IDENTIFICATION OF RISK FACTORS INVOLVED IN THE ELECTRICAL TRANSMISSION-LINE INSTALLATION PROJECT : A LITERATURE REVIEW

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ABSTRACT

The paper analyzes risk management process for electrical transmission line installation projects by pooling the associated risk factors that governs the risk level for the project. The paper collects the view point of various authors and experts on the subject and then the categorization of risk is done. It is being found that authors have mainly mentioned five types of risk factors. They are Environmental Risk Factors, Financial Risk Factors, Human Risk Factors, Human Resource (Management) Risk Factors and Technical Risk Factors. Technical risk factors are found to be most important by many authors. This is the reason why technical risk factors are further divided into nineteen sub technical risk factors in this study over a span of six major categories of project activities. In this manner the paper identifies and classifies the risk factors present in electrical transmission line installation project.

Keywords : Risk management; Risk factor identification; Risk factor classification; Technical risk factors; Electrical transmission line installation.

INTRODUCTION

Risk management process is an important aspect for any project. Its importance increases even more when the project is a construction work based on site project like that of an electrical transmission line installation project. Electricity is needed in ample amount for any economy to prosper and its demand is increasing in both developed and developing countries. In a country like India according to the estimate the demand of electricity will surpass 950,000 MW by 2030. In order to transmit such a huge amount of power many new electrical transmission line installation projects are already undertaken under the 11th five year plan. The problem associated with such project in India is that the performance of such projects is always under risk. The duration, cost and quality of power transmitted is highly variable and there is a delay in installation of electrical transmission line project because of the risks factors that are involved in such projects.

Many studies are concentrated on the operationof electric transmission lines but construction phase of such projects is also very crucial and a lot of scope is present for standardization of this phase in electrical transmission line projects. In the studies done by numerous authors it is pointed that such projects are riddled with a large number of risks. In order for the project to be to successfully completed, the risk management of project becomes a compulsion. Risk management process in electrical transmission line installation can only be completed when the factors that contribute to the risks are identified. In this study the collection

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of such factors is being done. The risk factors are given by many authors for various construction projects. In this study the construction project's risk factors are also identified along with the specific risk factors involved in electrical transmission line installation.

Power transmission is an important aspect for development. Improper commissioning and delay in electrical transmission line installation projects can create havoc in the plan of development and hence it is utmost necessary that such projects remain on track and are completed on time with the desired parameters. This is possible only when the difficulties ranging from day to day operational problems to strategic risks are pre calculated and proper risk mitigation plans are in place. Once again the project risk factors play a very important role in formation of risk mitigation plan for electrical transmission line installation projects, which are the backbone for development of economy.

In this study risk factors affecting the project performance are identified. Various authors have given analysis in this regardwhere some have provided ageneral risk factor approach for construction projects, while others have concentrated on specific risk factors like technical risk factors or environmental risk factors. In many studies a classification of risk factors in electrical transmission line installation projects is being done and then they are analyzed with the help of various sub factors that are present in the main risk factors itself. Authors like [33], [1], [8] are some of the few who have done remarkable work in risk management of such construction projects. The study deals with the vivid collection of various risk factors and point of view of such unique study given by authors on different risk factors. The study has also developed a base for selection of risk factors useful in risk management of electrical transmission line installation projects. Such an analysis is very much needed especially when more and more such projects will be undertaken by the government and other private firms in the next ten years or so. The study specifically pools the risk factors and identifies the sub risk factors according to the importance associated to them by various authors for electrical transmission line installation projects. The study embanks on developing risk breakdown structure for electrical transmission line installation projects.

SURVEY OF LITERATURE

In most of the transmission line installation projects there are a wide number of inter related factors that influence the output. Those factors which can prove to be a threat for such projects are termed as risk factors. In order to successfully perform the risk management activity in an accurate manner identification of these risk factors is very important. In order to indentify these risk factors a collection of studies is done. In these studies by different authors different aspects of risk management are dealt with utmost accuracy.

The most common categorization of risk factors was found in the studies of authors like [7] and [9]in which the complete risks are divided into basic categories of technical risks, environmental risks, financial risks, human resource management related risks and legal risks. Many different authors have shown the importance ofthese factors. Another author [6] has also given the same criteria of risk division for the study on risk assessment of international hub airports. In all the above mentioned studies the methodology for risk assessment is based on a common guideline which is the division of risk into various pre defined categories. Then the experts are asked to give their opinion on the importance of these risks, finally the risk mitigation plan is prepared accordingly. Different models are also given to measure the impact values of these risks to prepare an accurate risk management plan. Another study by [25] uses a very prominent division of risk into external and internal risks, which are further analyzed through Monte Carlo method to calculate their impact, but due to extensive inter relation between the various risks in electrical transmission line installation projects such a division is not followed in this paper.

Another important aspect of the division of

risk factors lies within the definition of risk factors itself. Since most of the studies are done with respect to a particular industry or project, the definition also changes accordingly. Another set of authors are present which have done such categorization of risks are [3], [6], [13], [17], [18] and [35].All of these have done the divisions of risk factors in different projects on somewhat similar basis that is technical risks, environmental risks, financial risks, human resource management related risks and legal risks. Although each author specifies a different importance level to different risk factors mentioned above but all of them agrees upon the category of the division based on the above mentioned types. Names given to each category of risks may be different, like the legal risks in some studies are dealt by the name of governing authority related risks but their definition is somewhat similar. Hence with the above discussion it can be concluded that many of the authors follow the same categorization of risks, which is the risks associated with most of the projects and can be categorized into five basis categories. The five basic categories are -

I. Environmental Risk Factors
II. Financial Risk Factors
III. Human Risk Factors
IV. Human Resource (Management) Risk Factors
V. Technical Risk Factors

The various author's point of view on these risks is given in table 1 below. The table describes the risks factors advocated by different authors. The table tells us that the technical risks associated are the most favored risk factors as large number of authors give a huge importance these risk factors.

Table1 : Risk factors collected from various authors

Authors / Risk Factors	Aloini et al. (2012)	Bacc-arini et al. (2001)	Castro et al. (1995)	Chen et al. (2011)	Dey (2001)	Dikmen et al. (2008)	Erick-son et al. (2006)	Fan et al. (2008)	Fang et al. (2012)	Iyer et al. (2010)	Regos (2012)	Theve-ndran (2004)	Wu et al. (2008)	Wyk et al. (2007)
Technical Risk	[✗]	[✓]	[✓]	[✓]	[✓]	[✓]	[✓]	[✓]	[✓]	[✓]	[✗]	[✗]	[✓]	[✓]
Environmental Risk	[✗]	[✓]	[✗]	[✓]	[✓]	[✓]	[✓]	[✓]	[✗]	[✓]	[✓]	[✓]	[✓]	[✗]
Financial Risk	[✗]	[✓]	[✗]	[✓]	[✓]	[✓]	[✓]	[✓]	[✓]	[✓]	[✗]	[✓]	[✗]	[✗]
Human Risk	[✗]	[✓]	[✗]	[✗]	[✓]	[✗]	[✓]	[✗]	[✗]	[✓]	[✓]	[✓]	[✓]	[✗]
HR (Manage-ment) Risk	[✓]	[✓]	[✗]	[✗]	[✓]	[✓]	[✓]	[✗]	[✓]	[✗]	[✗]	[✓]	[✓]	[✗]

[✓] = Accepted and referenced by author, [✗] = Not referenced by author

RISK FACTOR DEFINITION

Now these risk factors given in table 1 are defined according to electrical transmission line installation projects. The five basic categories are

I. Environmental risk factors
II. Financial risk factors
III. Human risk factors
IV. Human resource (management) risk factors
V. Technical risk factors

These risk factors are hereby assessed one by one in terms of their occurring frequency and impact level as given by various authors.

I. Environmental risk factors – These are the risk factors which are the direct result of act of god. Earthquake, flood, thunderstorm etc are the factors that can make the whole project stall. Authors like [6], [8] and [9] have introduced factors like flood, earthquake etc under the category of environmental risks and have given considerable importance to such factors in project risk assessment.

Other authors like [3] and [13] have also

analyzed this risk factor but under the name of project surrounding factors or as interfering factors. Hence in the case of construction projects like electrical transmission line installation, environmental risk factors are important factors that should be considered while designing the risk mitigation plan. Author like [6] hasperformed the study specifically for environmental risk factors in international hub airports. Similarly the environmental risk factors are also given importance in electrical transmission line installation projects.

II. Financial risk factors : Transmission line installation projects includes a great amount of financial resources at stake and its installation and operating costs both are very high, so changes in the financial conditions can affect these projects to a great extent. Authors like [6], [8], [9], [12], [13], [14] and [20] have all mentioned the effects of economic conditions and share holders value in the projects. Many of the above mentioned authors like [8] have divided this risk into various sub risks like inflation risk and fund risk. While [6] has given importance to supply demand aspects of the project with respect to financial frame of reference. The factors like rate of return etc are also taken into consideration under this risk category.

III. Human risk factors – Under this risk category safety related risks are studied. In electrical transmission line installation projects a huge amount of machine work is needed, apart from that a large amount of work is needed to be done on the high tower lattice structures and hence human safety is another important aspect which is to be taken care of in such projects.Sometimes an existing transmission line is extended or inter connected with other lines, in such cases the live working on line can prove fatal for any personnel if there is slight carelessness in following the safety procedures. [8] has mentioned equipment risk which involves the risk related to the personnel using it.[3] have added the dimension of handling hazardous material by the workers on construction projects as an important safety related risk factor. [33]has also specifically analyzed the safety aspect for the workers working in construction projects and since electrical transmission line installation projects are highly construction based it becomes mandatory to analyze such factors in our study.

IV. Human resource (management) risk factors – The risk factors related to managerial aspects including organizational problems like vendor or supplier failure are important considerations for optimal performance of any project. Authors like [6], [8], [9], [12], [13] and [14],have all given importance to these factors. Although name given by these authors for such factors may be different but the capability of project team is always an important factor in any project,especially in electrical transmission line installation projects where technical sensitivity is high and a huge number of workers and business proceedings are involved. Some of the studies like that of [33] are specifically concentrated on human resource management factors in construction projects. Hence there are many aspects of this risk category and that is why it is being chosen as an important factor in our study.

V. Technical risk factors –Transmission line installation project is a highlytechnical sensitive project, so the importance of such risk factors is even more. Authors like [6], [8], [9], [12], [13], [14], [27], [28], [30], [32] and [34] all have been advocating the importance of these risk factors, but according to the case study undertaken by each author different technical risk factors are promoted in different studies. Many authors have used common factors, for example[8] has named factors like technology selection, implementation related risks and equipment or material selection related risks under technical risk category. Some authors like [6] and [37] have given a list of technical factors which can influence the projects.Issues like design, constructability, workforce reliability and durability, use of information technology and standardization of various procedures are the main risk factors in technical category. Since transmission line installation is mainly a construction based project the factors given above are equally important for our study.

Some of the studies reflect the operating technical risks associated with transmission lines like that of [29] and [37], while both of these authors have shown the importance of technical risk factors in transmission lines and power plants. Some of the factors like switching problems, commissioning delays and maintenance related problems are common or interrelated with installation phase problems or risk factors.Other authors which have indicated same type of technical risks during the operation of line are [2], [11], [16], [10], [31] and [38]. Hence for the installation phase technical risk factors of both construction projects and transmission line operating projects are needed to be analyzed. This study is extensively cautious and aware about the importance of technical risk factors in such projects. It is proved that technical risk factors hold a great importance and a huge number of such factors are present and hence to study them it is utmost necessary to find the various sub factors involved in the technical risk factor category for electrical transmission line installation projects. More so ever technical risk factors can also increase or decrease the effect of other risk factors. It is due to the huge importance and large number of types of technical risks present it is mandatory to analyze these risks in detail for accurate results to be produced in risk mitigation plans. The next section of the study is therefore based on identification of various sub factors present in technical risk factors of transmission line installation projects.

Selection of sub factors infused in technical risk factors ofelectrical transmission line installation projects

In this section of the study sub technical risk factors are analyzed and for analyzing the technical risks, most of the experts and present literature suggests that the efficient method is dividing the transmission line installation process in different sections and then study the various sections exclusively. Hence in order to determine the sub technical risk factors the whole transmission line installation process is divided into different project's sections. The main sections as given by [14] and other authors are -

I. Tower base preparation
II. Construction of tower
III. Ground wires, electrodes and conductor erection
IV. Stringing and Sagging
V. Installation of hardware
VI. Vibration Damper and Spacer installation

Now each of these sections is analyzed for inherent risks. The first and foremost section is -

I. Tower base preparation

In this section the base of the towers on which the conductors are fixed are erected. It mainly includes the soil testing and preparation of bed on which the tower's lattice system is constructed. Since the base of the tower is really important for exact and accurate positioning of towers, special care is given to this section. The main risk factors in this section as suggested by [11], [21], [22] and [31] includes the rock drilling etcbase preparation processes,Inaccurate tower blue prints, Unchecked soil parameters, Faulty Backfilling and Wood/Swamp matting and Faulty right of way.

II. Construction of tower

The study by [21] has given a large account of the reasons of deterioration in the towers used in transmission lines. Different towers are being taken for analysis, in fact wooden to normal steel lattice based towers all are studied with respect to their ability to sustain in service in optimum manner over a longer period of time.The main reasons identified by the author for tower related problems are Premature start of footing, Lattice failure in tower, Faulty mechanical considerations for cross arms. Other authors like [10], [11], [15], [24], [31] and [39] have stressed on following the IEEE guidelines and feel that IEEE guidelines neglected on site is a major reason of disturbances, it also introduces aground penetrating radar (GPR) based system for tracking the project on ground and check whether guidelines are being followed or not.

III. Ground wires, electrodes and conductor erection

This factor is studied by authors like [19] but the work of [5] is served as the base for consideration in terms of conductor related issues in transmission lines. In this study cost related assessment is done for upgrading of a transmission line and during the analysis conductor related technical aspects are studied. Another factor studied in the study by [5] is No accurate tension and counterpoises in the conductor's erection. [15]has generated a number of factors that can affect the conductor related issues. Overall the main factors given by [5], [11] and [38]in this risk category are Improper stringing in Ground wires, No testing of impulse current on ground rods and Crossing with nearby transmission lines already present.These factors are the main factors which are studied by authors for ground wires, electrodes and conductor erection related risks.

IV. Stringing and Sagging

Authors like [5] and [19] have specifically studied the sagging and stringing problems. The main factors devised by them are Faulty sag installation, Permit problems from local authority and no proper usage of guard structure and net. Along with these some other areas are also given importance but in the case of sagging related risks these are common view points from authors[2], [16], [21] and [22]. These authors have also indicated the importance of stringing and sagging as an important factor for tower installation. Hence the common problems related with conductor stringing are identified, although sagging effect is more important when line is crossing from a river or other likewise hurdles and also if the line is in the mountainous region.

V. Installation of hardware :

Different authors like [4], [11], [21]and [22] have applied different approaches for hardware installations, the main issues are Improper assembling of Hold down weights(especially in hilly areas) and Emergence of uplift problem due to incorrect tension on the joints of insulators. In every transmission line this process is repeated and it directly affects the sag accuracy, stress on insulators, tower lattice and tower performance.Safety is another important issue that is related with installation of hardware related risk in transmission line installation projects.

VI. Vibration Damper and Spacer installation

Authors like [2], [15], [24] and [39] have identified many factors that are directly or indirectly related with vibration damper and spacer installation related risks. Improper testing of 'wind caused damage' on the surface of conductor and Improper handling of large diameter light weight conductors and splices are the main reasons for problems related to vibration damper and spacer installation. Numerous studies have been done for the selection of conductor in transmission line but more stress is needed on the study of conductor type and its effect on vibration and safety arrangements. Overall it is derived that vibration damper and spacer installation issue can be solved if the technical details are sorted out at the planning phase only, while keeping in view the environmental profile of the site where transmission line installation is needed to be done.

Hence after collecting the technical risk factors supported by many authors, as per the study stated above, the following risks are finally selected as the most important technical risk factorsand are shown in Table 2.

PROCESS DIAGRAM FOR RISK FACTOR IDENTIFICATION

As per the above study, figure 1given below is the process view of the summary of the risk factor identification performed in this paper. This process diagram explains how in this study risk factors for transmission line installation project are identified and since technical risks are found to be more important due to higher references given by authors and experts, separate risk factor analysis is needed to be done specifically for technical risk factors only and it results in nineteen sub technical risk factors in transmission

Table 2 : Showing the sub factors present in technical risk factors in transmission line installation projects

Activity	Risk Serial no and Risk Involved
I. Tower base preparation	TR1-Inaccurate tower blue prints TR2-Unchecked soil parameters. TR3-Faulty Backfilling and Wood/Swamp matting TR4-Faulty right of way
II. Construction of tower	TR5-Premature start of footing TR6-Lattice failure in tower TR7IEEE-guidelines neglected on site TR8-Faulty mechanical considerations for cross arms
III. Ground wires, electrodes and conductor erection	TR9-Improper stringing in Ground wires TR10-No testing of impulse current on ground rods TR11-Crossing with nearby transmission lines already present. TR12-No accurate tension and counterpoises in the conductor's erection
IV. Stringing and Sagging	TR13-Faulty sag installation TR14-Permit problems from local authority TR15-no proper usage of guard structure and net
V. Installation of hardware	TR16-Improper assembling of Hold down weights (especially in hilly areas) TR17-Emergence of uplift problem due to incorrect tension on joints of insulators
VI. Vibration Damper and Spacer installation	TR18-Improper testing of 'wind caused damage' on the surface of conductor. TR19-Improper handling of large diameter light weight conductors and splices.

line installation projects.

The process identifies the list of important sub technical risk factors and this study can prove as abase for risk mitigation planning for electrical transmission line installation projects.

CONCLUSION AND SCOPE FOR FURTHER STUDIES

The paper presents an account of various risks given by different authors for analyzing the project risk management. In our case the electrical transmission line installation projects are being studied. In the first segment of the paper general viewpoint of various authors is collected on project risk and five major risk categories are suggested by various authors and experts. The five major risk factors pooled in this study are Environmental Risk Factors, Financial Risk Factors, Human Risk Factors, Human Resource (Management) Risk Factors and Technical Risk Factors. Technical risk factors are being discussed and advocated by many authors as compared to other risk factors, the weight given to technical risk factor is also far greater than any other risks in the studies. In order to identify the technical risk factors this paper collects the view point of various authors on technical sub risk factors particularly.

In the second portion of study the sub factors in technical risk factor are analyzed and for this the project is divided in six divisions or stages and in each stage the risk identification is done. In the end nineteen sub technical risk factors are identified in this paper. Hence the Technical risks

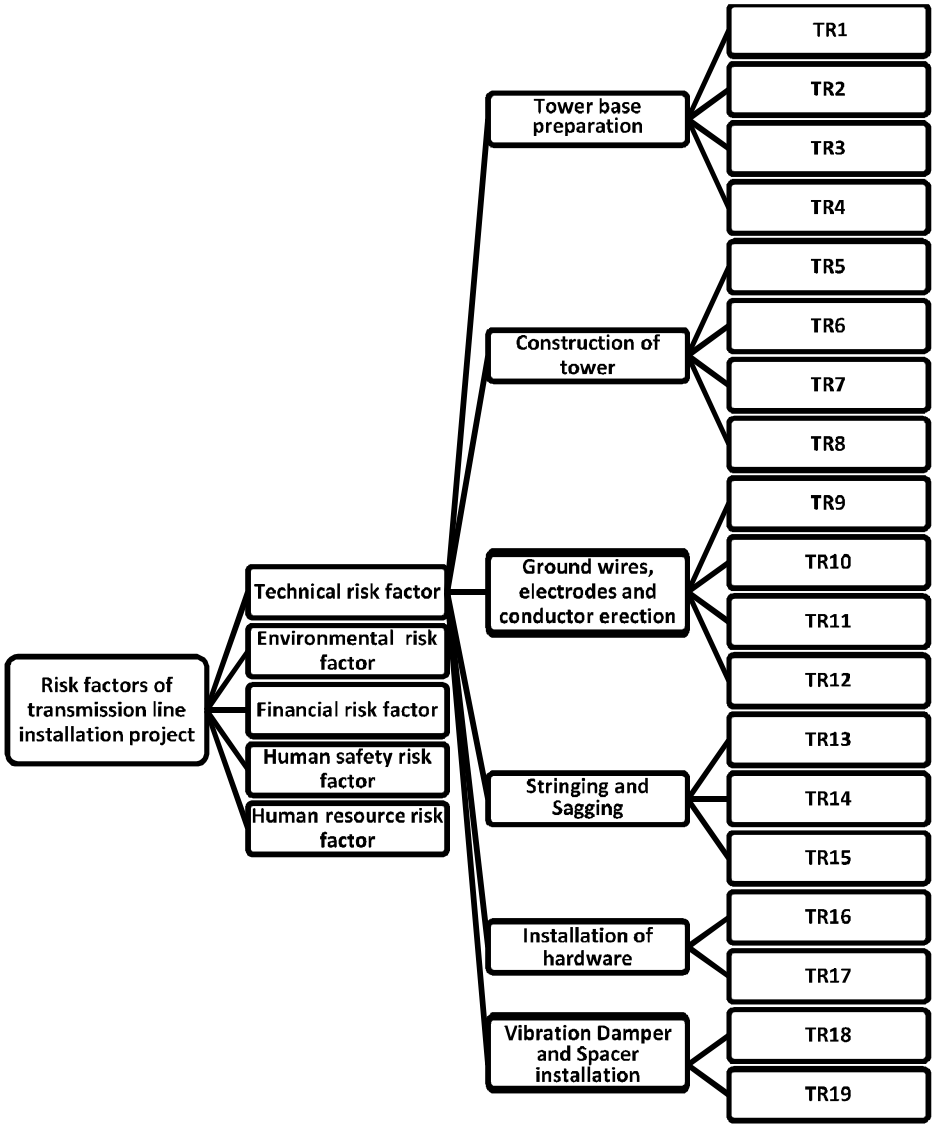

Figure 1: Process diagram evolved in the study for risk factor identification

are further sub divided into nineteen technical risk sub factors by dividing the project in six main categories.

The paper has produced a series of risk factors which can help in assessing risk level at any part of the electrical transmission line installation project. Technical risk factors came out to be most important since a huge number of studies are found to be concentrating on technical risks only and these technical risk factors are heavily inter related with other type of risks like environmental, financial etc so that is why study of technical risk came out to be very important for electrical transmission line installation projects.

In future similar studies can be done for other projects also but a real time analysis of secondary data is needed for that. More over this study can be helpful in analyzing the risk standards for a particular type of project by making a data base for each risk factor identified. This data base can prove helpful in analyzing the

risk level of any project from a specific industry standard. The accuracy of this study can be increased by applying various other models for risk assessment. In future division of risk into factors and sub factors can prove very helpful in deciding risk mitigation plan for a large number of projects. The overall linkage of risks is also needed to be assessed in future for a large variety of other type of projects. This methodology of breaking the project into smaller activities and then identifying the risk factor in each category can be helpful in other projects and also separate treatment for each section can be given.

In future more case studies of same type of projects can be analyzed in order to create an exhaustive ready to use list of risk factors, more over in this study the technical risk factors are analyzed in detail since they turn out to hold exponential importance level in risk assessment while in other type of projects some different risk types can also hold more importance.In future other risk factors can also be studied to make this process more accurate and this methodology can prove as a breeding ground forperforming standardize risk mitigation planning and can increase the accuracy of a conventional risk management process for different projects.

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