

Uncertainty Assessment for Updating Platform Decommissioning Alternatives Cost using Net Present Value Approach

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Abstract

Background/Objectives: Offshore oil and gas platform are aging in Asian Pacific Region and requiring a transparent decommissioning framework to address the major environmental impacts and cost pertaining the removal of offshore structures. This paper endeavors to establish a benchmark model to update platform decommissioning cost for four decommissioning options. **Methods/Statistical Analysis:** This paper provides a benchmark methodology adopting a case study for a previous decommissioning project to estimate and update future decommissioning cost based on Net Present Value (NPV) approach. Linear regression was established to predict cost inflation in decommissioning projects to be put to use in NPV method. Monte Carlo Simulations were employed to assess and evaluate uncertainty, and variability of each decommissioning alternative cost model to validate their exemplary implementation. **Findings:** After implementing Net Present Value methodology to attain platform decommissioning cost, it was found that platform decommissioning costs were USD91,997,398.97 USD29,312,019.08 USD36,913,049.82, and USD21,185,843.13 for complete removal, partial removal, conversion to reef, and re-using platform for wind turbine power generation respectively. These cost data reveal the tremendous cost incurred by platform's owners due to decommissioning. Uncertainty and variability of cost update estimation were demonstrated through Monte Carlo Simulations. After running 100,000 simulations, the results showed insignificant discrepancy with uncertainty ratio varies between 0.023% and 0.10% for the four decommissioning alternatives. Therefore, Monte Carlo Simulation exhibits a very good agreement with the cost estimate using NPV which just confirms the viability and applicability of utilizing NPV method in updating decommissioning cost for offshore installations. Hence, the contribution of this study is significant and timely efficient, allowing for cost update through systematic method instead of embracing regression analysis which is tedious and time-consuming. **Application/Improvements:** Net Present Value methodology may be useful and newly tool in updating platform decommissioning cost, and can strengthen its applicability in this field by incorporating probabilistic method as such Monte Carlo Simulation.

Keywords: Net Present Value, Measuring Uncertainty, Monte Carlo Method, Platform Decommissioning Cost

1. Introduction

The oil and gas offshore industry is rapidly approaching a decommissioning crisis as significant numbers of offshore

platforms are reaching the end of their design life. Currently, there are more than 7500 platforms worldwide which were installed in shallow and deep water depth to produce and process the hydrocarbons¹. Decommissioning operation is

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understood to be the reverse process of platform installation with less complexity and constrains in project milestones. The requirement for shallow and deep water platform removal is merely similar, despite the high cost incurred in deep water decommissioning². From operators' prospective decommissioning is a responsibility that will contribute to hugely incurred expenses in the future, however from government's view decommissioning represents a threat to the society and must be removed in compliance with international laws and regulations. Decommissioning activities are likely to increase in Asia Pacific Region and in Peninsula of Malaysia, Sabah and Sarawak in particular. According to³, there are around 300 fixed offshore platforms scattered in Malaysian's region. Approximately, 48.1% of these structures have exceeded their 25-30 years design life⁴. It was also reported all platforms in Malaysia territory are fixed platforms which were installed in shallow water depth not exceeding 200 meters⁴.

Offshore structures are composed of topside and substructure, where substructures can be either gravity based which rest on the sea bed through its own weight or footing and a jacket anchored to the seabed⁵. The trend of decommissioning activities kept rising significantly in conjunction with reservoir depletion, whenever there is no mark of hope the Enhanced Oil Recovery (EOR) process is still eligible for enhancing the productivity. There are several decommissioning alternatives available to dispose of offshore platform structures including complete removal, partial removal of the upper portion while neglecting the lower portion in place, and dismantling the structure before toppling them in the sea floor as artificial reef⁶. The cost of decommissioning offshore structures is heterogeneous as there are no two identical platforms, so the cost is directly dependable on the cost of services, size of the structure, and the time required to complete each step of the process⁷. Economic analysis using NPV approach is crucial in identifying the best removal option by which the superior option has the lowest NPV⁸.

The process of offshore platform decommissioning comprehends several steps involving, project management, engineering and planning; permitting and regulatory compliance; platform preparation; well plugging and abandonment; conductor removal; mobilization and demobilization of derrick barge and equipment; platform removal; pipeline and power cable decommissioning, material disposal and site clearance⁹.

1.1 Platform to Reef

Rig to reef is a routine of converting offshore oil and gas platform into artificial reef. The creation of artificial reef is a good example of how the oil and gas industry, societies, and government can agree on a consensus stand that might enhance the marine organisms. The practices of turning the obsolete structures to biotic reef have been established in the United States, Brunei, and Malaysia¹⁰. Despite the high number of offshore platforms in Malaysia, there is only one platform of which was made into an artificial reef known as the Baram-8 platform¹⁰. Operators would rather exercise the artificial reef program rather than bringing the disused structures to shore since it leads to a significant reduction of the incurred cost. In the context, many advantages can be contrived of using platform as artificial reef. Manmade structures may enhance the ecological habitation of marine creatures by providing a biodiversity to preserve their proliferation and recreating a commercialized zone for fishing¹¹. The usage of platform as reef can potentially improve population connectivity, and minimizing the environmental impacts as well as lowering the incurred expenses¹².

2. Methodology

2.1 Regression Model Formulation

Regression model is a statistical method to investigate a relationship between independent and dependent variables in order to accomplish the paper's objective. A linear regression model is chosen over high-low method due to its reliability and consistency in cost estimation which allows us to predict the dependent variable (derrick barge price rate) based on the independent variable (number of year). Assumptions and a set of data was adopted from Proserv Offshore with a required modification to serve the purpose of attaining the annual inflation rate¹³. The quoted data for derrick barge price from 1996 to 2008 was tabulated as in Table 2. A mathematical formulation of linear regression model is defined as follows:

$$y = f(x) = a_0 + a_1x \quad (1)$$

Where, a_0 is the intercept of y axis at zero year, and a_1 is the slope of the model.

MINITAB software will be utilized to generate the outputs of R square, adjusted R², and a_0 and a_1 coefficient

as well as the linear regression model equation. Hence, the value of R^2 varies between 0 to 100%.

2.2 Inflation Rate

Inflationary trends in decommissioning cost are dependable on derrick barge price rate by which the derrick barge price is calculated using the established regression model.

$$(\%)Inflationrate_{F-I} = \frac{F-I}{I} \times 100 \quad (2)$$

Where, F is value of derrick barge price rate in the succeeding year, and I is value of derrick barge price in the preceding year.

Geometric mean is utilized to achieve the average inflation rate per year as defined by equation 3.

$$\left(\prod_{i=1}^n a_i \right)^{1/n} = \sqrt[n]{a_1 a_2 a_3 \dots a_n} \quad (3)$$

2.3 Financial Assessment of Decommissioning Options

Economic analysis is carried out to evaluate the resultant cost of four decommissioning options namely, complete removal, partial removal, and conversion to reef as well as re-using offshore platform for wind power generation. Decommissioning of offshore platform relies on several criteria to measure the feasibility of the project; one of these criteria is financial criteria which can be measured by using NPV approach. The NPV approach is prepared to provide a systematic update for platform decommissioning' cost

based on a previous field data. The proposed approach is demonstrated in a case study of a previous platform that has the expenses of all cost components. Gail Platform is adopted as the case study for this paper¹⁴. Table 1 summarizes the cost components of Gail Platform for three removal options including complete, partial removal, and conversion to reef which was estimated as in year 2000. The adjustment for inflationary trend was necessary in order to obtain the cost of decommissioning between the year 2000 and 2016 using NPV method. Hence, the decommissioning cost update is determined by implementing equation 4.

$$FC = PC(1+i)^t \quad (4)$$

Where, FC is future cost, PC is present cost at year 2000, i is inflation rate, and t analysis period in year.

Re-use Option: The re-use of offshore platform for wind turbine power generation involves initially partial removal followed by the installation of 4.3MW power wind turbine. The cost estimation of NPV for re-using offshore platform for wind turbine power generation undergoes a process of mathematical formulation as summarized below:

Future worth:

$$FC = PC * (1+i)^t \quad (5)$$

NPV for operation & maintenance:

$$NPV(t,n) = \sum_{t=1}^n \frac{C_t}{(1+i)^t} \quad (6)$$

Table 1. Cost components for complete, partial removal, and conversion to reef of Gail platform adapted from¹⁴

Cost components in Dollar USD (\$)	Complete removal	Partial removal	Conversion to reef
Semi-submersible crane vessel	7520000	4042752	4042752
Mob and Demob of crew and equipment	2671502	794098	774098
Well plugging & abandonment	4049414.56	4049414.56	4049414.56
Topside and substructures removal	1776756	1776756	1776756
pipeline decommissioning	1266942	1266942	1266942
conductor removal	3358667	957000	3358667
platform removal	23403352	1819834	3779271
onshore disposal	11150784	2893332	3196536
project management & engineering	3443460	775011	1148155
Site clearance	2086746	973769	973769
Total Cost at year 2000 (\$)	60,727,623.60	19,348,908.56	24,366,360.56

Where C_t is the net cash flow.

Annual energy output:

$$AEO = w * n * cf \tag{7}$$

Where, w is wind turbine power rate, n is number of hours per year, and cf is the capacity factor.

Net revenue:

$$NR = AEO * p \tag{8}$$

Where, p is the price of electricity which is estimated to be \$0.07.

NPV for re-using option:

$$NPV = TE - NPV_R \tag{9}$$

Where, TE is the total expenditure cost

2.4 Evaluation of NPV using Monte Carlo Simulation

Monte Carlo Simulation is utilizing to evaluate risks and uncertainties which are likely to exist since NPV’s approach deals with cost in future. Meanwhile, @ risk software using Monte Carlo Simulation has showcased its significance in assessing the associated risk and uncertainty in cost estimations. Practically, Monte Carlo simulation performs a risk analysis to show the possible outcomes and informs how likely they are to occur. This means, it can enable the stakeholders to decide which risk to accept and which ones to avoid, allowing for the best decision making under uncertainty. Therefore, one can be able to anticipate the percentage of success and failure in the project. The Algorithm of Monte Carlo Simulation is commenced with probability distribution inputs as presented in Figure 1.

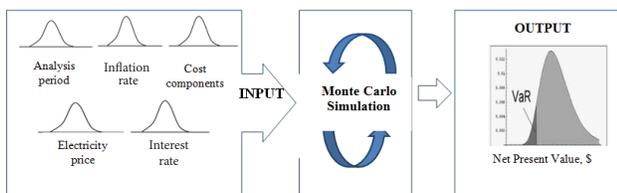


Figure 1. Assessing NPV using Monte Carlo Simulation.

3. Results and Discussion

3.1 Linear Regression Model

Regression model was developed by adapting previous attributes data from POCSR (Pacific Outer Continental Shelf

Region)¹³. These data were modified and used since there is no published data available for a decommissioned offshore platform in Malaysia. According to the model summary, as shown in Figure 2, it can be clearly seen that the independent variable (number of year) was crucial in the prediction of dependent variable (derrick barge price). Additionally, the graph shows R square value of 72.4% of the total variability of derrick barge cost. Compelling, the difference between R² and adjusted R² has no big discrepancy resulting in a minimal error on the output of dependent variable (Derrick Barge). The regression analysis also showed that the established regression model has a high ability to predict the derrick barge price rate since the adjusted R square value is beyond 50% which means the variability percentage in dependent variable is explained by the model as seen in Figure 2.

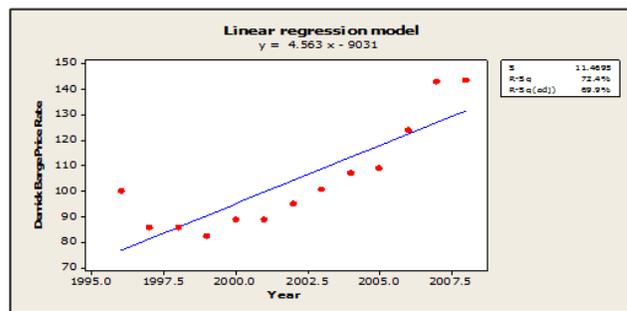


Figure 2. Derrick barge price vs number of years

The estimated price of derrick barge after year 2008 using the established regression model presented no big variance with the actual cost estimated by Proserv Offshore as in Table 2.

$$DB(USD) = -9031 + 4.563NY \tag{10}$$

Where, DB is Derrick Barge Price in USD, NY is Number of Years.

3.2 Inflation Rate

Table 2 summarizes inflationary trends across the period. Thus, it is denoted, there is a progressive increase in the price of the derrick barge due to inflation which will definitely impact the platform decommissioning cost eventually. Between year 1996 and 2008 the trends alternate a stable fluctuation, however the following years witnessed a steady inflation in derrick barge cost. An inflation of 15% in derrick barge price was observed by the end of 2007 followed by a drop to almost 0.5%

in the next year. Between the years 2008 and 2016, the established linear regression enabled us to predict the inflation in derrick barge price accordingly. The year 2009 witnessed a deflation of -5.10 percent, hence negative inflation rate is known as deflation. The prediction of derrick barge price rate was calculated by utilizing equation 10, allowing us to determine cost inflation using equation 2 as tabulated in Table 2.

In order to obtain the current inflation rate, it was necessarily to get the geometric average of overall annual inflation rate which was equivalent to 2.63%. This average rate of inflation was used in NPV approach to update the decommissioning cost for the four decommissioning options.

3.3 Updating the Cost of Platform Decommissioning using NPV Approach

The incurred cost of platform decommissioning was estimated using NPV method which involves the analysis and determination of the future value. This method is viable in conducting the economic analysis to predict the future cost of platform removal. The current estimated NPV for

complete removal, partial removal, and conversion to reef were calculated as seen in Table 3.

In contrast, the NPV for re-using platform for wind turbine power generation was estimated through a series of calculation as illustrated in the methodology section. The expenses involving wind turbine installations cost which was adopted from National Renewable Energy Laboratory (NREL) report. According to NREL, the capital expenditure cost for offshore wind turbine is about USD 1210/kw which is two times a typical onshore wind turbine system. A 4.3 MW wind turbine is chosen to be installed after completing a partial removal of the platform. This turbine was estimated to work for a 20 year lifespan with a 39% capacity factor¹⁵.

A necessary assumption was made for interest rate and electricity price with 7% and \$0.07 respectively. The annual revenue generated from 4.3MW wind turbine was calculated to be USD 1,028336.40 which shows a big amount of income will be earned as a result of re-using platform for other purposes as such wind turbine power generation. Not to forget the annual cost of operation and maintenance which was determined to be USD 341,748

Table 2. Derrick barge price rate with the corresponding Inflation rate

Year(n)	Derrick Barge Price Rate	Inflation rate (%)	Year(n)	Derrick Barge Price Rate	Inflation rate (%)
1996	100		2007	142.961	15.198
1997	85.695	-14.305	2008	143.639	0.474
1998	85.697	0.002	2009	136.067	-5.272
1999	82.35	-3.905	2010	140.630	3.353
2000	88.807	7.84	2011	145.193	3.245
2001	88.779	-0.031	2012	149.756	3.143
2002	95.146	7.172	2013	154.319	3.047
2003	100.556	5.686	2014	158.882	2.957
2004	107.328	6.734	2015	163.445	2.872
2005	108.963	1.524	2016	168.008	2.792
2006	124.101	13.892	Geometric average		2.63

Table 3. Decommissioning cost update using NPV method

Parameters	Complete Removal	Partial Removal	Conversion to reef
Total cost at year 2000(\$)	60727623.60	19348908.56	24366360.60
Inflation rate (%)	2.63	2.63	2.63
Analysis period (year)	16	16	16
NPV (\$)	91,997,398.97	29,312,019.08	36,913,049.82

which is equivalent to 6.6% of the CAPEX (capital expenditure) cost. Table 4, illustrates the parameters involved to achieve the NPV for re-using offshore platform for wind turbine power generation.

Tables 3 and 4 presented the NPVs for each decommissioning option with respect to the most significant factors contributed to the cost. The estimated NPV for complete removal, partial removal, and conversion to reef are USD 91,997,398.97, USD 29,312,019, and USD 36,913,050 consecutively. These costs are incurred expenses by platform owners. Despite, the capital expenditure cost of re-using platform for wind turbine power generation, an appreciable amount of net revenue was earned over the life cycle analysis of the wind turbine. Over 20 year life cycle of wind turbine, a net revenue of USD16, 939,951.98 was collected as profit. Hence, the NPV of re-using the platform for wind turbine power generation is determined by subtracting the capital expenditure cost of partial removal with the net revenue income which was USD 21,185,843. This economic analysis has fulfilled the objective of measuring the best decommissioning alternatives from economic perspective. Perhaps, the option with the least NPV is recognized to be the best one. Therefore, decommissioning alternatives could be put in ordinal as follows: re-using platform for wind turbine power generation, partial removal, conversion to reef, and finally complete removal respectively.

3.4 Uncertainty Assessment using Monte Carlo Simulation

Uncertainty analysis using @risk software was essential to deal with the uncertainty and risk evolved with the estimated NPVs for the four decommissioning options. NPV contributes to risk as it transacts with future costs which is yet to be investigated by Monte Carlo simulation. The simulation runs random numbers based on probability distribution assigned to the inputs towards attaining the most acceptable NPVs outputs. Each NPV of the four decommissioning was set for 100,000 numbers of simulations to

evaluate all scenarios in order to validate the feasibility of the estimation. After running 100,000 simulations to assess the associated risk in NPVs for complete removal, partial removal, conversion to reef and re-using option, the output results showed insignificant influence of uncertainties on NPVs which is explained in the following figures.

Figure 3 depicts the normal probability distribution for complete removal NPV. It is clear that there is only 5 percent probability of failure to update the decommissioning cost using NPV approach. Thus, the model shows approximately 95 percent of success in updating the cost of complete removal of offshore platform. The mean of total NPV distribution for complete removal was found to be USD92.22 X 10⁶ which is between USD 82.08 x 10⁶ and USD103.79 x10⁶ with 90 percent of confidence level. The uncertainty of complete removal NPV was estimated based on standard error with ± USD20869.95 which is equivalent to ±0.023%. Overall, the model showcased insignificant risk on estimated NPV which seems very hard to be treated as uncertain.

The probability distribution density of partial removal NPV is generated by the Monte Carlo Simulations as shown in Figure 4. The chart shows the central tendency of the cost (50th centile), and the reasonable maximum NPV at 90 % after running 100,000 simulations. The mean cost of partial removal NPV was estimated to be USD 29.94 million ranging from USD 21.73 million to USD 42.71 million. The results revealed that there is a possible uncertainty in the assessment with ± USD 21295.37 to be plus or minus to the partial removal NPV. After all, there is only 5 percent probability that estimation might fail.

The probability distribution density for conversion to reef NPV cost analysis estimation is established in the model as shown in Figure 5. The model was set for 100,000 numbers of iterations to generate random NPVs based on normal distribution inputs. The estimated NPV for conversion to reef ranged from USD 26.76 million to USD 47.96 million with a mean of USD 37.35 million. The model showed uncertainty and variability of estimated NPV which was approximately ±

Table 4. NPV for re-using option

NPV calculation for Re-use Option			
Total cost at year 2000 (\$)	\$19,348,908.56	NPV of O&M (\$)	\$3,626,776.02
Inflation rate (%)	2.63%	Annual energy output (KWh)	14,690,520
Analysis period (year)	16	Net Revenue (\$)	\$16,939,951.98
Future Worth (FW)	\$29,312,019.08	NPV of net revenue (\$)	\$8,689,377.68
Discount rate (%)	7%	NPV for re-use option (\$)	\$21,185,843.13

0.051%. Hence, the estimated NPV for reefing offshore platform is consistent with Monte Carlo Simulation output.

Figure 6 illustrates the output of re-using platform for wind turbine power generation NPV. The NPV model for re-using option is partially different from other NPV models as long as it combines both incurred cost and net revenue simultaneously. Therefore, the probability distribution density indicates, there is 90.4% probability of having NPV between USD 12.50 million and USD 31.50 million with a mean of USD 21.56 million. At level of confidence of 90 percent there is only ± 0.085 of uncertainty on the measurement model which has no significant effect of uncertainty on reusing platform NPV.

In summary, the calculated cost using NPV method were USD 91,997,399 USD29,312,019 USD36,913,050, and USD\$21,185,843, however once subjected to Monte Carlo Simulation assessment were USD \$92,230,049USD \$29,946,322 USD 37,351,196, and USD \$21,555,332 for complete and partial removal, conversion to reef ,and re-using platform respectively. This means, NPV approach has proved its susceptibility as the overall results showed insignificant discrepancy. Hence, the lower the NPV the better the removal option. The assessed 4 alternatives could be put in ordinal from least costly to most costly as re-using of platform for wind turbine power generation, partial removal, and conversion to reef and complete removal consecutively. Wholly, the re-using option is a cost- efficient and identified to be the best decommissioning alternative.

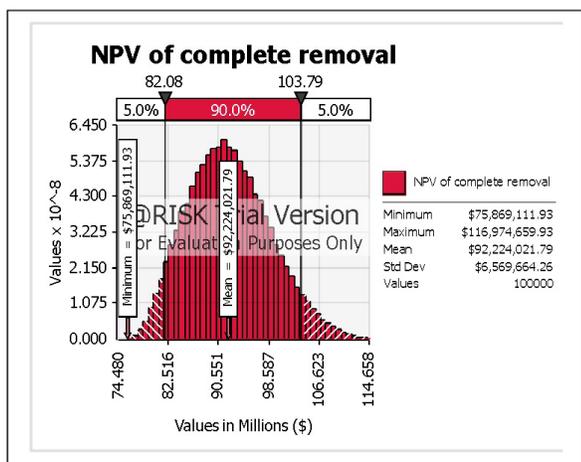


Figure 3. Distribution of complete removal NPV model

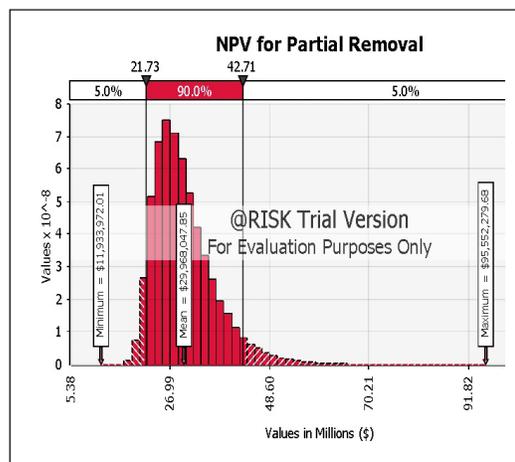


Figure 4. Distribution of partial removal NPV model

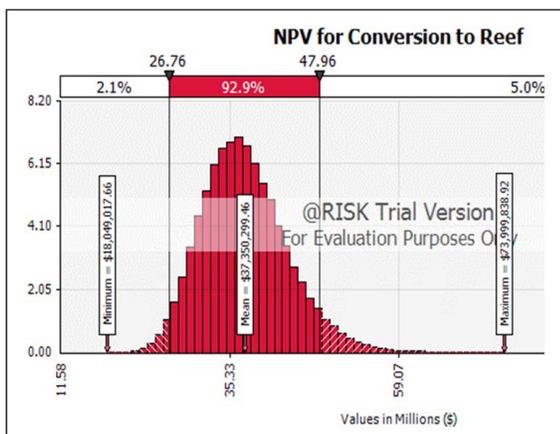


Figure 5. Distribution of Conversion to reef NPV model.

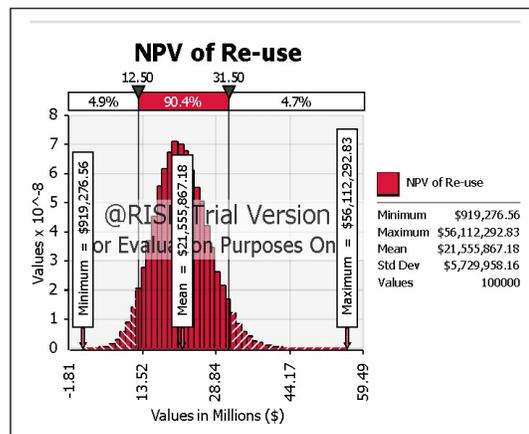


Figure 6. Distribution of Re-using as wind power NPV model

3.5 Sensitivity Analysis for NPV Estimation

Sensitivity analysis is applied to determine which input variable impacts the estimation of NPV for decommissioning alternatives. The results of sensitivity analysis for platform decommissioning options are presented as in figures 7, 8, 9, and 10. The following sensitivity analysis charts showing the input variables and their impacts on NPV for the four platform decommissioning options. The sensitivity analysis for complete removal, partial removal, and conversion to reef showed the most effective inputs parameters on NPV of the three options. It is clear the two most parameters influencing the estimated NPV were inflation rate and analysis period which contribute to more than 15% of NPV' uncertainty as revealed in figure 7, 8, and 9. The inflation rate is the most significant parameter which leads to more than half of the total uncertainty. In contrast, the remaining 3 to 4 inputs parameters have such a small effect on NPV that it hardly seems necessary to treat them as uncertain parameters.

Indeed, inflation rate, and number of year are the most influential parameters, but their uncertainty percentages on NPV vary from model to another, due to random or systematic error in the input data, since the input data are not constant.

The resulting sensitivity analysis chart presenting the inputs parameters as seen in Figure 10. Figure 10 shows the most significant variables affecting re-using platform NPV. It is clear that NPV is most sensitive to inflation rate, electricity's price, and the annual cost of operation and maintenance which contribute to 80%, 41%, and 29% of total uncertainty of the model consecutively. In fact, the last six inputs contribute to a minor influence on NPV, so it is not essential to interact with them as uncertain variables. The reason inflation rate dominates the cost as explained by sensitivity analysis is because inflation in platform decommissioning cost relies on derrick barge price which is exponential with time. Therefore, NPV is much more sensitive to inflation rate input.

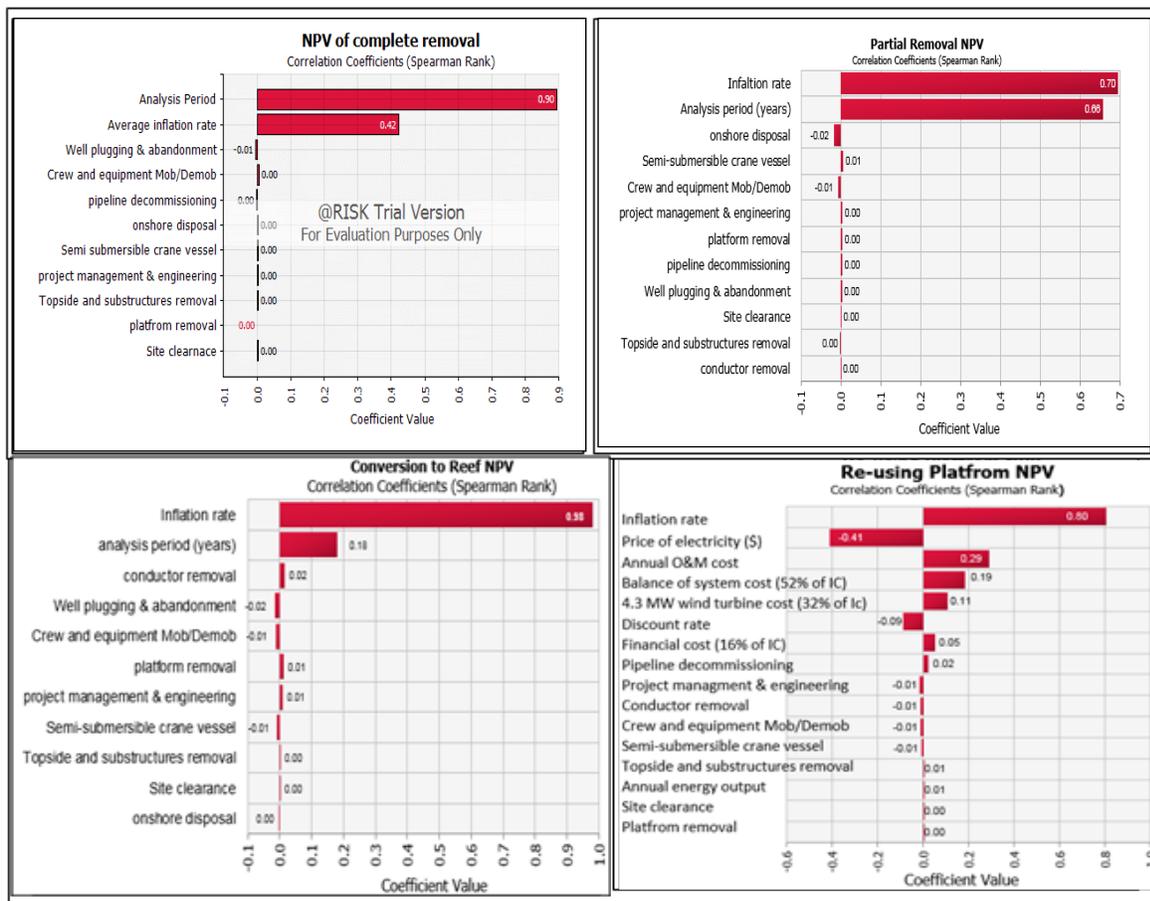


Figure 7,8,9&10. Sensitivity analysis results for complete removal, partial removal, conversion to reef, and re-using platform models.

4. Conclusion

Offshore structures turn to be a liability instead of being asset whenever the cost of operating these infrastructures exceeds the hydrocarbons revenue. The described methodology in this paper has given a reasonable and reliable output for cost estimation of platform decommissioning. The established regression model was decisive to attain cost inflation in order to apply NPV approach to update decommissioning cost. Furthermore, economic analysis for four decommissioning options was conducted by adopting NPV approach to identify the best alternative. As elaborated in result and discussion section, the calculated NPV for complete removal, partial removal, and conversion to reef are expenses to be incurred by platform's owners. Meanwhile, re-using offshore platform for wind turbine energy generation has generated a net revenue of USD16.94 million. Risk and uncertainty were evaluated using Monte Carlo Simulation. After running 100,000 simulations, the generated output of NPV for complete removal, partial removal, conversion to reef, and re-using platform were USD \$92,230,049 USD \$29,946,322 USD 37,351,196, and USD \$21,555,332 respectively. Hence, the associated uncertainties with cost estimation using NPV approach were determined to be between 0.023%, and 0.10% which is considered as insignificant. Wholly, re-using platform for other means as such power generation is likely to be the most acceptable option providing numerous benefits that can satisfy both parties operators and other users of the sea.

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