} which is the risk indicator value is obtained from multiplying the probability obtained from Markov analysis with the impact value of that risk factor.

Hence the study deals with quantifying the risk factors with the help of probability. Markov analysis is used to give that probability and the seed value that is the transition matrix that is required for Markov, is obtained by qualitative data analysis that is completed by questionnaire and expert discussions. Hence in this study the balance is established in between the various quantitative and non quantitative methods available for risk assessment and this is what makes the study more useful and flexible in its approach, finally the risk value calculated is divided into percentage of total R_{value} so that in accordance with the percentage employed by the analysis we can distribute the risk mitigation resources so that the investment in risk process is optimized. The study shows that technical and human resource related risks are having highest risk levels so special care is needed to be given for these risk factors while designing risk mitigation plan for such a project.

The purpose of this paper is to introduce a model that requires very less input but the accuracy level for deciding the risk level should be high, hence the Markov analysis is used in order to have a probability of risk occurrence being generated which will be analyzed along with the impact level to give final risk value for that electrical transmission line installation project, that also with very less amount of historical data requirements.

LITRATURE REVIEW

Risk management process is defined and analyzed by many authors but sector specific studies are less in number and more so over a dedicated study for an electrical transmission line installation project are very few, risk management is generally seen over as a planning process for a series of events that can be related with one another or independent events which can cause problems with the upbringing of the project at various levels. The risk management process is analyzed by many authors (Dey, 2001; Dey, 2010; Aloini et al., 2012; Fang and Marle, 2012; Dikmen et al., 2008; Thevendran and Mawdesley, 2004; Fan et al., 2008; Chen et al., 2011 Menches, and Hanna,2006) with different aspects, some have even taken a specific risk factor and worked on its importance in risk management but all the studies generally point out in the direction that risk assessment and monitoring is essential for preparation of risk mitigation plan or for having a better risk management plan, although different techniques may be used or the industry type can be different but the risk factor decision is very general and the overall process is one or the same.

The uncertainty management is also given in-depth analysis by many authors (Soderholm, 2008; Sun, Wei and Yue, 2008; Tavares, Ferreira and Coelho, 1998), mainly the calculable events in a project are called as risks and the incalculable are called by the name of uncertainty, even power network sector is also studied keeping in view the optimization of project risk management, but still specific studies on transmission line installation phase, which itself is a big phase, is missing. Although techniques which are suggested are different but mainly they are of two types that is quantitative and qualitative.

The main difference that lies is the decision or choice related to the type of techniques to be used. The main techniques that are used are ISM (Interpretive Structural Modeling), AHP (Analytical Hierarchy Process), Decision tree based approach and Probabilistic methods etc. So what we can analyze is that the process for risk management is quiet well accepted and generalized and is based on risk factor decision and treatment but the technique that are to be used for dealing with these risk factors needs to be worked upon since one technique is entirely different from the other and hence we have decided to analyze upon such a technique which can be accurately used to predict these risk factors with less dependence on historical data and still being more reliable.

Risk assessment for any particular project is a daunting task, many authors (Baccarini and Archer, 2001; Barber, 2004) have given insight on this aspect also, since for this risk ranking of projects, what is of utmost importance is the measurement of risks involved in the projects, both the authors have introduced the methodology of risk rankings on the basis of five point rating method and generalized system based assessment for the benchmarking of the whole project respectively. Similarly (Thiry, 2002) has also given a value based model in which it is proved that performance based tools that reduce uncertainty are better adapted for project success. The tools that are used for ranking of risk factors can be ISM (Interpretive Structural Modeling), AHP (Analytical Hierarchy Process) and Monte Carlo as demonstrated by different authors (Iyer and Sagheer, 2010; Olaru et al., 2014).

The studies are also done specifically on power sector (Wyk et al., 2007; Regos, 2013; Tummala and Burchett, 1999) but special consideration to electrical transmission line installation section is missing, although each of these studies analyses exhaustively the factors and considerations that are necessary for power sector projects, the studies are more concentrated on operating condition risks but in our study we have included the risks that are present during installation phase of electrical transmission line installation. These studies are also used in pooling of risk factors for our own analysis and considering various risks factors that are taken for consideration in our own study also but only after expert discussion on these collected risks.

For Markov Analysis the probability that is needed to prepare the transition matrix is obtained with the help of expert discussion, many authors (Tanimoto & Hagishima, 2005; Skulj, 2011) have given different viewpoints regarding collection of probabilities, the mathematical approaches seems to be having a very large number of assumptions for generating functions for probability but these assumption are impractical for our case study of transmission line installation projects and hence we can say that deriving out these probabilities mathematically always proves full of constraints. Hence, in order to generate transition probabilities we have taken expert opinion from Delphi method, Skulj (2011) has used conditional desires as risk reducing methods, which is based on probabilistic studies only on the other hand authors (Tanimoto & Hagishima, 2005) have also taken survey method to derive the transition probabilities, in their paper for the Markov dealing with the operation of air conditioner in dwellings, we have field data collected and then parameters are decided on which the probability function is generated in the form of sigmoid function. Finally, the transition probability of on and off of air conditioner is calculated and shown on the graph for different dwellings on the basis of temperature differences, similarly in our study we have generated probabilities for risk occurring and non occurring from field data and expert opinion on these transition probabilities and finally to increase the accuracy we have calculated probabilities for about fifty period's of state transition matrix and the result is used to generate the overall risk model by multiplying it with impact function hence generated. The calculation is done simply by collecting data for each of the risk factors and then they are fed into a single value by taking the average, this average value then work as seed value for the Markov process and generate probability of risk occurrences.

RESEARCH METHODOLOGY

Markov Analysis

It is a technique which forecasts probabilities of future events by analyzing presently known probabilities. It is a very simple yet effective method in which a matrix of transition probabilities is developed, which is a matrix of conditional probabilities of being in a future state with respect to a current state. Then this transition matrix is multiplied with original probability matrix and with each ongoing multiplication we get a new probability finally when there is an equilibrium point for probability at each period we reach the final probability. This analysis is used extensively in predicting market changes and bad debts in case of finance but it can be very well used in prediction of risk occurrences in the same fashion.

Now we will find out the various risk factors that are involved in any conventional transmission line installation project, then after collection of these risk factors from literature survey, we have taken expert opinion regarding each major risk factor, the various risk factors that are collected by expert opinion and literature survey are shown in table 1.

Table 1: Showing Risk Factors Considered in the Study

Authors /Risk Factors	Aloini et al. (2012)	Baccarini et al.(2001)	Castro et al.(1995)	Chen et al. (2011)	Dey (2001)	Dikmen et al. (2008)	Erickson et al. (2006)	Fan et al (2008)	Fang et al. (2012)	Iyer et al. (2010)	Regos (2012)	Thevendran (2004)	Wu et al. (2008)	Wyk et al. (2007)
Technical Risk	N	S	S	S	S	S	S	S	S	S	N	N	S	S
Environmental Risk	N	S	N	S	S	S	S	S	N	S	S	S	S	N
Financial Risk	N	S	N	S	S	S	S	S	S	S	N	S	N	N
Human Risk	N	S	N	N	S	N	S	N	N	S	S	S	S	N
HR Risks	S	S	N	N	S	S	S	N	S	N	N	S	S	N

S= Supported by author, N= Not Supported by author

Here the main risk factors that have been collected are Technical Risk, Environmental Risk, Financial Risk, Human risk and Human Resource (HR) risk.

Steps involved for calculation of risk value for each risk factor –

Step I – Take each risk factor one by one, since we have got five major risk factors identified they are Technical Risk, Environmental Risk, Financial Risk, Human risk and HR risk, we will be taking each risk one by one, for example if we assume $R_{Technical} = \pi\ (1) = [1, 0]$ in I state, that means risk has occurred in state I so the probability of risk occurrence in state I is 1 and the probability of non occurrence of risk is 0.

Step II – Now prepare matrix of transition probabilities **P.**

$$P = \begin{pmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{pmatrix}$$

Where P_{11} = Probability that risk occurred in first state and will occur in next state also.

P_{12} = Probability that risk occurred in first state and will not occur in next state.

P_{21} = Probability that risk do not occurred in first state but will occur in next state.

P_{22} = Probability that risk do not occurred in first state and will not occur in next state also.

Step III – We know that $\pi\ (1) = [1, 0]$, now find $\pi\ (2)$ which is equal to $\pi\ (1) * P$, similarly

$\pi\ (3) = \pi\ (2) * P$, now generate a state probability table for each risk, as shown in Table 2.

Table 2: Format of State probability table

Period	State I	State II
π (1)	1	0
π (2)		
π (3)		
π (4)		
π (n)		

In our study the above table is prepare by the help of MS Excel QM. The final values of probability will be reaching the equilibrium as the number of periods will be increased.

Step IV – The result derived in step III shows the probability of risk occurrence. This way the same process is repeated for all other four risk factors.

The probabilities for matrix of transition (P) are assessed with the help of historical data from the companies working in transmission line installation projects and through expert opinion by Analytical Delphi method, with the help of questionnaire asking for probability of transition and impact value.

Model for Risk Assessment

Let us consider P be the probability of risk occurrence derived out from Markov analysis, I be the impact value of that particular risk, for generating the impact value we have done the following considerations, all the given factors are measured by Delphi method and are marked on a scale of 0 to 1 hence giving the indexed results, the direct and indirect proportionality for I upon various factors is shown below.

I α Cost loss associate with that risk (C)

I α Life loss associate with that risk (L)

I α Project delay loss associate with that risk (D)

I α Ability to drive other risks (A_D)

I α Frequency of occurrence in a single project (F)

I α 1/ Effect of risk mitigation plan in indexed form (R_M)

I α 1/ Cost of risk mitigation plan in indexed form (C_{RM})

Overall I α 1 / ((R_M) - (C_{RM}))

Hence the functions of Impact value (I) can be written as –

$I = K\,(C*A*L*D*A_D*F) / ((R_M) - (C_{RM}))$ — (i)

When we have derived I, the next thing is the generation of R_{value}, which is the rating of the risk, this value is obtained by the multiplication of probability derived from Markov analysis with the risk impact value that is $R_{value} = P * I$, where $I = K\,(C*A*L*D*A_D*F) / ((R_M) - (C_{RM}))$, hence the overall risk function will be as given under –

$R_{value} = P * [K\,(C*A*L*D*A_D*F) / ((R_M) - (C_{RM}))]$ ———————————— (ii)

DATA ANALYSIS

After performing all the above stated steps in research methodology we have got the following results, in case of the probability assessment by Markov analysis (after 50 step transition matrix) for five types of risk factors, the transition matrix is developed with the help of expert discussion using Delphi method in which only those personals which are having related work experience of more than 5 years are chosen and then opinions are collected from questionnaire, if there is a wide difference in opinion we resolve it by mutual discussion and reach at the consensus, we have got the following results which are shown in table 3.

So out of five major risk factors identified Environmental Risk, Financial Risk, Human risk and HR risk are having low probabilities of risk occurrence in equilibrium state probability, wherever Technical Risk is having high probability of occurrence.

The final risk value (R_{value}) derived from expert discussion by Delphi method using equation (ii) taking constant K = 1 for getting equal weights for comparison of all the five risk factors are shown below in table 4.

Table 3: Probability Assessment by Markov Analysis

Risk category	Probability value derived from MS Excel QM software			
Technical Risk	**50 step transition matrix**			
		1 1	1 2	1 2
	1 1	0	0.436241611	0.5637584
	1 2	0	0.436241611	0.5637584
	End prob(given init)		0.436241611	0.5637584
Environmental Risk	**50 step transition matrix**			
		1 1	1 2	1 2
	1 1	0	0.153005465	0.8469945
	1 2	0	0.153005464	0.8469945
	End prob(given init)		0.153005465	0.8469945
Financial Risk	**50 step transition matrix**			
		1 1	1 2	1 2
	1 1	0	0.250000001	0.75
	1 2	0	0.25	0.75
	End prob(given init)		0.250000001	0.75
Human Risk	**50 step transition matrix**			
		1 1	1 2	1 2
	1 1	0	0.194233687	0.8057663
	1 2	0	0.194233687	0.8057663
	End prob(given init)		0.194233687	0.8057663
HR Risks	**50 step transition matrix**			
		1 1	1 2	1 2
	1 1	0	0.280370027	0.71963
	1 2	0	0.280355844	0.7196442
	End prob(given init)		0.280370027	0.71963

Table 4: Showing Comparison of all the Five Risk Factors on the Basis of R_{value}

Risk Factors	P	C	L	D	AD	F	R_M	C_{RM}	(C*A*L*D*AD*F)	(R_M - C_{RM})	FINAL (I)	R_{value} = P * I
Technical Risk	0.4362	8.33	5.69	5.66	7.25	3.69	8.63	5.9	7176.919446	2.73	2628.908	1146.839
HR Risks	0.2804	6.51	5.4	6.91	6.35	5.63	8.9	4.87	8684.301962	4.03	2154.914	604.1732
Human Risk	0.1942	3.25	7.8	2.41	1.4	8.61	5.9	5.6	736.421049	0.3	2454.737	476.7926
Environmental Risk	0.153	4.58	7.58	7.28	5.63	3.65	5.347	2.6	5193.585938	2.747	1890.639	289.2781
Financial Risk	0.25	5.7	2.6	5.2	5.2	5.48	6.89	2.5	2196.015744	4.39	500.2314	125.0578

From table 3 we can very well say that technical and HR related risks are having highest R_{value}.. Moreover we all can say here that the analysis provides a very sound detail for risk mitigation plan in which we can say that those risks whose R_{value} are higher should be given more importance, we can express it also in terms of percentage and then total investment of all sorts that are decided for risk mitigation can be usefully divided on the basis of this percentage only, as shown in table 5 below.

Table 5: Showing the R_{value} of Each Risk in Terms of Percentage of Total R_{value}.

Risk Factors	R_{value} = P * I	%
Technical Risk	1146.8	43.406
HR Risks	604.17	22.867
Human Risk	476.79	18.046
Environmental Risk	289.28	10.949
Financial Risk	125.06	4.7332
Total	2642.1	100

Hence the results also guide how much investment can be done for each risk in terms of percentage of total monetary level kept aside for risk mitigation. The results shows that same methodology can be used to upkeep the risk mitigation plans for any project and since the Markov analysis being based on transition probabilities the overall accuracy is greater as compared to the case of pure probabilistic methods.

CONCLUSION AND FUTURE STUDIES

The paper analyzes the various aspects of risk assessment when there is very low historical data available, by the use of Markov analysis and expert opinion for impact value. The paper also gives a model for risk assessment which comprises of impact value of each risk, this impact value hence generated when multiplied by the probability derived from Markov analysis shows that the risk level can be very well decided, in our study Technical and Human resource (HR) are found to be most important risks since they both governs about total 66 percent of total R_{value} , hence when ever risk mitigation plans are needed to be fulfilled for electrical transmission line sector we need to be especially careful for such risks.

Another important aspect of this study is that we need to have better and trained work force which will reduce the HR risks and human life risks both, since collectively they form about 41 percent of total R_{value}, these risks are heavily interrelated and hence on applying proper training to the HR team and the workers we can drastically reduce such risks, which will be helpful in removing unnecessary risks that come in between the project schedule.

In future such studies can be very helpful in deciding the risk level or standards for the entire industry, moreover the same methodology can be very well employed at the projects where the historical data is very less, the results shows that with very less amount of time and monetary inputs we can have a complete analysis of risk for any project, moreover its better than non quantitative methods that are used generally, since these non quantified methods are only used because of lack of historical data for probabilistic methods but this method is based on probability but still requires comparatively very less historical data. The study revels and proves how efficiently the risk value can be calculated with the combined use of Markov analysis and model derived in the study, the overall risk mitigation can be very efficiently dealt since the results are quantified without the need of historical data, in future such decisions can also be done by the use of automated systems since the process can be very well converted into algorithm and can be even directly attached as a module with various project management software. Hence the study proves very helpful for not only electrical transmission line projects but in numerous other type of projects also, which involves great monetary and non monetary inputs at the stake.

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