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Risk Analysis on Offshore Windfarm Industry in South Korea: Based on the Jeonnam Offshore Windfarm Project

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Abstract: Recently, the Korean government has been actively promoting the smart city as their strategic agenda. However, to build smart cities that are greener, the authors believe it is essential to rapidly transit conventional energy sources such as fossil fuels to renewable energy. Although there is a big potential for Offshore wind in Korea, there has not been a full-scale commercial offshore wind farm until today. Since Korea is relatively a new market compared to the EU, it can be risky for developers. The authors will introduce risk management best practices in the offshore wind industry applicable to the Korean environment. This paper will mainly introduce an offshore wind project size of 99 MW. The project is expecting a Finance Close (FC) in Q3 2022, so the project team has prepared a risk register with over 150 risks and levers throughout the project lifecycle. Overall risks include risks with Development Expenditure (DEVEX) impact, a Capital Expenditure (CAPEX) impact, and an Operating Expenditure (OPEX) impact. Based on the identified risks, a more qualitative assessment of Cost and Schedule Impact was conducted. In conclusion, a Monte Carlo simulation was performed to propose a quantitative risk assessment to evaluate a benchmark contingency of the project cost.

Keywords: Project Management, Risk Management, Offshore Wind Energy, Monte Carlo Simulation

1. INTRODUCTION

South Korea is the 13th largest greenhouse gas emitter, which is about 1.38 percent of the global emissions. In the 2021 U.N. Climate Change Conference COP26, the South Korean government promised to reduce GHG emissions by 40 percent from 2018 levels. To achieve this goal, renewable energy has a big potential and is capable of possibly replacing conventional energy sources such as nuclear power and fossil fuels in Korea [1]. Out of various renewable energy sources, i.e., solar, geothermal, onshore, offshore wind, etc. offshore wind has a high potential due to fewer environmental constraints compared to onshore wind and solar. Also, there is a global trend of high attention to renewable energy [2]. Moreover, the wind industry has increasingly moved offshore to achieve stronger and more stable wind speeds. Like any other construction project, building an offshore wind farm has significant risks due to its higher complexity [3]. Project risk management is a spontaneous action to be practiced throughout the entire project [4]. Best practices in risk management can help the project reduce the time delay, cost overruns, and any other negative consequences on the project. In chapter 2, potential risks were identified using qualitative risk assessment through risk workshops. Then in chapter 3, quantitative risk assessment is performed by analyzing the cost and schedule impact of every risk. For a more comprehensive risk assessment, the Monte Carlo simulation is performed, and the results are discussed.

The goal of this paper is to first implement a risk assessment and perform a quantitative risk assessment [5] of the currently identified risks particular to a Korean market from the developer's perspective. In this study, offshore wind sector subject matter experts in each package (i.e., Foundations, Wind Turbines, Cables, O&M, Finance, and Permitting, etc.) were brainstormed/interviewed to identify and categorize risk. After identifying various types of risks particular to the Korean environment, a risk assessment is developed to evaluate the cumulative risk among the offshore wind in Korea. Finally, Monte Carlo Simulation was conducted to evaluate project risk contingency to propose and share best practices in risk management

2. RESEARCH METHODOLOGY

To assess the risks associated with offshore wind in Korea, the process is as follows. First, a qualitative risk assessment with subject-matter experts who have more than 10 years of offshore wind experience is conducted. A qualitative risk assessment method compiles, combines, and presents evidence to establish a nonnumerical estimate and description of risk [10]. As a result, risk description, risk responses, and mitigations are collected. Second, based on the identified risks, a quantitative risk assessment is conducted using the Monte Carlo Simulation. Quantitative risk assessment depends on numerical expressions of risks in the risk characterization [10]. Good risk management begins with divergent thinking: many ideas and various perspectives [10]. For this purpose, initial risks were successfully brainstormed by subject matter experts from the offshore wind industry.

2.1 Commercial/financial risk assessment

It is understood that the risks involved during construction, commissioning, and operating an offshore windfarm are reflected in the cost of the capital [9]. For commercial/financial risk in the offshore wind industry, it is an important first step during the development phase of the project often with an impact on the DEVEX budget for the project. In this study, a total of 13 risks were identified during the workshop. Key financial risks are summarized in Table 1 below.

Table 6. Summary of Key Commercial/Financial Risks

No.	Key Risk Description	Mitigation/Action Plan	Probability (%)
1.	Offtake Price Decrease	• Investigate other options 3. Meeting with MOTIE to better understand SMP price change	4. H – 30% to 60%
2	Risk of FC being delayed beyond 1 Sep NTP longstop dates	• Continue to target FC as 1 Aug • Conduct meeting with KEPCO and get signed MoM to confirm KEPCO	5. M – 15% to 30%

		intentions to meet contract schedule (Dec 2023 Grid Available)	
3	REC Multiplier Am-Tae Island Approval	• Continue dialogue with KEA and initiate pre-notification	6. M – 15% to 30%
4	Bankruptcy of a contractor or subcontractor	• make sure contractors have sufficient Open financial stability and if not, the case make sure back-up strategy is available	7. M – 15% to 30%

2.2 Environment and consents risk assessment

There are various permits required before building an offshore wind farm in Korea. Also, it is essential to obtain key permits before the Financial Close of the Project. A total of 20 environmental and consenting risks were identified. Key risks are summarized in Table 2 below.

Table 7. Summary of Key Environment and Consents Risks

No.	Key Risk Description	Mitigation/Action Plan	Probability (%)
1.	Risk of Requirement for additional radar mitigation measures due to change in WTG rotor diameter	• Discuss with Shinan county to first approve Open the PWOP on the condition of future agreement with the MND • Agree strategy and plan for potential update 100% Open of study with expert consultant 8.	VH – 60 % to 100%
2.	Critical Habitat Assessment	• Initiate drafting of Critical Habitat Assessment Q1 2022 when marine bird data are available • Monitoring findings 9. from marine bird surveys 10.	VL – 0% to 5%
3.	Securing Private Landowner Agreements	• Secure agreement on cable route with Shinan county • Confirm if negotiated amount with remaining landowners is above CAPEX allocation • Complete negotiations at the earliest opportunity with landowners	M – 15 % to 30%
4.	Marine Bird Surveys	• Monitor results from monthly bird surveys and initiate collision risk modelling in Q1 2022	L – 5% to 15%

2.3 EPC risk assessment

EPC Risks encapsulates all engineering packages including Foundations, Wind Turbine Generator, Electrical &Transmissions, and QHSE. A total of 81 EPC risks were brainstormed/identified during the workshop. Due to building a full-scale commercial offshore wind farm in Korea for the first time, there were many risks related to various construction activities as summarized in Table 3 below.

Table 3. Summary of Key EPC Risks

No.	Key Risk Description	Mitigation/Action Plan	Probability (%)
1.	Localization cost of foreign WTG supplier	• Agree on risk split with the turbine supplier	H – 30% to 60%
2.	Cable fault due to seabed mobility	• (condition) monitoring (CMS) • Understand the revenue impact of cable fault during operation	L – 5% to 15%
3.	Grid availability	• Follow-up the progress of building KEPCO S/S and 154 kV transmission line • Monthly progress updates to PM team on KEPCO status • Establish grid connection TF	L – 5% to 15%
4.	Main transformer failure during commissioning	• Ensure sufficient quality control during installation and commissioning	VL – 0% to 5%

2.4 O&M risk assessment

Table 4. Summary of Key O&M Risks

No.	Key Risk Description	Action Plan	Probability (%)
1.	Curtailment of the wind farm required by KPX due to grid restriction	• Review assumptions on project business a case when there is more clarity	L – 5% to 15%
2.	Seabed mobility impacting array/export cables integrity – water depth for jack-up	• Regular inspections of the cables (OPEX budget to include frequent inspection/corrective actions)	L – 5% to 15%
3.	Currency risk for SAA (39% EUR)	• JOWP will introduce mechanism where FX basket will be revised every 5 years	VH – 60% to 100%
4.	OPEX reflecting detailed design and final EPC contract agreements	• Workshop with packages (include handover process) to revise/align with design basis	VL – 0% to 5%

The life cycle of an offshore wind farm consists of several phases from the project development until decommissioning. OPEX consists of operational costs, maintenance, inspection, insurance, leasing, taxes, etc. [6] A total of 22 risks were identified during the workshop. A summary is shown in Table 4 below.

2.5. Initial risk assessment results

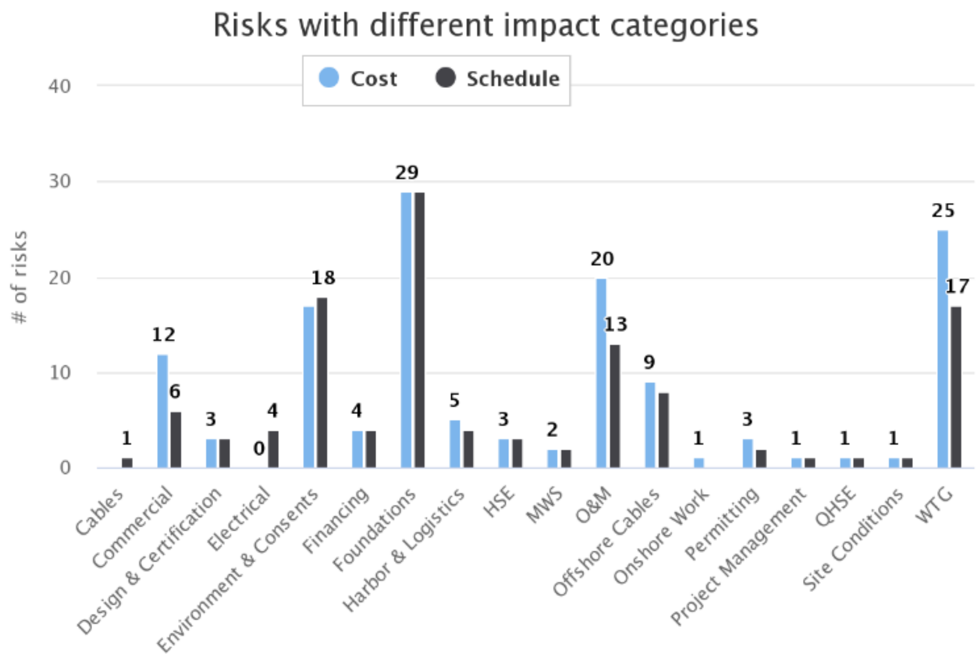

Figure 18. Risks with different Impact categories

A total of 131 risks were categorized shown in the histogram above. Based on these risks, the Heatmap was generated shown in Figure 2 below based on the probability scale shown in Table 5 below.

Table 5. Probability Scale

Probability	% Range	Color Code	Description
P1	VL – 0% to 5%	Green	A similar event has not yet occurred in our industry
P2	L – 5% to 15%	Green	A similar event has occurred somewhere in our industry
P3	M – 15% to 30%	Amber	Has occurred several times last year worldwide
P4	H – 30% to 60%	Red	Occurs several times
P5	VH– 60% to 100%	Red	Occurs weekly

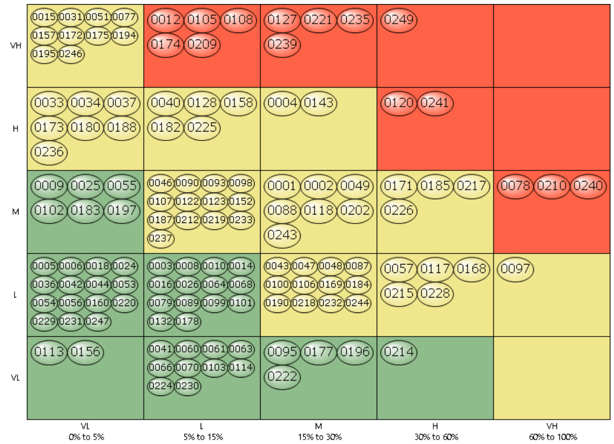

Figure 19. Risk Live Matrix Example

3. QUANTITATIVE RISK ASSESSMENT USING MONTE CARLO SIMULATION

3.1. MONTE CARLO SIMULATION

For quantitative risk assessment, Monte Carlo simulation (MC simulation) is an effective approach to performing what-if analysis with many hundreds of iterations [7]. It is a popular simulation technique, which enables risk analysts to propagate the uncertainty in a decision problem and produce a numerical description of the range of potential model outputs [10]. In this study, the authors have used 100,000 iterations with a triangular distribution. In general, the MC simulation includes the following steps: First, specify the uncertain input parameters of cost & schedule. Second, triangular distribution will be selected to describe the possible value range for each uncertain input parameter. Lastly, generate the output variable by randomly selecting input values based on the triangular distribution for 100,000 iterations.

3.2. THE TRIANGULAR DISTRIBUTION

In probability theory and statistics, it has three parameters: a lower limit a, upper limit b, and mode c, where $a<b$ and $a \leq c \leq b$ [8]

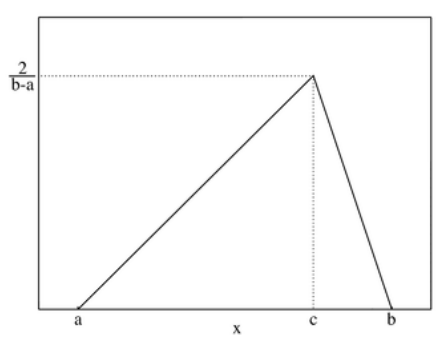

Figure 20. Probability Density Function for Triangular Distribution

In each run, a random number between 0 and 1 is generated for each risk. This will be measured towards the probability of the identified risk. If it is lower than the probability, the risk will fire. When risk fires, it is given a value based on a triangular distribution of the three estimates (min, most likelihood, and max) given during the qualitative assessment. Then, a new randomized number between 0 to 1 is then used to select a value from the triangular distribution. All fired risks are then counted as the value of each simulation run. The simulation runs are then sorted from lowest to highest to create P10, P50, and P90 values.

4. RESULTS AND DISCUSSION

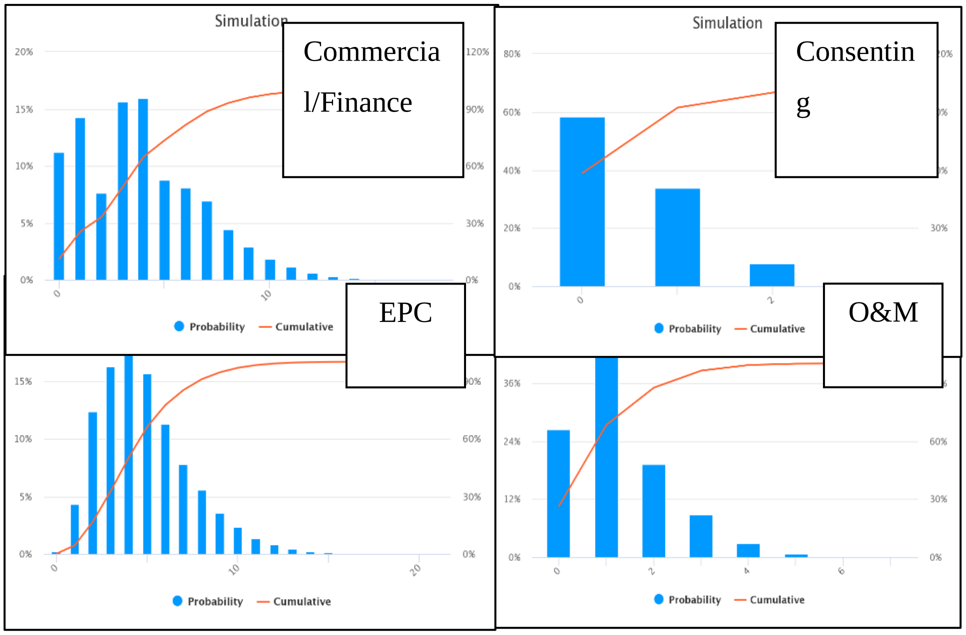

Figure 21. MC Simulation Result on the cost impact of each package

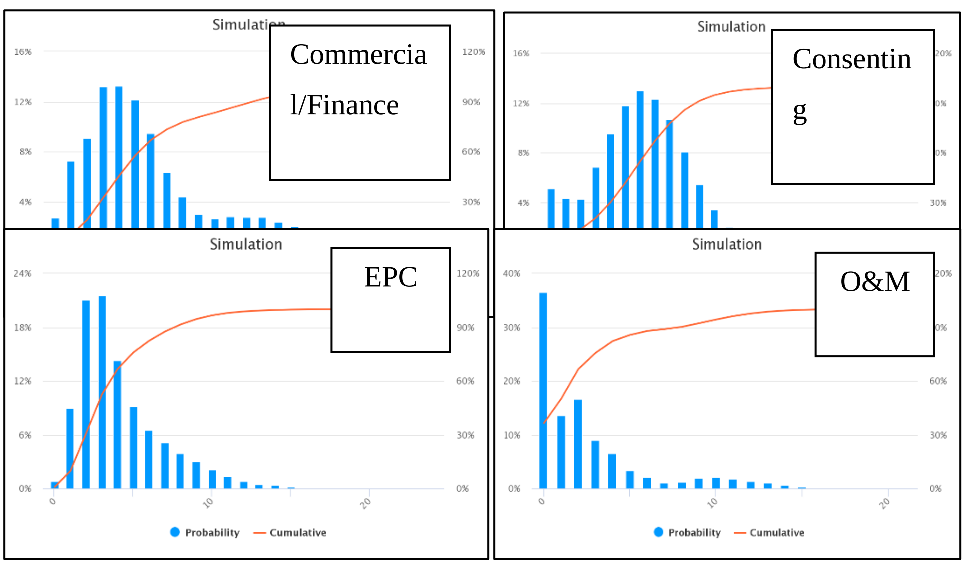

Figure 5. MC Simulation Result on Schedule impact of each package

After running the Monte Carlo Simulation for both cost and schedule, the result is shown above in Figure 4 for Cost Impact and Figure 5 for Schedule Impact. As the result is shown, the MC simulation was run for each package. First, for commercial/financial risks, the MC simulation run had a result of 65.56 billion KRW and 133 days for P50 contingency. Second, for environment/consenting risks, the MC simulation run had a result of 5.53 billion KRW and 124 days for P50 contingency. Third, for EPC risks, the MC simulation run had a result of 51.43 billion KRW and 175 days for P50 contingency. And finally, for O&M risks, the MC simulation run had a result of 9.96 billion KRW and 24 days for P50 contingency. In summary, the MC simulation run showed the result of contingency below 10% of the total project cost, which is a typical benchmark contingency for best practice in risk management.

5. CONCLUSION

In this study, a comprehensive discussion of risks associated with an offshore wind farm in Korea from the Developer's perspective is introduced. This paper also presented the Monte Carlo Simulation result on offshore wind packages (i.e., WTG, FOU, E&T, O&M, Finance, Permitting, etc.) with the most likely contingency value of P50 results on both costs and schedule. Building an offshore wind farm is a relatively new market for Korea so there is high anticipation of risks from various packages. This paper presented good insights into key risk categories in offshore wind and further investigated potential risks in the Korean offshore wind market, which can eventually help decision-makers de-risk when building an offshore wind farm in the new market.

Korea is a challenging market to build an offshore wind farm due to being a new market. Despite various constraints, the authors have performed insightful risk assessments that can help decision-makers to mitigate foreseeable risks in the project. Also, this paper can be benchmarked to other new markets around the globe in the future.

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