Research Article
Logarithm Transformation Model for Estimating the Cost of Offshore Platform Decommissioning for Deep and Shallow Water

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Abstract: Offshore oil and gas installations are often costly to fabricate and install, in the same vein, it is obvious to ascertain that the cost of decommissioning will also be expensive. The usual practice is to decommission those platforms after reaching or exceeding their economic lifespan of usually 25 to 30 years without an iota of hope or likelihood of Enhanced Oil Recovery (EOR). The biggest challenge facing oil and gas industry is developing an accurate cost estimate for offshore platform decommissioning. However, experienced decommissioning contractors are extremely limited globally. The burden of decommissioning earlier platforms which did not incorporate the costs of decommissioning in their concession agreements with operators falls squarely on operators. In recent concession contracts, operators are mandated to set aside an annual amount into a special account created specifically to cater for decommissioning at the end of the concession or economic life of the platform. However, a common challenge facing the industry is determining accurate decommissioning costs for offshore platforms. This study attempts to use logarithm transformation of multiple regression approaches to establish a generalized regression cost model for determining the cost of a particular platform. On the whole, the results show a reflection of the cost incurred in decommissioning a Harvest platform which is only 0.39% higher than the actual cost estimate. As such it falls within the pre-determined range of 15%. Consequently, the results could be used to define a Zone of Possible Agreement (ZOPA) for offshore platform decommissioning contractual arrangement before engaging in negotiations with decommissioning contractors in order to improve value for money.

Keywords: Cost estimate, decommissioning liability, offshore oil and gas installations

INTRODUCTION

In the upcoming years, decommissioning activities especially in the Asian Pacific region will increase as a large number of the existing offshore structures approach the end of their productive live. The platform owners now face the challenging task of uncertainty to cost of the decommissioning. However, in Malaysia, it has been reported that 60% of the 300 fixed offshore platforms have exceeded their 25-years design life (Zawawi and Liew, 2013). These are distributed or spread across the four different oil fields in Malaysia which include offshore Sarawak, offshore Sabah region, Peninsular Malaysia and Malaysian-Thailand Joint Development Area (JDA) as shown in Fig. 1 and most of these platforms are in shallow waters between 50 to 80 m (164 to 262 feet) depths.

In view of this trend, offshore decommissioning activity can be expected to rise in the near future. However, it should be noted that only a few or handful of offshore installation have so far been removed or decommissioned till date in Asia pacific as a result of lack of good regulatory framework in place and shaky

decommissioning plans (Twomey, 2010). Contrary to that, Gulf of Mexico is one of the regions with vast experience in decommissioning market globally whereby an average of 136 offshore installations have been removed in one decade as reported by Kaisera and Byrd (2005) and Kaiser and Snyder (2013). Figure 2 shows a typical life cycle for an oil offshore platform.

For instance in Malaysia, many of the offshore installations that were constructed earlier circa 1970s and later date, are quite approaching the end of their life cycle and need to be removed without causing any environmental hazards (Kurian and Ganapathy, 2009). Normally, offshore platform decommissioning can be achieved by; Complete Removal, Partial Removal, Remote Reefing, Conversion to a Weather Forecast Center and even conversion to a Tourist Attractions Center. However, for tourist attraction center and weather forecast zone it was considered as unrealistic because of the cost of maintenance is so high (Mallat *et al.*, 2014). For complete removal, there are (10) different steps to the process, these are: Project Management, Engineering and Planning; Permitting and Regulatory Compliance; Platform Preparation;

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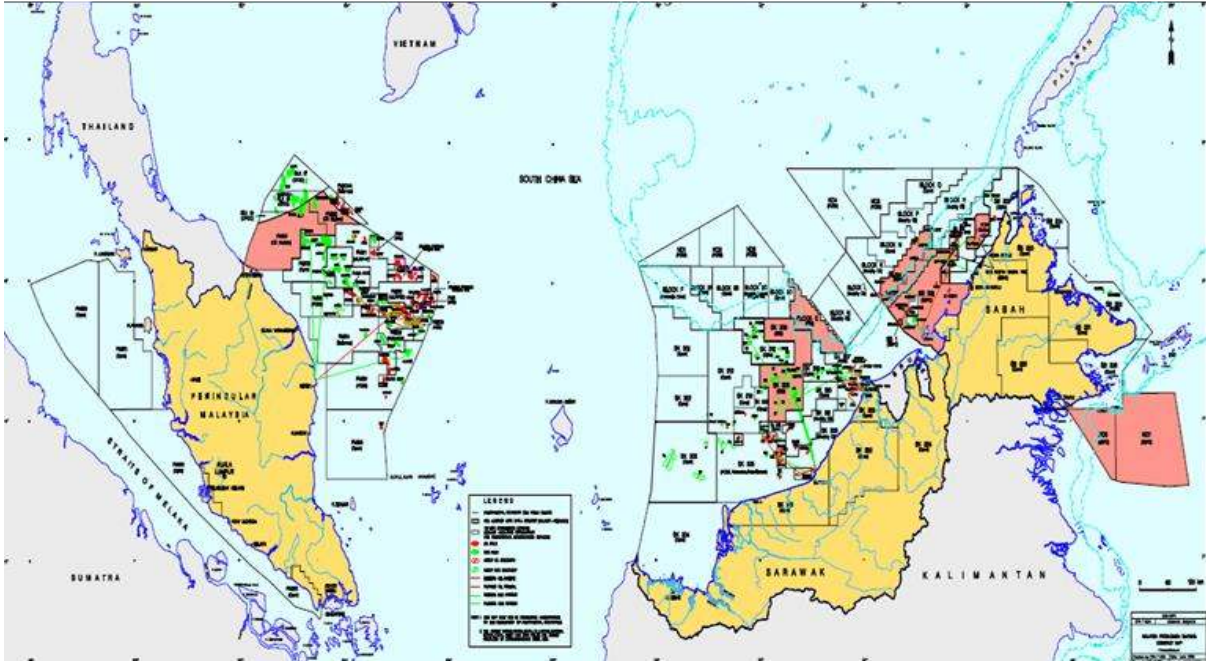
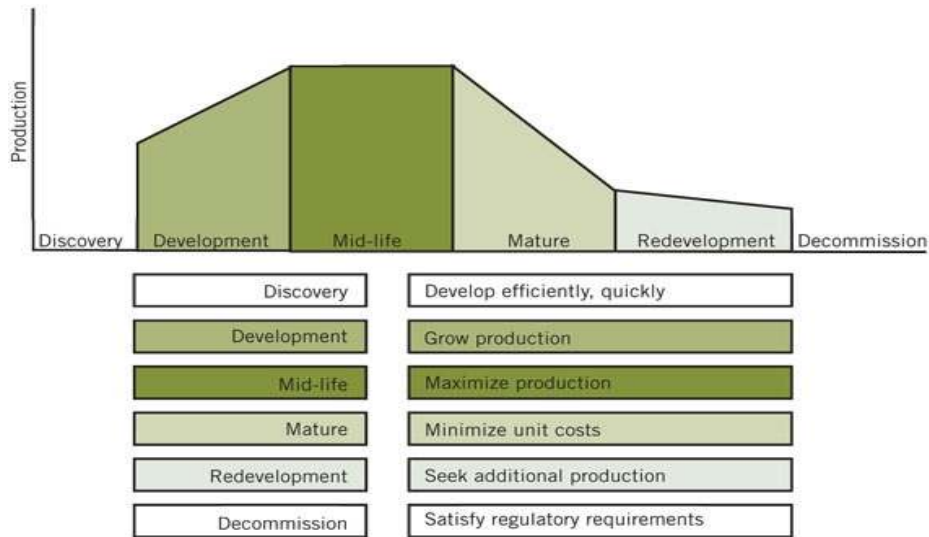Fig. 1: Distribution of fixed offshore platforms in Malaysia

Fig. 2: Oil and gas lifecycle (Kaiser and Liu, 2014)

Well Plugging and Abandonment; Conductor Removal; Mobilization and Demobilization of Derrick Barges; Platform Removal; Pipeline and Power Cable Decommissioning; Materials Disposal; and Site Clearance (Proserv Offshore, 2010) (Fig. 3).

DECOMMISSIONING OVERVIEW

What is decommissioning? It is pertinent however to note that, the word decommissioning does not appear in the 1982 United Nations Conventions on Law of Sea (UNCLOS). Moreover, the word is also missing in the 1952 Geneva Convention on the Continental Shelf. The International Maritime Organization (IMO) Guidelines and standard has not defined the word decommissioning (Hamzah, 2003). In spite of the fact that decommissioning is not defined, all the aforementioned international treaties stressed the need to remove all abandoned offshore platforms. Obviously the word "offshore platform decommissioning' has a recent origin. It attracts the attention of international oil and gas industries following the Brent Spar controversy of 1995 (Osmundsen and Tveterås, 2003; Löfstedt and Renn, 1997). According to Bemment (2001) the word

Fig. 3: Stages of offshore platform decommission (Proserv Offshore, 2010)

decommissioning is defined as the process which the operator of an offshore oil or gas installation and pipeline goes through in order to plan, gain approval for and implement the removal, disposal or re-use of an offshore installation at the end of it economic life. The process can generally be divided into (3) main stages or phases as follows.

Pre-decommissioning activities: Also known as the planning stage, at this stage a decommissioning plan is developed in detailed and the programme of study is devised.

Decommissioning activities: This is the main decommissioning stage as its involve removal and re-use, recycling, leaving in-situ, or disposal of all, or part, of the installation as the case may be.

Post-decommissioning activities: Site survey, site clearance and post-decommissioning inspection.

Decommissioning practices: Globally, decommissioning of offshore installation has been considered to be one of the biggest challenges facing the oil and gas industry as it presents a great liability to the government (Treasury, 2012). Decommissioning is the partial or complete removal of offshore/onshore oil platform at the end of the production process. The basic aim of a decommissioning project is to render all wells permanently safe and remove most surface/seabed signs of production activity (Kaiser and Byrd, 2005). The quest for complete removal of offshore platforms happens to be a new practice (Parente *et al*., 2006); and hence has few precedence in terms of the Malaysian situation. However, internationally, there has been a huge growth in the decommissioning market spurred by several incidents which have fuelled the policy of complete removal. The Shell intended reefing of its Brent Spar which was opposed by the general public (Ibanez, 2011); and subsequent policy changes in the North Sea resulting from the Oslo-Paris (OSPAR)

commission guidelines have served to focus policy attention on complete removal. The reversal of disposal method for Shell's Brent Spar rises from an initial estimate of 38.5 million USD for reefing to a final total sum of 71.4 million for complete removal (Osmundsen and Tveterås, 2003). The authors also report the huge cost increases of a change in disposal method on Phillips Petroleum's Ekofisk filed platform which will cost the company an estimated 460 million USD compared with 100 million USD for reefing.

Decommissioning alternatives generally fall under three categories:

- Removal
- Disposal at sea
- Conversion to other uses (Ibanez, 2011)

But article 60 of the United Nations Convention on the Laws of the Seas (UNCLOS) provides for a general principle of full removal (Lyons, 2013) and this is also more favored by environmentalists who contend that leaving the structure at sea is hazardous to the marine environment (Ibanez, 2011). However, there have been several arguments against complete removal apart from the huge costs of the process. In the Gulf of Mexico where there have been over 6000 offshore structures since 1947 out of which about 2000 have been removed (Kaiser and Pulsipher, 2003); it is reported that between 10,000 to 30,000 fishes live on each platform (Stanley and Wilson, 2000). Furthermore, using the analysis of material and energy flow, with the equivalent financial flows for different types of decommissioning scenarios, it was concluded that it is not clear that complete removal as currently required by regulations is environmentally justified unless very large values were placed by society on a clear seabed and trawling access (Ekins *et al*., 2006). It has also been argued that rather than removing the platforms, Mariculture on them may be a more viable option under certain favorable conditions (Kaiser *et al*., 2010). It has also been suggested that they could be rented or sold to aqua

culturists although this does not relieve the operator of the responsibility for decommissioning (Kaiser *et al.*, 2011). Jørgensen (2012) in his treatise argues that OSPAR bowed to political pressure in its guidelines requiring complete removal and suggests that Rigs-to-reefs should not be excluded categorically but a case-by-case determination of the suitability of a structure for reuse as an artificial reef was a more logical and appropriate in the North Sea.

The need for a cost model for decommissioning cost estimate: Malaysia has grown in the energy market from a net importer to a major industry player over the last couple of decades. The oil and gas sector contributes about 40% of Malaysia's total revenue and 17% of its Gross Domestic Product (GDP) (Lintzer and Salomon, 2013). However, whenever a platform has achieved its design lifespan and at the same time it is running or operated at a lost, at this point the platform needs to be decommissioned (Kurian and Ganapathy, 2009). Of the 300 offshore platforms in Malaysia, many of which are in shallow waters (50-70 m depth), about 60% have exceeded their design life (Zawawi and Liew, 2013). Although Malaysia's long experience in offshore oil and gas is fully appreciated by other ASEAN countries and has been relied on by Vietnam in the development of its own infrastructure and regulation, it does not have any specific legislation on decommissioning (Lyons, 2013). Moreover, because the earlier concessions did not originally include decommissioning, the job of removing oil platforms has become a liability for the government which operates through the Petroliam Nasional Berhad (PETRONAS). The Petroleum Development Act (PDA), 1974 vests PETRONAS with "the entire ownership and the exclusive power, rights, liberties as well as privileges of all the activities involve in exploring, winning and getting petroleum whether onshore or offshore of Malaysia". Furthermore, the Production Sharing Contract (PSC) documents further specify that PETRONAS shall have legal title to equipment and assets for petroleum operations. These two provisions make PETRONAS the sole concessionaire of petroleum resources and ownership of upstream facilities respectively; hence its liability for decommissioning and its residual liability (Fewings, 2005).

Furthermore, in Malaysia, decommissioning plans will have to comply with at least eight other laws which include: Merchant Shipping Ordinance, Continental Shelf Act, Exclusive Economic Zone Act, Environmental Quality Act, Fisheries Act, Occupational Safety and Health Act, Natural Resources and Environmental Ordinance and Conservation of Environment Enactment (Ibanez, 2011). However, it is important for PETRONAS to work in line with global best practices in this area to develop cost models for determining and establishing probable estimates for decommissioning to aid negotiations with contractors. A similar practice has been adopted by the U.S Mineral Management Services (MMS) by ascertaining the cost

of decommissioning at a point in time and updating the cost every five years to reflect the impact of market, technology, inflationary and regulatory policy changes on costs. One of the easiest ways to achieve this is to develop a decommissioning cost models through the use of mathematical modelling due to the uniqueness nature of offshore platforms. Although the relationships between the variable might not be perfectly linear, regression have been criticized as crude and only consider mean of the dependent variable (s), multi-factor regression however play an important roles in highlighting relative variations in a given attribute for establishing a realistic predictions or estimate (Kleinbaum *et al.*, 2013; Minogue, 2005). Due to its ability to accommodate variation or changes among the variables, regression cost model have been consider as the useful means of developing cost estimate for offshore platform decommissioning. In the U.S a general bond covers decommissioning while a supplemental bond is used to update the cost over time. The purpose of the supplemental bond is to protect the U.S. Government from incurring financial losses by ensuring sufficient funds are set aside to cover the full cost of decommissioning by another party in the event the current operator/lessee becomes financially insolvent and is unable to carry out its contractual obligations under the lease (Proserv Offshore, 2010).

Every platform is unique in design and complexity, however this uniqueness is limited to design and weight (size) while the major features remain the same. Where differences exist between platforms, they do so simply on the basis of size or proportion; hence, a factor can be calculated to cater to such proportional differences pro-rata. It has also been found that early concession in a negotiations depended on the point a negotiator intends to stand within their 'Zone of Possible Agreement' (ZOPA). A promotion focused party gained an upper hand in negotiations if the prevention focused party conceptualized their goals within the lower range of their ZOPA (Trötschel *et al.*, 2013). The implication of this in negotiations is that the client needs to understand the needs of the contractor before stating their own position. However, the ZOPA of the client tends to often be lower given the fact that they are promotion-focused, hence want the contract executed.

The challenges of accuracy: It is palpable to ascertain that, industry engaged in constructing an offshore oil and gas platforms has vast experience more than that of dismantling it. Paucity of data is the greatest challenge of offshore platform decommissioning cost estimate (Fowler *et al.*, 2014). The reliability of estimates varies with the level of experience of those preparing the estimates, of which at present there are very few. In addition to that, many nations have blanket regulations requiring obsolete structures to be removed.

Basically, there are two methods of cost estimate the "bottom up" and the "top down" approach (Kaiser and Liu, 2014). The bottom up method of cost estimation involve breaking down of the whole work in

to individual units of activities also known as Work Breakdown Structure (WBS), the cost of each unit is estimated, total sum of these discrete unit of work is added to a contingency sum to gives the overall cost of the project The ingredients of this total cost includes; the cost of labor, materials, plants, overhead and profits (Proserv Offshore, 2010). On the other hand, the top down approach involve the use of reliable historical cost data of completed and similar project to estimate the current project. The cost of the completed project is divided by it weigh and multiply the result by the proposed platform weight to be remove to give a rough estimate. The total cost can be represented by this equation:

Total cost = Cost per metric tons (historic data) ×proposed platform weight in tons

Adjustments can be made to the historical data to normalize for size, water depth; location of the platform, sea condition, complexity, inflation and other factors by means of statistical tools such as regression models to achieve the normalization, this method of approximate estimating is highly criticized of being subjective. Though criticized, it is on the other hand recommended as a useful tool for cost planning because it gives an initial cost estimate at the earliest phase of a project (Myers, 2013). However, the combination of the two methods above coupled with the experience of the estimator gives reasonable estimates. Whatever the estimates produced, due to high uncertainty a general contingency of 15% is applied to all phases of the decommissioning process with the exception of project management, regulatory compliance and mobilization/demobilization of the DB (Proserv Offshore, 2010). The importance of accuracy in cost estimation of any project cannot be over emphasized, considering a scenario of Sydney Opera House where by the Initial cost estimate of the project in 1959 was USD 7 million, the final cost of project was over USD 103 million yielding a cost blowout of over 1,400%. Initial estimated duration of the project was 4 years and the final completion period of the project was 14 years (Shofner, 2006). This makes Sydney Opera House's project the most expensive cost overruns in the history of mega projects globally. Although the architect loss his job then, Sydney Opera House adds about USD775 million to Australian economy every year (Murray, 2013). Risk of inaccurate cost estimation in offshore platform decommissioning is directly proportional to complexity of the structure, experience of the estimator, availability of data; sea condition etc. and hence accurate cost estimates are highly desirable during the early stages of a project. Underestimation normally results in delay as well as increase to the actual cost of the project. On the other hand, underestimation also causes delay and increase to the project cost.

METHODOLOGY

According to Cresswll (2002) when research objectives are identified, the researcher is therefore confronted with the problem of constructing a research design or program that will ensure the attainment of the laid down objectives and testing of the predetermined hypothesis.

Research designs are programs or a plans that assist and guide the researcher in the process of establishing, collecting, sorting, analyzing, evaluating and interpreting observations of data Nachmais (Stephen and Christopher, 2004). Furthermore, the research design has to be focused towards meeting the aim and objectives of the research and to provide a program used by the researcher to answer the research questions.

Nature of data for computing Offshore platform Decommissioning Cost Estimate (OFDCE): Secondary data source are generally suitable for constructing Offshore platform Decommissioning Cost Estimate (OFDCE). Work breakdown structure and decommissioning cost algorithm developed by Proserv Offshore (2010) Offshore, would be employed in developing the logarithms-stages cost equations to establish the cost of offshore platforms decommissioning. Hence, the challenges of compiling constant-quality Offshore platform Decommissioning Cost Estimate (OFDCE) can be summarized by the following three factors:

- Offshore platforms are notoriously heterogeneous. No two platforms are identical.
- Decommissioning cost often varies upon the location, water depth, sea condition etc. The cost of an offshore platform decommissioning is not fixed and can change throughout the decommissioning process until it is completely decommissioned. This means that, decommissioning cost value can only be known with certainty after it has been completely decommissioned.
- Offshore platform decommissioning is infrequent. In many countries, very few or none of the platforms are decommissioned annually except in the GOM many platforms are decommissioned every year.

Mathematical formulation:
Simple regression: This is a method of estimating numerical relationship between variables (Connor *et al*., 2014). It can be defined as the science of estimating in functional form, the dependence of one variable upon another, for a simple linear function in the form of:

$$Y = a + Log\,(bx)$$

where

a = The intercept on Y-axis, when x = 0 and b is the slope at which the differential Co-efficient of y with respect to x

The constants "a" and "b" of simple regression linear function (y = a + Log (bx)) were determined by:

$$b = \frac{n \sum xy - (\sum x)(\sum y)}{n \sum X^2 - (\sum X)^2}$$

$$a = y - Log(bx)$$

The value of a and b would be computed using a computer software.

However, a logarithm transformational technique have been considered to cater for skewed distribution in the data to develop a mathematical models that allows us to "predict" one variable based on another variable.

Assumptions to the cost estimate: A number of general as well as specific assumptions were set aside by Proserv Offshore (2010) Offshore which was modified by the author to suite the proposed estimate to serve the general application and uses of the estimate.

General assumptions: The following are the general assumptions considered in this research:

- Onshore normal hour/day = 9
- Offshore normal hour/day = 12
- Offshore effective hour/day = 8.5
- Man-hours efficiency @ onshore = 75%
- Man-hours efficiency @ offshore = 65%
- Efficiency during harsh weather condition = 40%
- Saturdays and Sundays has been considered as public holidays (weekends)
- Costs are estimated in 2015 and United States Dollars (USD or USD)
- The estimate carried out with this model will gives 60% level of accuracy
- This estimate focuses on shallow and deep water, not more than 1,198 feet and on Malaysian platforms, although the model could be adopted elsewhere
- Reverse installation techniques will be use to remove the platforms by means of high technology
- Derrick barges will be mobilized from Asia
- Platforms shall be transported to the shore after complete removal by means of dumb barge for the purpose of disposal
- For the purpose of cutting of steel or any other composite materials, techniques other than explosives shall be use
- For the purpose of this research no value shall be attached to the decommissioned structure, pipelines as well as the power cable for resale or salvage
- Cost of mobilization/demobilization of Single Derrick Barge is considered for the entire project
- The round-trip mobilization/demobilization times for Derrick Barge (DB) is: 120 days for a DB

having a 2,000 ton maximum lift capability (DB 2000) mobilized from southeast Asia
- The downtimes for weather contingency for the demolition operational process is assumed to be: 15%
- No downtime is assumed as a result of the presence of whales or marine lives
- A general contingency (provisional work) of 20% is applied to all phases of the decommissioning

Coefficient of determination: The coefficient of determination which is represented by letter R^2 shall also be used in the analysis of the research work to determine the proportion of the total variation among the variables in the equations that is the dependent and independent variables (Tanaka and Huba, 1989). It is a measure of correlation that does not have a more precise meaning. This technique results in a proportion or percentage that makes it relatively easy to arrive at a precise interpretation. It is computed by squaring the Co-efficient of correlation. The coefficient of determination R^2 may vary from 0 to 100%.

Hence MINITAB package will be used in generating the output of r and R^2 in each and every experiment of the regression analysis of the research.

RESULTS AND DISCUSSION (REGRESSION MODELS)

Project management, engineering and planning: A multi-factor transformation regression cost model was derived as follows:

$$PE\&P (USD) = -12611096 + 3485652 \ Log. \ WD \ (FT) + 1554020 \ Log. \ TW \ (ton)$$

where,
PE&P (USD) = Total cost for project management, engineering and planning in USD
WD = Water depth (ft)
TW = Total weight of platform (ton)

Example: Using Harvest Platform located in Pt. Arguello/Pt. Arguello oil field.

The Harvest Platform is an 8 legs jacketed platform located in Pt. Arguello oil field area in a water depth of about 675 feet and weight 32,815 metric tons:

$$PE\&P (USD) = -12611096 + 3485652 \ Log. \ WD \ (FT) + 1554020 \ Log. \ TW \ (ton)$$

$$PE\&P (USD) = -12611096 + 3485652 \ Log \ (675) + 1554020 \ Log \ (32815) = -12,611,096 + 9,861,968.35 + 7,018,066.84$$

PE&P = 4,268,939.20 USD/platform

Project Management, Engineering and planning cost for Harvest platform is estimated to cost USD 4.3 million.

Permitting and regulatory compliance: A regression cost model was derived as follows:

$$P\&RC \ (USD) = 369478 + 72555 \ Log. \ TW \ (ton)$$

where,
P&RC (USD) = Total Cost for Permitting and Regulatory Compliance Cost in USD
TW = Total weight of platform (ton)

Example: Using Harvest Platform located in Pt. Arguello/Pt. Arguello oil field:

$$P\&RC \ (USD) = 369478 + 72555 \ Log. \ TW \ (ton)$$

$$P\&RC \ (USD) = 369478 + 72555 \ Log \ (32815)$$
$$= 369,478.00 + 327,663.63$$

$$P\&RC \ (USD) = 697,141.63 \ USD/platform$$

Permitting and Regulatory Compliance cost for Harvest Platform is estimated to be USD 0.7 million.

Platform preparation: A multi-factor transformation regression cost model was derived as follows:

$$Ppre \ (USD) = -7665033 + 3889790 \ Log. \ WD \ (FT) + 19969 \ Log. \ TW \ (ton)$$

where,
Ppre (USD) = Total Cost for Platform Preparation in USD
WD = Water depth (ft)
TW = Total weight of platform (ton)

Example: Using Harvest Platform:

$$Ppre \ (USD) = -7665033 + 3889790 \ Log. \ WD \ (FT) + 19969 \ Log. \ TW \ (ton)$$

$$Ppre \ (USD) = -7665033 + 3889790 Log \ (675) + 19969 \ Log \ (32815) = -7,665,033.00 + 11,005,397.52 + 90,181.45$$

$$Ppre \ (USD) = 3,430,545.97 \ USD/platform$$

Platform Preparation cost for Harvest Platform is estimated to be USD3.4 million.

Well plugging and abandonment (rig-less method): A regression cost model was derived as follows:

$$WP\&A \ (USD) = -2081198 + 4636608 \ Log. TNW$$

where,
WP&A (USD) = Total Cost for well plugging and abandonment in USD
TNW = Total number of wells

Example: Using Harvest Platform:

$$WP\&A \ (USD) = -2081198 + 4636608 \ Log \ (19)$$
$$= -2,081,198.00 + 5,929,079.18$$

$$WP\&A \ (USD) = 3,847,881.18 \qquad USD/platform$$
having one well

Well plugging and abandonment cost for Harvest Platform is estimated to cost USD 3.8 million.

Conductor removal: A multi-factor transformation regression cost model was derived as follows:

$$C.R \ (USD) = -23988927 + 8742653 \ Log. \ WD \ (FT) + 4659585 \ Log.TNC$$

where,
C.R (USD) = Conductor removal cost in USD
WD = Water depth in feet
TNC = Total number of the conductors

Example: Using Harvest Platform:

$$C.R \ (USD) = -23988927 + 8742653 \ Log. \ WD \ (FT) + 4659585 \ Log.TNC$$

$$C.R \ (USD) = -23988927 + 8742653 Log \ (675) + 4659585 \ Log \ (19) = -23,988,927.00 + 24,735,621.12 + 6,513,820.30$$

$$C.R \ (USD) = USD \ 7,260,514.41/platform$$

Conductor removal cost for Harvest Platform is estimated to be USD 7.3/platform.

Mobilization and demobilization of derrick barges: A multi-factor transformation regression cost model was derived as follows:

$$M\&D.DB \ (USD) = -18067910 + 11451991 \ Log. \ WD \ (FT) - 872585 \ Log. \ TW \ (ton)$$

where,
M&D.DB (USD) = Total Cost of Mobilizing and demobilizing derrick barges in UDUSD
WD = Water depth in feet
TW = Total weight of platform (ton)

Example: Using Harvest Platform:

$$M\&D.DB \ (USD) = -18067910 + 11451991 \ Log. \ WD \ (FT) - 872585 \ Log. \ TW \ (ton)$$

$$M\&D.DB \ (USD) = -18067910 + 11451991 \ Log \ (675) - 872585 \ Log \ (32815) = -18,067,910.00 + 32,401,161.34 - 3,940,657.04$$

$$M\&D.DB \ (USD) = USD10,392,594.30/platform$$

Mobilizing and demobilizing derrick barge cost for Harvest Platform is estimated to be USD 10.4 million.

Platform removal: A multi-factor transformation regression cost model was derived as follows:

$$PL.R\ (USD) = -81238204 + 35806271\ Log.\ WD\ (FT) + 1512375\ Log.\ TW\ (ton)$$

where,
PL.R (USD) = Platform Removal cost in USD
WD = Water depth in feet
TW = Total weight of platform (ton)

Example: Using Harvest Platform:

$$PL.R\ (USD) = -81238204 + 35806271\ Log.\ WD\ (FT) + 1512375\ Log.\ TW\ (ton)$$

$$PL.R\ (USD) = -81238204 + 35806271\ Log\ (675) + 1512375\ Log\ (32815)\ -81,238,204.00 + 101,306,817.63 + 6,829,995.01$$

$$PL.R\ (USD) = USD\ 26,898,608.64/platform$$

Platform Removal cost for Harvest Platform is estimated to be USD 26.9 million.

Pipeline and power cable decommissioning: A multi-factor transformation regression cost model was derived as follows:

$$P\&PCD\ (USD) = -13749382 + 4034946\ Log.\ WD\ (FT) + 1561569\ Log.\ TW\ (ton)$$

where,
P&PCD (USD) = Pipeline and power cable decommissioning cost in USD
WD = Water depth in feet
TW = Total weight of platform (ton)

Example: Using Harvest Platform:

$$P\&PCD\ (USD) = -13749382 + 4034946\ Log.\ WD\ (FT) + 1561569\ Log.\ TW\ (ton)$$

$$P\&PCD\ (USD) = -13749382 + 4034946\ Log\ (675) + 1561569\ Log\ (32815) = -13,749,382.00 + 11,416,087.94 + 7,052,158.68$$

$$P\&PCD\ (USD) = 4,718,864.62/platform$$

Pipeline and power cable decommissioning cost for Harvest Platform is estimated to be USD 4.7 million.

Material disposal: A multi-factor transformation regression cost model was derived as follows:

$$MT.D\ (USD) = -45296288 + 14914185\ Log.\ WD\ (FT) + 3694222\ Log.\ TSW$$

where,
MT.D (USD) = Material Disposal cost in USD
WD = Water depth in feet
TSW = Total Structural Weigh (Weight consists of Jacket, Deck and Pile) in ton

Example: Using Harvest Platform:

$$MT.D\ (USD) = -45296288 + 14914185\ Log.\ WD\ (FT) + 3694222\ Log.\ TSW$$

$$MT.D\ (USD) = -45296288 + 14914185\ Log\ (675) + 3694222\ (29040) = -45,296,288.00 + 42,196,759.89 + 16,487,300.27$$

$$MT.D\ (USD) = 13,387,772.16/platform$$

Material Disposal cost for Harvest Platform is estimated to be USD 13.4 million.

Site clearance: A multi-factor transformation regression cost model was derived as follows:

$$S.C\ (USD) = -908127 + 1122960\ Log.\ WD\ (FT) - 235006\ Log.\ TW\ (ton)$$

where,
S.C (USD) = Total Cost for Site Clearance in USD
WD = Water depth (ft)
TW = Total weight of platform (ton)

Example: Using Harvest Platform:

$$S.C\ (USD) = -908127 + 1122960\ Log.\ WD\ (FT) - 235006\ Log.\ TW\ (ton)$$

$$S.C\ (USD) = -908127 + 1122960\ Log\ (675) - 235006\ (32815) = -908,127.00 + 3,177,194.96 - 1,061,304.11$$

$$S.C\ (USD) = 1,207,763.85/platform$$

Site Clearance cost for Harvest Platform is estimated to be USD 1.2 million.

Weather contingency: A multi-factor transformation regression cost model was derived as follows:

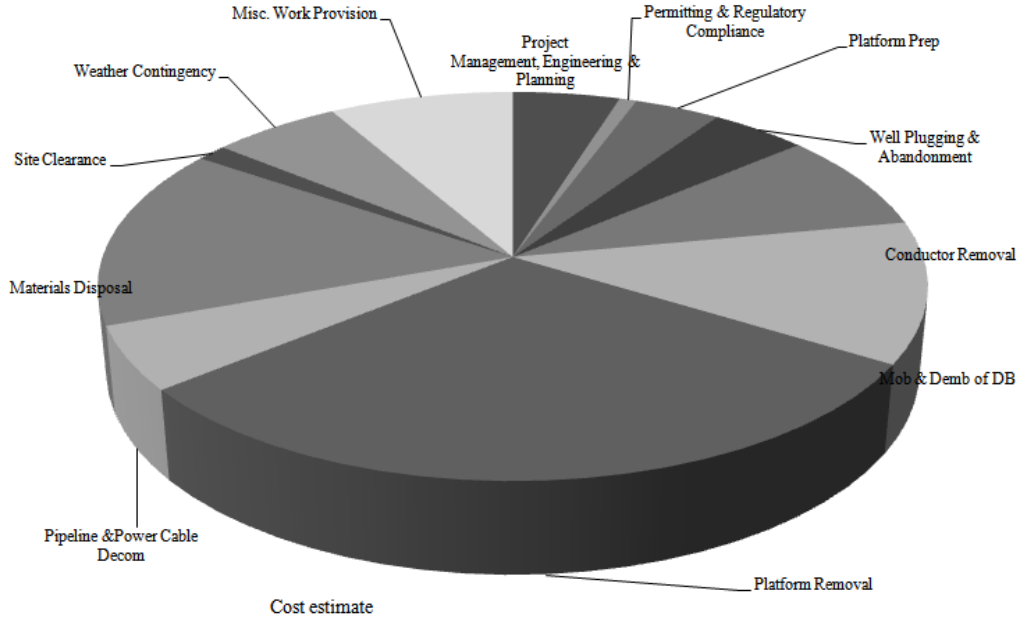$$W.C\ (USD) = -14549994 + 5790978\ Log.\ WD\ (FT) + 733789\ Log.\ TW\ (ton)$$

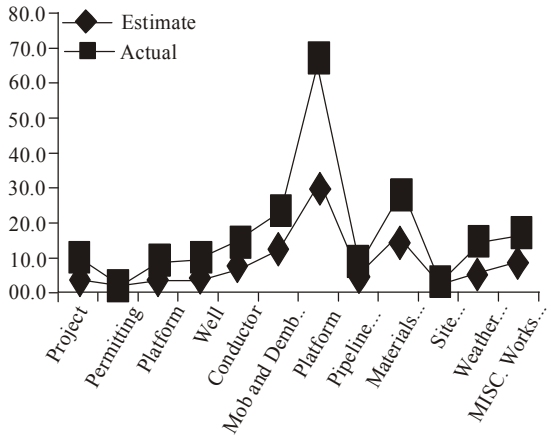Fig. 4: Decommissioning cost percentages by category for harvest platform

Fig. 5: Comparison of decommissioning cost percentages by category

where,
W.C (USD) = Total Cost for Weather Contingency in USD
WD   = Water depth (ft)
TW   = Total weight of platform (ton)

Example: Using Harvest Platform:

$$W.C \ (USD) = -14549994 + 5790978 \ Log. \ WD \ (FT) + 733789 \ Log. \ TW \ (ton)$$

$$W.C \ (USD) = -14549994 + 5790978 \ Log \ (675) + 733789$$

$$Log \ (32815) = -14,549,994.00 + 16,384,435.90 + 3,313,844.26$$

$$W.C \ (USD) = 5,148,286.16/platform$$

Weather Contingency cost for Harvest Platform is estimated to be USD 5.1 million.

Miscellaneous work provision cost: A multi-factor regression cost model was derived as follows:

$$M.WP \ (USD) = -21702162 + 5945305 \ Log. \ WD \ (FT) + 2710671 \ Log. \ TW \ (ton)$$

where,
M.WP (USD) = Miscellaneous Work Provision cost in USD
TW   = Total weight of platform (ton)

Example: Using Harvest Platform:

$$M.WP \ (USD) = -21702162 + 5945305 \ Log. \ WD \ (FT) + 2710671 \ Log. \ TW \ (ton)$$

$$M.WP \ (USD) = -21702162 + 5945305 \ Log \ (675) + 2710671 \ Log \ (32815) = -21,702,162.00 + 16,821,073.87 + 12,241,586.51$$

$$M.WP \ (USD) = 7,360,498.38/platform$$

Miscellaneous Work Provision cost for Harvest Platform is estimated to be USD 7.4 million.

Results and discussion: Figure 4 and 5 shows the trend of decommissioning cost percentages by categories for actual estimate from Proserve and that of the finding from the author's research work. It can also be deduce from the above graph that, the findings of this study

Table 1: Summary of regression models

Example no.	Variables	R^2	Correlation	Regression equation
1	Planning cost vs. log. water depth and log. weight of platform	87.0	0.928	PE and P (USD) = -12611096 + 3485652 Log. WD (FT) + 1554020 Log. TW (ton)
2	Permitting and regulatory compliance cost vs. log. weight of platform	1.5	0.823	P and RC (USD) = 369478 + 72555 Log. TW (ton)
3	Platform preparation cost vs. log. water depth and log. weight of platform	89.3	0.945	Ppre (USD) = -7665033 + 3889790 Log. WD (FT) + 19969 Log. TW (ton)
4	Well plugging and abandonment cost vs. log. total no. of wells	59.0	0.768	WP and A (USD) = -2081198 + 4636608 Log. TNW
5	Conductor removal cost vs. log. water depth and log. total no. of conductors	73.1	0.726	C.R (USD) = -23988927 + 8742653 Log. WD (FT) + 4659585 Log. TNC
6	Mobilization and demobilization of derrick barges vs. log. water depth and log. total weight	67.0	0.818	M&D.DB (USD) = -18067910 + 11451991 Log. WD (FT) -872585 Log. TW (ton)
7	Platform removal cost vs. log. water depth and log. total weight	73.4	0.857	PL.R (USD) = -81238204 + 35806271 Log. WD (FT) + 1512375 Log. TW (ton)
8	Pipeline and power cable decommissioning cost vs. log. water depth and log. total weight	61.9	0.783	P&PCD (USD) = -13749382 + 4034946 Log. WD (FT) + 1561569 Log. TW (ton)
9	Material disposal cost vs. log. water depth and log. total structural weight	82.2	0.903	MT.D (USD) = - 45296288 + 14914185 Log. WD (FT) + 3694222 Log. TSW
10	Site clearance cost vs. log. water depth and log. weight of platform	79.5	0.887	S.C (USD) = -908127 + 1122960 Log. WD (FT) - 235006 Log. TW (ton)
11	Weather contingency cost vs. log. water depth and log. no. of conductor	76.6	0.874	W.C (USD) = - 14549994 + 5790978 Log. WD (FT) + 733789 Log. TW (ton)
12	Miscellaneous work provision cost vs. log. weight of platform and log. total no. of conductors	86.8	0.922	M.WP (USD) = -21702162 + 5945305 Log. WD (FT) + 2710671 Log. TW (ton)
	Total	837.3	10.234	
	Average	69.8	0.853	

shows a movement in regular pattern consistent with that of Proserve. Moreover, Harvest platform was used for testing the models, the actual cost of decommissioning harvest platform was USD 88,278,478.00 and it was established and found out that the estimated cost for decommissioning harvest platform using the established logarithms transformations models was USD 88,619,410.50, giving a difference between the actual and the estimated cost to be USD 340,932.50 which is equivalent to +0.39% more than the actual cost (Table 1).

CONCLUSION

From the oil and gas industries' point of view, offshore platform decommissioning is a liability to the operators as well as a risk to the government and hence presents a responsibility in monetary term to be incurred in future by the platform owners. It is the last phase of offshore oil and gas installation's lifecycle which is usually designed for about 25 to 30 years. Lack of transparency in decommissioning practices causes uncertainties in the decommissioning market and making it difficult to establish and determined the magnitude of the decommissioning cost and its residual liabilities. Due to international conventions that laid more emphasis on complete removal, countries with abandoned offshore installations in their territorial waters are under pressure to ensured compliance. However, in recent concession contracts, parties to the contract incorporate a clause that mandate the operators to set aside an annual amount into a special account created specifically to cater for decommissioning at the end of the economic life of a platform. Moreover, a common challenge facing the industry is determining accurate decommissioning costs estimate for offshore platforms decommissioning due to the nature of offshore oil and gas installations as no two platforms are the same, platforms are located in an environment that is complicated as well as the few experts in decommissioning market do guard their data for academic and industrial consumptions.

These and many more culminates to a further element of uncertainty into current estimates. Hence taking this into cognizance, a model was designed to enumerate a range rather than an exact cost estimate. Therefore, this study attempts to use logarithm transformation of multiple regression approach to generate a cost model for estimating the cost of offshore platform decommissioning in water depth ranging 95≤1198 feet.

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