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Incorporating Uncertainty in Analyzing the Financial Feasibility of Solar Project in India*

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The recent drops in tariffs and the prevalent construction delay become concerns harming the financial sustainability of India's solar projects. However, the conventional financial assessment method does not adequately incorporate those risks. This paper suggests a way to incorporate construction delay risk of solar projects in the financial analysis. The paper identifies the key risk factors affecting the financial sustainability of the solar projects in India. To assess the identified risks, the paper builds a hypothetical solar project and runs Monte Carlo simulation by using @Risk Software. The financial and sensitivity analysis portray the impacts of construction delays on the key financial indicators, especially net present value and payback periods.

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1. INTRODUCTION

India has been utilized its ample solar potential by promoting the penetration of solar photovoltaic (PV) technologies in its national electricity grid. India's solar potential is estimated to reach 748 GW, and most parts of India are estimated to have solar radiations of 5 - 6 kWh/m^2/day. In addition to its solar potential, International Energy Agency Photovoltaic Power Systems Programme (2015) emphasized that the prices of solar PV modules, which take a large portion of solar PV construction cost, have drastically fallen by nearly 80% since 2009. In order to increase its national solar capacity up to 100GW by 2022, the government has implemented supportive policy measures, such as feed-in-tariffs, tax incentives and energy subsidies. By 2014, India became the fifth largest renewable investor. A year later, it had the world's ninth largest solar PV capacity.

However, India has not successfully explored its massive solar potentials. Though India's investment in solar power has increased significantly, Central Electricity Authority (2016) announced that only 10% of its solar potential or 7.8GW was installed by the end of June 2016. Based on India's solar potential of 748GW, there needs to be a significant increase of solar capacity installed. Bridge to India (2017), an energy consulting firm in India, warned a significantly dropped PPA electricity tariff due to excessive competition in recent years, in addition to India's not strong financial and regulatory system, becomes a concern that obstructs new private investment as well as leads to project delays or failures. According to Bridge to India (2016), already almost 40% of projects in state tenders has experienced significant delays or has scrapped. This implies the inclusion of potential risks, such as construction delay, financing issues, in their investment decision making becomes important in doing renewables in India. Also, continued delay and failure of solar deployments in India damage India's national efforts to boost solar PV investment and its national renewable target. Thus, the potential risks, including construction delays, output risk, and policy risk should be considered in the financial analysis in India. If the impacts of those risks significantly hamper the profitability of solar projects in India, those risks will obstruct further private investment in solar PV, which is required to exploit India's huge solar potential.

This paper aims to examine how the inclusion of the potential risk factors, especially the construction delays, affect the financial feasibility of a solar project in India. This study develops a financial model for financial analysis and runs Monte Carlo simulations to take into account various sources of uncertainties. Previously, the sensitivity analysis that alters the inputs has been widely used to assess uncertainties in researches, such as Wiser and Pickle (1998). However, the effectiveness of the traditional method is limited because it does not include the probability distributions of the input variables and use arbitrary values of the inputs. Instead, Harrison (2010) showed that Monte Carlo simulation considers the uncertainty of input variables with probability distributions and provides a probability distribution of the output. Khindanova (2013) applied Monte Carlo simulation method to evaluate a wind power generation investment. The study built both deterministic and probabilistic models to assess the investment risks and showed tradeoffs between risks and costs of a wind power generation project. Kroniger and Madlener (2014) assessed the risks associated with the investment in a hydrogen storage system through Monte Carlo simulations. Also, Madlener and Wenk (2008) used Monte Carlo simulation to assess the investment in five different technologies. Though many studies applied Monte Carlo simulation to assess renewable energy investments, Monte Carlo simulation method has not been widely applied to the investments in solar PV. Also, the impacts of the construction delay risk on the financial performance of solar projects in India remained unexplored. Thus, this paper contributes to the policy research and financial analysis of solar investment by applying Monte Carlo simulation.

This paper establishes a simple financial model of a solar PV project in India that incorporates various potential risk factors. In section 2.1, the paper introduces @Risk Software that helps the paper to run Monte Carlo simulation. In section 2.2, the paper explains the methodology that was used to examine the financial performance of the project. In section 2.3, the paper provides an overview of the base case project, Gangakhed solar PV project (a part of Asian Development Bank (ADB) Solar Park project in Maharashtra state) and the modified factors that are included in order to reflect the recent solar PV market conditions. The financial model and assumptions have been established based upon the base case project, other literature regarding macro-economic indicators, and recent information about renewable projects in India. In section 2.4, the paper explains potential risk factors that the project can face in construction and operation periods and how those risk factors affect the financial feasibility of the solar PV project. In section 3, the paper shows how each policy option affects the financial performance of the project. Section 4 is for conclusion and policy implication.

2. METHODOLOGY

2.1. @Risk Software

@Risk Software, developed by Palisade Corporation, is an Excel-based program that performs risk analysis using Monte Carlo simulation. This program includes functions that identify the distribution of existing data set, create various distributions, and run Monte Carlo simulation. By using those functions, @Risk Software enables the Excel-based financial model include those variable into the analysis. This paper establishes the financial model based on the information given by ADB project document, business reports, and solar and macroeconomic dataset from National Aeronautics and Space Administration (NASA) and World Bank. Afterwards, the paper uses @Risk Software to identify the best distribution set for the historical solar radiation dataset, identify key variables, and run Monte Carlo simulation by using distributions of selected key variables. @Risk Software provides the detailed statistical results that enable to show how those key variables affect the financial performance of the project. Lastly, @Risk Software allows to run sensitivity analysis that enables the paper analyzing the effects of different specifications, such as altering the mean construction delay periods.

2.2. Decision-Making Criteria

In order to attract the private investment, the understanding the decision-making process of private investors should be taken into account. Based on the financial model, the analysis focuses on the Net Present Value (NPV) and the Payback Period as important deciding factors. The Net Present Value is the method that compares the present value of future cash flows discounted by the discount rate to the initial investment. *T* and *R* denote the time period and discount rate, respectively. If the value is positive, the project provides a higher return than the required rate of return on the investment.

$$NPV = \sum_{t=1}^{T} \frac{Net\,Cashflow_t}{(1+r)^t} - C_0\,. \tag{1}$$

NPV is a key indicator that shows whether the project is worth to invest. This method considers the time value of money since the discount rate is the combination of the rate of returns of debt and equity that the developer can expect from other alternative investment opportunities. Another criterion used in the paper is the simple payback period. It is the number of periods that are required to recover the investment. If a project takes a long time to recover its investment, the developers will be less likely to invest in the project. The paper examines the effects of construction delays on these decision criteria.

2.3. Case Project: Gangakhed Solar PV Project in Maharashtra, India

In this section, the paper uses the information of the case project to establish the financial model of a solar PV project. This paper adopts some parts of the Gangakhed solar PV project, which is a part of the Maharashtra Solar Park Program, proposed by the Asian Development Bank. Based on this case,

Table 1 Gangakhed Project Summary

Capacity	30 MW
Technology	Multi-Crystalline PV
Location	Gangakhed, Parbhani dist. 18.882N 76.695E
Evacuation	33kV overhead transmission line (about 13km)
Adjusted Project Cost	INR 53.002 M per MW (Central Electricity Regulatory Authority, 2016)

Source: Mishra *et al*. (2014).

assumptions, such as solar radiation, loss factors and the rate of return of investors, are made by using other previous studies and publicly available dataset in order to incorporate a complete model as well as to address uncertainties. In order to reflect the dropped price of PV module in recent years, the benchmark cost provided by Central Electricity Regulatory Commission in March 2016 has been used to calculate the construction cost instead of Gangakhed project's construction cost per MW.

This study uses "Monthly Averaged Insolation Incident on a Horizontal Surface (kWh/m^2/day)" over 1984-2005 periods, provided by NASA, as an important input to incorporate the variability of the amount of electricity generated. By using @Risk Software, the paper defined the distribution of solar radiation data based on Akaike Information Criteria. As a result, the triangular distribution, which had the lowest Akaike Information Criteria, with minimum 4.88161 (kWh/m^2/day), maximum 5.47 (kWh/m^2/day), and mean 5.27387 (kWh/m^2/day) is selected.

In this analysis, the values of the parameters are selected in a conservative manner. The model uses the benchmark costs of PV modules, land, and transmission calculated from the Central Electricity Regulatory Commission, but a successful and experienced developer can develop a solar PV project with lower costs. Also, it assumes that through site selection and optimal tilt of modules could increase the solar radiation by 10%. Since NASA solar radiation data are collected not from the project site but from data collection points, site selection process may find a better project site with better solar quality than NASA's collection point. In addition, finding the optimal tilt angle, either by using non-tracking or tracking system, provides better chance to utilize more solar radiation for generation. These site selection process and technology reflect the 10% increase of solar radiation assumed in this paper.

To conduct the financial analysis, the 2016 electricity tariff of Rs. 4.43/kWh in the Maharashtra region, is used. In order to lower the electricity auction tariff, the auction process additionally provides varying levels of Viability Gap Funding (VGF) that the grant funds requested by bidders providing some portion of the upfront capital investment. Since the amount of VGF varies by bidders, the paper decides not to take this into account in the analysis. It assumes that the project is composed of 70% of debt and 30% equity. Based on those parameters, the model estimates the electricity generation and the cost as follows.

$$\begin{aligned} Electricity\ Generation = {} & Solar\ Radiation_t * Area\ needed * \\ & Module\ Efficiency * (1 - Loss) * degradation_t, \end{aligned} \tag{2}$$

$$Cost_t = Construction\ Cost + Inverter\ Cost + O\&M. \tag{3}$$

Table 2 displays the parameters, and their values and distributions used in the financial modeling of the case. The model uses two key variables, which are solar radiation and construction delay periods, and runs Monte Carlo simulation with 10,000 iterations reflecting the uncertainties of solar radiation, technical advancement, and its construction costs.

Table 2 Base Case Parameters

Distribution

Parameters	Value	Distribution	Source
Annual Solar Radiation	Min: 4.88161 (kWh/m^2/day) Max: 5.47 Mean: 5.27387	Triangular	NASA
Construction Delay Periods	Lambda = 5	Poisson Distribution	

Constant

Parameters	Value	Source
Construction Cost (INR/MW)	53.002 Million MR	Central Electricity Regulatory Authority (2016)
Plant Life	25 Years	Mishra *et al*. (2014)
Area Needed	8m^2/kWp	EPIA and Greenpeace (2011)
Electricity Tariff	Rs. 4.43 / kWh	Auction Tariff in June 2016
Module Efficiency	16%	Fraunhofer Institute for Solar Energy System (2016)
Annual Degradation of PV Module	0.5%	Jordan and Kurtz (2012)
Loss in PV System	Inverter Loss: 4% Soiling: 1% Other Losses: 17%	National Renewable Energy Laboratory (2016)
Inverter[1]	Life: 10 years Cost per MW: INR 4,000,000	Central Electricity Regulatory Authority (2016)
Operation Period	25 Years	Mishra *et al*. (2014)
O&M cost (INR/MW)	1.19 Million	Bridge to India (2017)
Construction Cost	Benchmark: 50,132,000 (Rs/MW)	CERC (2016)
Cost of Construction Delay Periods	Interest Payment during the delayed periods	
Rate of Return (Debt)	Domestic 10-year bond rate: 7.49% Spread: 400 bps Amortization for 12 years	
Rate of Return (Equity)	16%[2]	Bloomberg New Energy Finance (2016)
Inflation Rate	4.92% (2015-2016 Average)	World Bank

[1] In order to avoid burdening the inverter expense at once and to create maintenance reserve, the paper assumes to create reserve account and equally distribute the expense for 10 years.

[2] According to Bloomberg New Energy Finance (2016), the cost of equity for solar projects in India was estimated as 15.5%. Based on the information above, the paper decides to use 16% as the required rate of return for equity investment.

Depreciation Method	Straight line method (Accelerated) - 10 years: 7%/year - Rest: 1.33%/year	Mishra *et al*. (2014)
Tax Rate	33.99% (Minimum Alternative Tax at 19.8% for 10 years)	Mishra *et al*. (2014)
Exchange Rate	INR 66.724/USD (Average of daily FX from September 1st, 2016 to October 31, 2016)	Bloomberg

2.4. Key Risk Factors

The solar projects face various risk factors during the construction and operations periods. One of the major risk factors is the completion risk, which includes construction delay and extra construction cost. A characteristic of infrastructure projects, including solar projects, which requires large upfront investment, lead the project developer to have high leverage ratio. Though operational revenue is the only income source and there is no operational revenue during the construction period, the project requires to pay or capitalize the interest expenses that increase the required investment cost of the project. That is, the construction delay is a major risk for infrastructure projects. In India, the construction delay of solar projects is not uncommon. In recent years, a number of solar projects in India experienced the construction delay. Issues, such as land acquisition and permit issues, can delay the construction periods and amount considerable cost overrun. Also, unexpected accidents can also require the project to bear extra construction cost. Though it is a major risk factor, India does not have a publicly available database that shows the progress and status of solar project constructions in India. Therefore, the paper uses information gathered by news articles and interviews to establish hypothetical distribution to incorporate the construction delay risk into the financial analysis. Kenning (2016) mentioned that nearly 50% of solar capacity allotted between October 2011 and September 2014 had not been commissioned by the expected commissioning period, December 2015. Also, Manoj Kohli, the executive chairman of SB Energy, interviewed that three to six-month delay is not uncommon in India.[3)]

Intermittency is another key barrier for a solar project. Unlike other traditional power generation technology, renewables, including solar power, are intermittent that cannot provide stable electricity generation. Solar is the only fuel for the plant, and without solar radiation, the solar power plant cannot generate electricity and earn revenue to pay debt services. Though the case project site seems to have stable and solid solar radiation historically according to NASA dataset, it is hard to predict the actual amount of future solar radiation during the operations period beforehand. It indicates that the revenue stream will not be stable and fluctuate continuously according to the variability of the solar radiation. Also, changing environmental and social surroundings, such as changing weather patterns and air pollution, can affect the performance of the solar power plant. For instance, air pollution with dust and particulate matter reduces the efficiency of solar panel and reduces the amount of electricity generated and revenue. Therefore, this paper identifies the distribution of historical solar radiation data and incorporate it into the model.

The level of electricity tariff is a key factor that decides the financial performance of the project. Since the sales of electricity are the only revenue source for the project, setting appropriate electricity tariff is vital to determine the financial sustainability of the project. Though the project cost has been dropped rapidly thanks to a significant drop in solar panel cost, it is still an expensive option other than traditional power generation technologies, such as coal power plants. Also, to compensate the missing chances to generate revenues due to intermittency, the electricity tariffs need to be set at the level that can assure the developers to pay debt services and receive the normal return. In India, the auction process is used to determine the electricity tariffs, and the recent aggressive biddings and intense competition continuously lower the electricity tariff below Rs 3 per kWh. However, this tendency raises serious concerns about the financial sustainability of the tendered projects. The developers continue to take higher risks, and the assumptions made by developers are too optimistic that any serious potential

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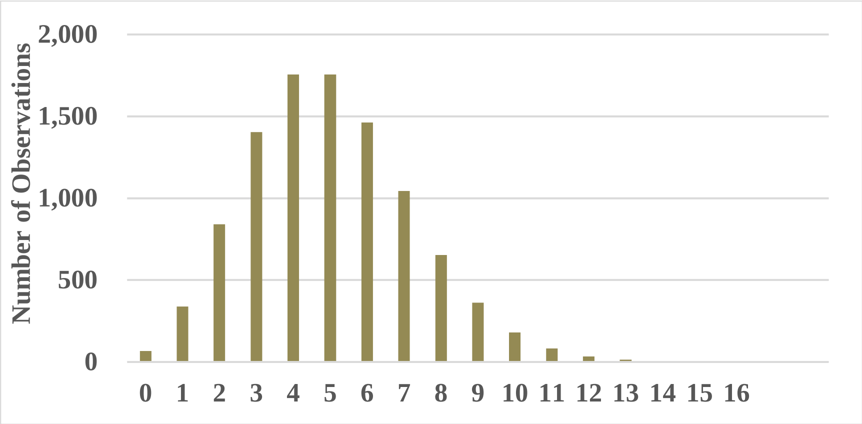
[3)] K. Chandrasekaran (2017).

Figure 1 Construction Delay Month (Distribution)



risks can make those projects vulnerable.

Based on the information, the paper establishes a hypothetical distribution of construction delay by using Poisson distribution. Since the construction delay period does not occur at the same time or same project and the construction delay period of a project is independent to that of another project, Poisson distribution can be a way to express the distribution of the construction delay periods. As shown in figure 1, the paper initially sets lambda of 5 that means the most frequent delay month as 5 months.

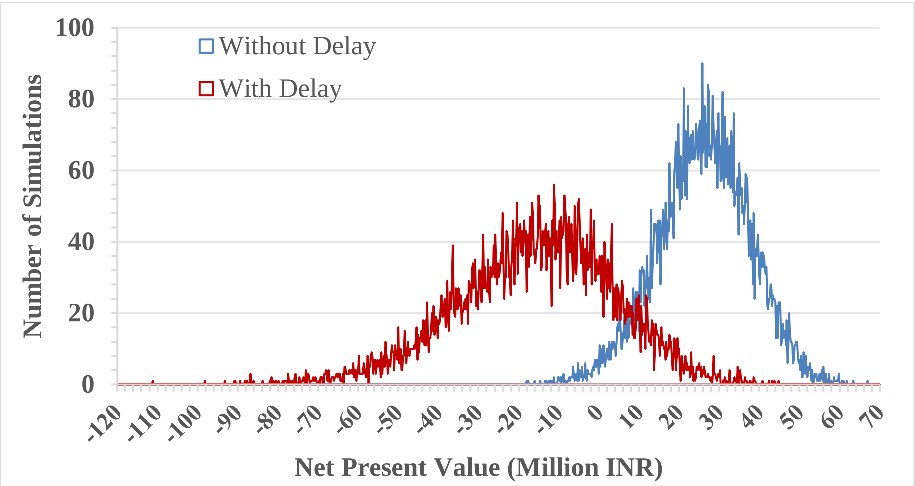
The additional costs accrued during the construction delay periods are limited to the accrued interest payments and the overhead expenses equivalent to 5% of total construction cost in order to analyze the financial feasibility conservatively. The additional costs for interests and overhead expenses are covered by debt financing. In addition, it assumes that the construction delay happens before the purchase of solar panels and includes the potential cost reduction in construction cost caused by panel price drop during delayed periods. Since the cost of panel accounts for approximately 62% of total construction cost measured by CERC and its price continues to drop rapidly, delaying the purchase of solar panel may reduce the project cost. PVX spot market price shows that the crystalline solar module prices in Southeast Asia and Taiwan drop 0.59% on average per month between September 2013 and

May 2017.[4)] Thus, the construction cost is designed to be reduced by 0.59% per month during the construction delay periods.

3. RISK AND FINANCIAL ANALYSIS

By using @Risk Software, the paper iterates 10,000 simulations with two key variables and analyzes the impacts of project construction delay on the project financial performance. The base case uses the auction tariff of INR 4.43/kWh without Viability Gap Funding (VGF). Since the parameters are selected in a conservative manner and the case does not include the Viability Gap Funding that recovers some portion of construction cost and has been included in many of the recent auction cases, the project is likely to provide negative results.

Figure 2 The Impacts of the Construction Delays on Net Present Values



4) PVXchange (2017).

Figure 3 The Impacts of the Construction Delays on Payback Periods

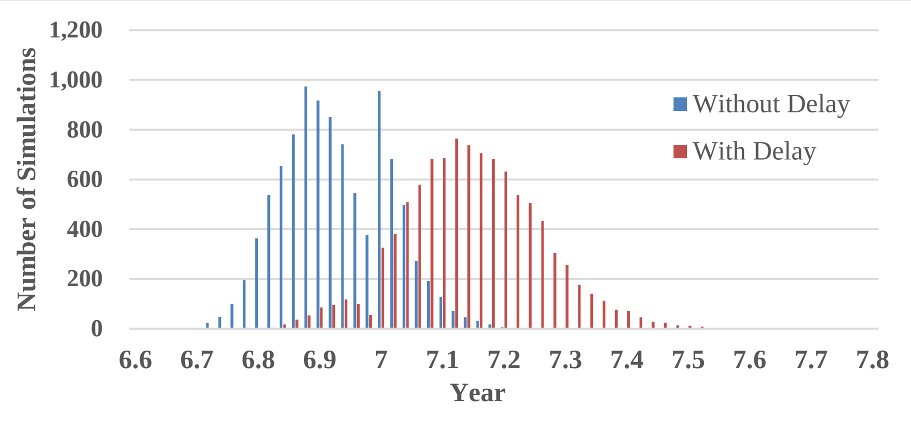
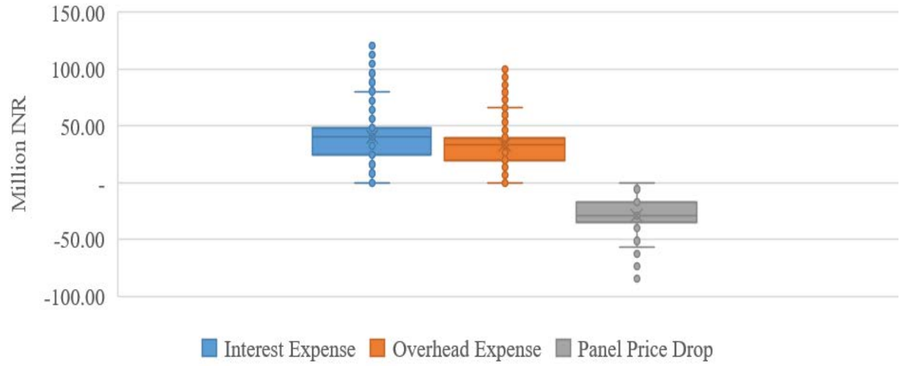


Table 3 Summary

	Unit	Delay	
		No	Yes
NPV (Average)	M INR	25.97	–15.90
NPV (Min)	M INR	–18.17	–111.35
NPV (Max)	M INR	66.84	44.80
Payback Periods (Average)	Year	6.94	7.16
Payback Periods (Min)	Year	6.72	6.79
Payback Periods (Max)	Year	7.25	7.66
% Below NPV=0	%	1.51	79.01

The analysis shows that the project initially provides solid financial results without including the construction delay and additional costs occurred by potential delays. This traditional method shows that the solar developers in India may believe that the investment is financially feasible and sustainable. Without incorporating the construction delay, the project's average NPV and payback periods are INR 25.97M and 6.94 years, respectively. Only 1.51% of all iterations shows negative NPV. Though only 1.5% of the simulations

Figure 4 Additional Expenses from Construction Delay (by factors)



has negative NPVs, it is notable that a large portion of simulations are located near NPV=0 and have tight profit margins. Combined with low auction tariff, this result can be partially explained by the volatile revenue streams caused by solar radiation and high benchmark construction cost identified by Central Electricity Regulatory Commission.

If the construction delay is considered in the analysis and additional costs occurred by construction delay are included, all of the project's financial performance indicators deteriorate. Average NPV and the payback periods become – INR 15.90M and 7.16 years, respectively. Especially, 79% of all scenarios has negative NPV, and a project with the lowest performance has NPV of – INR 111.35M. Compare to the traditional method that only 1% of simulations shows negative NPV, construction delay causes serious negative impacts on the sustainability of the solar project. That is, only few month of construction delays can make the project unsustainable, especially for the projects with near zero NPVs.

The impacts of each of the additional expenses or benefits occurred by the construction delay are shown as above. While the panel price drop reduces the construction cost by 28.94M on average, additional interest expense and overhead expense increase INR 40.14M and INR 33.13M, respectively.

3.1. Sensitivity Analysis with Different λ

In this section, the paper conducts sensitivity analysis by altering values of λ of Poisson distribution. This analysis shows a better picture of the impacts of construction delay periods on the financial performance of solar projects in India.

Figure 5 The Distribution of Construction Delay Months with Different λ Values

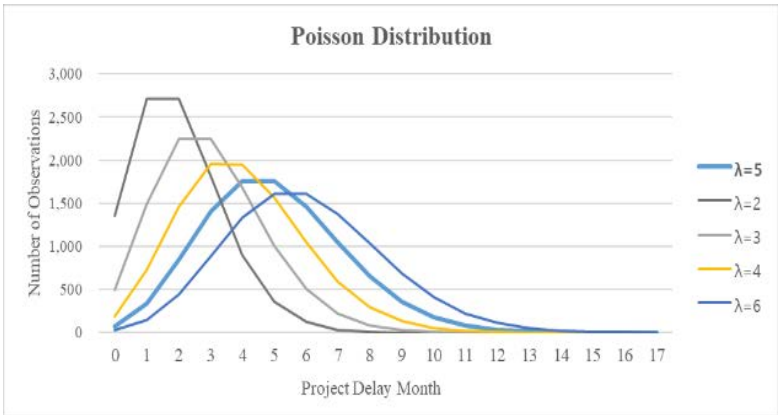


Figure 6 The Distributions of NPVs with Different Construction Delay Periods

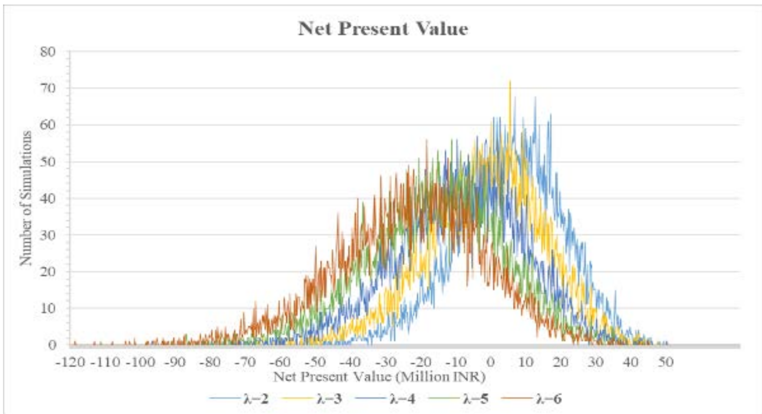


Table 4 Summary with Different λ Values

	Average NPV (M INR)	NPV<0 (%)	Payback
λ = 2	5.41	34.15%	7.05
λ = 3	–1.67	51.93%	7.09
λ = 4	–8.77	67.10%	7.12
λ = 5	–15.90	79.01%	7.16
λ = 6	–23.06	86.97%	7.19

The shape of the distribution of the construction delay periods differs by the values of Lambda. If the most frequent delay periods are located in the front, the impact of the construction delays on the financial performance will be reduced since the paper identified that the construction delay increases the construction cost in the previous section. Thus, the paper conducts sensitivity analysis by altering Lambda over the range of 3-6. The distribution graph of different lambdas is provided as below.

As the λ value increases, the distribution of NPV becomes flater and shifts toward left-side. This result means that if the construction delay month is expected to be longer, the financial performance of the project is likely to be less profitable, and it becomes harder for project developers to forecast the performance of the project. Especially, if the forecasted NPV of the project is near to zero, the construction delay is likely to deteriorate the financial sustainability of the project.

4. CONCLUSION AND POLICY IMPLICATION

This study examined how construction delay frequently occurring in India affects the financial feasibility of a solar project. Based on the financial model designed in this paper, it runs Monte Carlo simulations to analyze the financial feasibilities of a solar project in India. The essential cost factors, such as interest expense and 5% of overhead costs as additional construction delay costs, and the potential benefit of the drop in solar panel costs are included in the financial analysis.

The risk and financial analysis show that the traditional method to assess the financial feasibility does not adequately reflect the project risk factors and evaluate the sustainability of the project. Especially, the rapidly declining trend of electricity auction tariffs is likely to have squeezed developers' returns from the recently allotted projects and amplified the impacts of construction delay on the financial sustainability of the projects. In this analysis, it included only the essential cost factors, such as interest expense and low level of overhead costs, as types of the construction delay costs. The inclusion of basic cost overrun from construction delays damaged the financial sustainability significantly and made it difficult to understand the project's financial performance. However, the construction delay typically faces additional and further cost overruns, such as labor and rental costs, administrative costs, legal disputes. For example, poorly designed construction and project designs may fail to provide estimated output performance and require the adjustment of the original plan. Social and environmental issues, such as local settlement or environmental assessment, during the project lifetime can occur additional costs for assessing and resolving the issues. A recent report from Ernst & Young that analyzed 100 of the world's megaprojects in utility, power, and water sector showed that more than half of the projects experienced delays and over budget issues, and the global average overspend was more than 30% above the initial estimates. Thus, the inclusion of other additional cost overruns into the analysis will further damage the financial sustainability of the project.

The analysis indicates that the construction delay of a project could damage the financial feasibility of the projects, especially if the project is financially tight. Uncertain factors may deteriorate the financial performances of the projects, and they raise the project failure rate. If such project failures caused by the construction delay, it will eventually discourage the India's aggressive promotion of renewable energy. Failing to implement the national energy plan could increase social and economic costs to the national economy.

Therefore, it is quite necessary and appropriate for the policymakers to examine the solar auction process, which is important policy measures to promote solar project. This process can prevent excess bidding from the solar developers and introduce a system and database that could monitor the progress of solar projects in India.

To improve the project's financial sustainability, it is desirable for the authority to establish rules for hindering excessive auction competition that encourages the auction bidders not to bid too low in the solar auction process. The authority needs to require project developers to include their contingency plan in the auction process for the possible project delays. Also, it is necessary to design a comprehensive and well-organized selection process for developers. Before opening the solar auction, the authority needs to set transparent criteria to evaluate the potential bidder's ability, such as financial, governance, and prior experience comprehensively. Successful solar developers with know-how and experiences construct a solar PV project with lower costs than the benchmark cost and other competitors. They have experiences to avoid potential delays and know-how to handle potential delays during the project lifetime. It is a key for the authority to select successful and experienced developers in order to raise the probability of the successful completion of projects.

In addition, the authority should monitor the progress of allotted projects continuously and thoroughly and provide information to the public. Lack of information, such as incorrect local environment data including solar radiation, environmental regulations, etc., may lead the developers miscalculate the financial feasibility and make wrong decisions. For instance, the environmental regulations and local disputes are also sources of the project construction delay, and the solar radiation and local environmental data directly affect the estimation of the electricity generation and revenue stream. By establishing a transparent system that collects data and information and improve the accessibility to the public, solar developers establish a better business model to evaluate solar projects. Moreover, it can enhance the authority's capacity to evaluate and select better projects as well as shorten the time periods require to get permissions or settle any administrative disputes. An efficient administrative process can reduce the construction delay periods.

Moreover, establishing strict performance criteria that all solar projects require to satisfy as well as providing financial incentives to highly efficient panels and better performing inverters may lead solar project developers to improve the financial performance of their projects. Excess biddings may lead the solar project developers to lower the costs to win the auction and use lower efficient panels and equipment with lower price. Such sequences may increase the possibility that the commissioned projects fail to reach the expected performance and increase the operation and management costs to repair or replace those equipment. Therefore, stricter performance criteria that all solar project developers must satisfy as well as the financial supports, such as tax incentives and subsidies, to high efficient equipment are needed to be introduced.

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