Decommissioning Cost Estimation Study

By

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13558

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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Approved by,

____

(Name of Main Supervisor)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NUR AFIQAH BINTI JUSOH

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Abstract

This research began with a review of the technical literature available on decommissioning with the objective to evaluate key factors in determining total costs to plug wells and to estimate well plugging and abandonment total cost by using the best options of research methodology. Because decommissioning activity tends to pick up pace near the end stage of a given project when income from the oil field has dropped and the ageing infrastructure at times has low or no economic value, early cost estimation is vital to guarantee a success of a project. Moreover, wells plugging and abandonment that is one of the main stages of decommissioning operation is forecasted to contribute to the largest component (43%) of decommissioning expenditure for over the next ten years. Thus, it is crucial to have a further study on how this well plugging and abandonment cost can inflate and affect the overall decommissioning cost estimate. This is done by two methods of cost estimation. The first method is called "bottom-up" approaches where well plugging and abandonment activities are broken down into distinct and identifiable units and the cost of each unit are estimated by conducting a survey and added together to obtain the overall cost estimate for well plugging and abandonment. This research is then furthered by using the second method of cost estimation called "top-down" approaches where a regression analysis is carried out by using available historical data of decommissioning projects. By having some picture of the major cost for decommissioning, the platform owner can have more accurate cost estimation and locate their budget accordingly, many years before the end life of an offshore platform in order to eliminate surprises for themselves, governmental bodies, the public and shareholders.

Acknowledgement

I have paid undivided attention and taken efforts in completing this project. However, it would not have been possible without the kind support and help of many individuals that I would like to extend my sincere thanks. First and foremost, I would like to take this opportunity to thank the project supervisor, Dr Noor Amila Bt Wan Abdullah Zawawi who has been giving constructive comments and support. Advice and guidance given by her has been a great help throughout the project period. Furthermore, a special gratitude the author would like to give to Mr Abdullahi Baba, whose contribution in stimulating suggestions and encouragement for the project completion. Thanks for the guidance and constant supervision as well as for providing necessary information regarding the project and also for their support in completing it. Last but not least, my thanks and appreciations also go to Universiti Teknologi Petronas, for offering me this opportunity to be involved in the decommissioning study which is very new in Malaysia through my FYP project. These experiences are very valuable and irreplaceable.

Chapter 1: Introduction

1.1 Background of Study

In the Asia Pacific Region, there was an estimated 950 offshore structures installed by the year 2000 (Twomey, B., 2009). Since 2000, some 801 new offshore structures were installed in the Asia Pacific Region. Presently there are some 1751 offshore structures in the Asia Pacific Region with Indonesia and Malaysia leading in numbers.

Country	No of Offshore Installations	Fixed	Gravity Base	Jack-up Production Unit	Semi-Sumersible Production Unit	Stacked Leg	Spar	Monotower	Mobile Offshore Barge	Semi-Sub	Tension Leg
Australia	62	54	5	2	1						
Bangladesh	1	1									
Brunei	159	159									
China	131	130	1								
India	251	249		1	1						
Indonesia	477	463		3		8		1			2
Japan	4	4									
Malaysia	328	322			1		1		4		
Myamar	9	9									
New Zealand	5	5									
Papua N Guniua	1	1									
Phillippines	7	6	1								
South Korea	1	1									
Taiwan	3	3									
Thailand	261	260		1							
Malaysia-Thailand JDA	14	14									
Vietnam	37	36			1						
TOTAL	1751	1717	7	7	4	8	1	1	4	0	2

Figure 1 Types of Offshore Installation in the Asia Pacific Region

Adopted from Twomey, B. G. (2009). *Introduction to Offshore Asia Pacific* [Presentation].

Particularly in Malaysia, there are roughly 328 offshore installations with great diversity in the types of offshore structures installed in four regions:

Peninsular Malaysia, Sarawak, Sabah and the Malaysia-Thailand Joint Authority. According to Twomey (2009), there are some 617 offshore installations at present, regionally, have exceeded their 25 years life and about 48% of these 328 Malaysia's offshore platforms have exceeded their operating lives.

It is well-known that the operating life of oil and gas fields has a limitation, and when a field hits the end of its operational life, a strategy must be planned to have it plugged and discontinue the operations or to have it removed. As many oil and gas fields are now approaching or already in the twilight of their productive lives, the offshore platforms decommissioning is an issue of rising concern within the industry where the oil and gas industry, globally, including Malaysia, now faces the challenging task of decommissioning redundant oil and gas installations as decommissioning is a significant and inevitable stage in the life of a field.

UK Offshore Operators Association (UKOOA) defines decommissioning as the process which the operator of an offshore oil and gas installation goes through to plan, gain government approval and implement the removal, disposal or re-use of a structure when it is no longer needed for its original purposes.

1.1.1 Decommissioning Cost Estimate in Gulf of Mexico and North Sea

Mineral Management Service (MMS), Department of Interior, USA formed Pacific Offshore Continental Shelf Region (POCSR) Facility Decommissioning Team (OFDC) in year 2004 to carry out cost estimation for platform decommissioning. The cost report estimates the costs for each phase of the decommissioning development process. US Material Management Service (MMS) Department categorized the decommissioning cost into eleven (11) decommissioning phase namely:

a) Engineering & Planning
b) Permitting and Regulatory Compliance
c) Platform Preparation and Marine Growth Removal
d) Well Plugging and Abandonment
e) Conductor Removal
f) Mobilization and Demobilization
g) Platform and Structural Removal
h) Pipeline and Power Cable Decommissioning
i) Platform transportation and disposal
j) Site Clearance
k) Contingency Factor

Figure 2 shows a percentage breakdown of decommissioning cost for Pacific Offshore Continental Shelf Region (POCSR) according to their category of decommissioning phases.

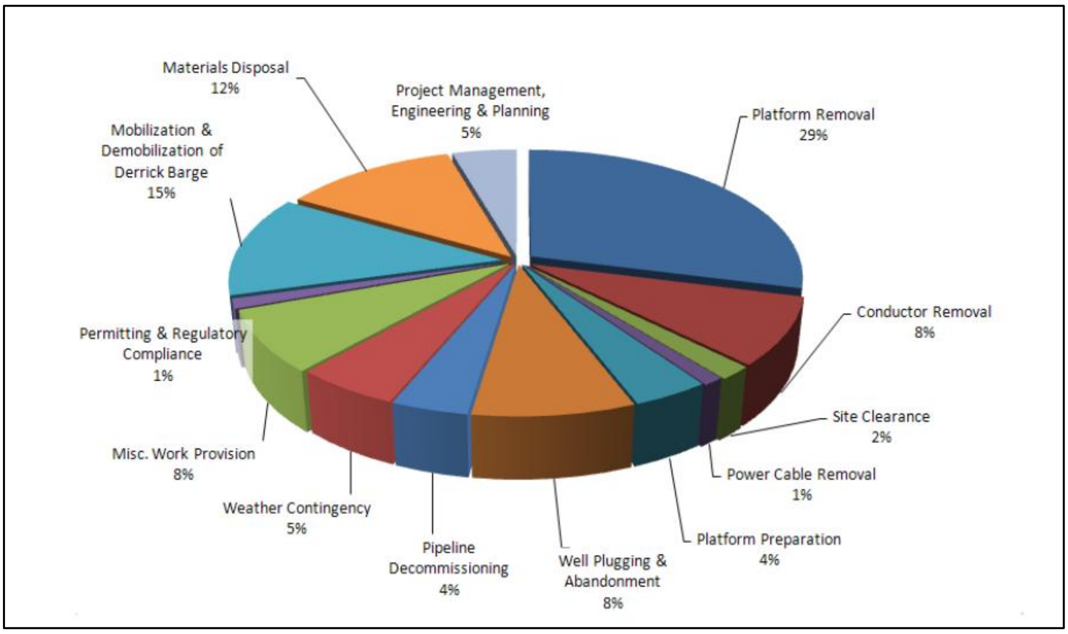


Figure 2 Decommissioning Cost Percentages by Category

Adopted from Proserv Offshore. (2010). *Decommissioning Cost Update for removal Pacific OCS Region Offshore Oil and Gas Facilities.*

The below table is the estimated decommissioning cost for each platform in the POCSR that were developed by the OFDC team established on information they obtained from MMS files, oil and gas operators, consultants, and technical decommissioning studies supported by the Minerals Management Service (MMS).

Table 1 Platform Decommissioning Cost

Platform	Platform Decommissioning Cost ($ Million-2009 Dollars)
A	25.6
B	30.5
C	23.7

Edith	29.2
Ellen	35.9
Elly	21.4
Eureka	94.2
Gail	88.8
Gilda	42.8
Gina	12.0
Grace	41.6
Habitat	28.6
Harmony	155.9
Harvest	88.3
Henry	18.6
Heritage	149.6
Hermosa	80.4
Hidalgo	67.9
Hillhouse	26.0
Hogan	34.5
Hondo	91.7
Houchin	33.0
Irene	32.6

This study on costs of the decommissioned platforms in U.K. and U.S.A. showed that the costs vary significantly due to factors such as location and type of the facility (level of complexity), number of structures need to be removed, water depth and weight associated with the structure, the number and well depth and conductors, method of removal, transportation and disposal options.

Cost estimate case studies conducted for Gulf of Mexico and North Sea are discussed in this research with an objective to be used as a reference in estimating decommissioning cost for Malaysia platforms. .

1.1.2 Ketam Platform Decommissioning Cost

Currently in Malaysia, there is no particular decommissioning cost study has been conducted. The cost estimation presented in this research will be based on the estimated costs of decommissioning Ketam Platforms.

Based on the information from Sarawak Shell Berhad, SSB, the actual cost of the Ketam decommissioning by onshore disposal was RM 46.0 million, and plus RM 16.4 million associated with well plugging and abandonment. Thus, the total cost was RM 62.4 million.

From these figures, it is seen that from the operator's point of view, decommissioning represents a cost to be incurred in the future, while from the government's perspective, decommissioning signifies a risk of noncompliance and potential liability. While from the servicing company's point of view, decommissioning symbolises a potential revenue sources.

1.2 Problem Statement

There are two problems identified that leads to the purpose of this research.

i) Morakinyo (2002) points out that decommissioning activity tends to pick up pace near the end stage of a given project when income from the oil field has dropped and the ageing infrastructure at times has low or no economic value.

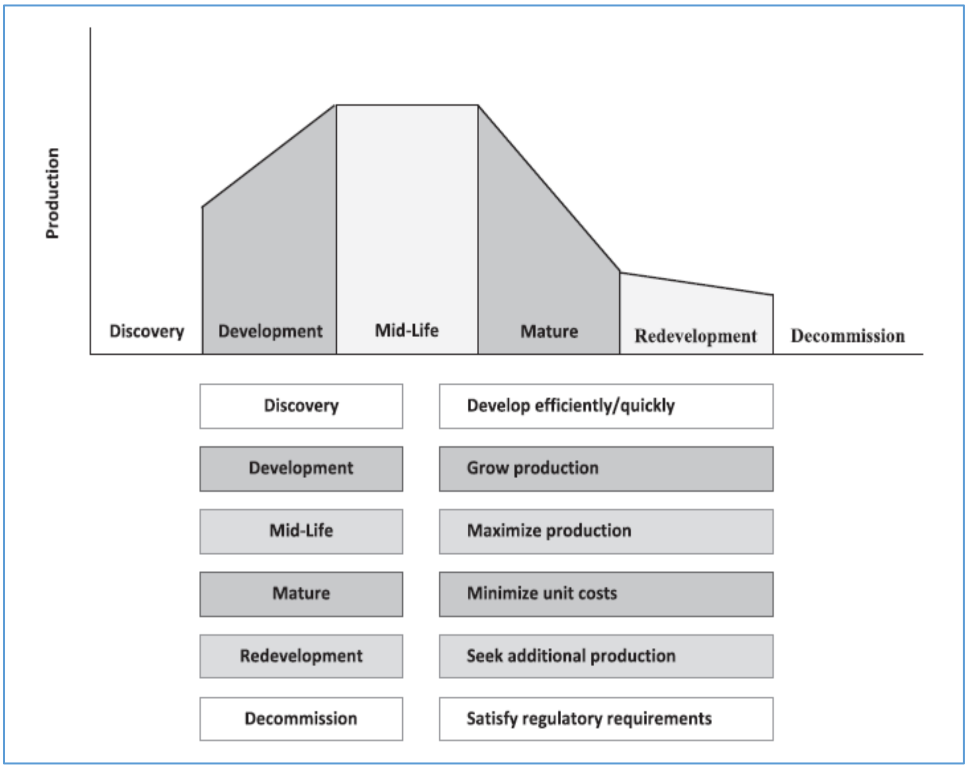


Figure 3 Stylized schematic for life cycle development of offshore oil and gas properties

Adopted from M.J. Kaiser, M. Liu / Marine Structures 37 (2014)

The reasons for estimating have remained much the same from the beginning that is, before embarking upon a significant project or other endeavors requiring expenditures of large sums of money, the total cost must be identified as soon as possible. It is the responsibility of the estimators to eliminate surprise for the management. The cost estimators must make every effort to produce reliable project cost estimates, so that projects can be delivered "within budget." (Humphreys, K. K., & Wellman, P., 1996).

Globally, platform decommissioning cost estimation has been considered as the greatest challenge of all time. This is due to the technical activities involve in a challenging environment and furthermore decommissioning market is still new (Twomey, 2010).

For example, initially, the Ketam Decommissioning BPEO Assessment valued that decommissioning the Ketam facility under onshore disposal would cost around RM27.6 million. However, data from SSB indicated that the actual cost of the Ketam decommissioning by onshore disposal was RM 62.4 million. Thus, decommissioning cost can become unexpectedly very expensive. If the platform owners save only 5% from their total production revenue while the actual cost of decommissioning is 20% , they will probably go out of business as at decommissioning stage, there is no more production, means no more money to cover the cost.

Moreover, offshore decommissioning operations are more complicated and considerably more expensive than onshore work due to the logistical concerns associated with working in remote environments in waters of different depths and weather conditions. When water depth increases, structure size increases and specific marine vessels are required for lifting operations. Besides, the projects are farther from shore and require greater planning and execution time. In addition, limited number of vessels are available to perform the work. All of these issues increases project cost and uncertainty. Therefore, early detailed planning and cost estimation is vital to guarantee a success of a project.

ii) As forecasted in Oil and Gas UK Decommissioning Insight Report (2013), wells plugging and abandonment that is one of the main stages of decommissioning operation will contributes to the largest component (43%) of decommissioning expenditure for over the next ten (10) years. Refer graph below.

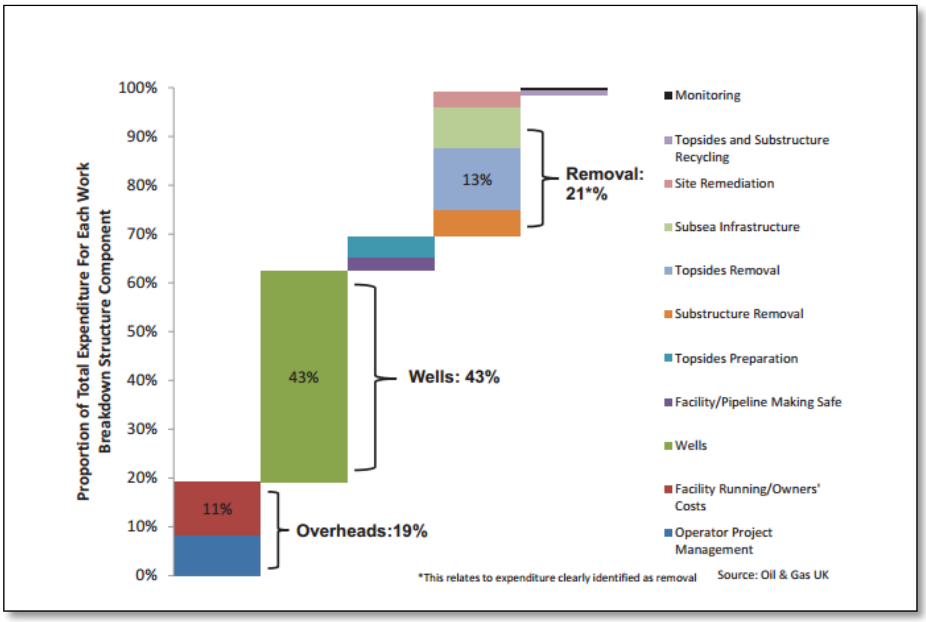


Figure 4 Forecast of Total Decommissioning Expenditure on the UKCS by Component of Work Breakdown Structure, from 2013 to 2022.

Adopted from Werngren, O. (Ed.). (2013). *Oil & Gas UK Decommissioning Insight 2013*.

Apart from that, based on the information collected from the Presentation on 'Ketam Decommissioning Project (1999 – 2004)' by Dasline Sinta, Decom Project Leader, SSB, the cost associated with well plugging and abandonment for Ketam facility was RM 16.4 million. That was 27% of the total decommissioning cost.

Table 2 Actual Cost for Decommissioning Ketam Facility by Onshore Disposal

Ketam Platform Element	Onshore Disposal
Well Abandonment	RM16,410,000
Topsides and Pipeline Cleaning	RM3,340,000
Pipeline and Platforms Abandonment	RM35,100,000
Onshore Scrapping	RM4,060,000
Post Abandonment Survey	RM650,000
Total	RM62,440,000

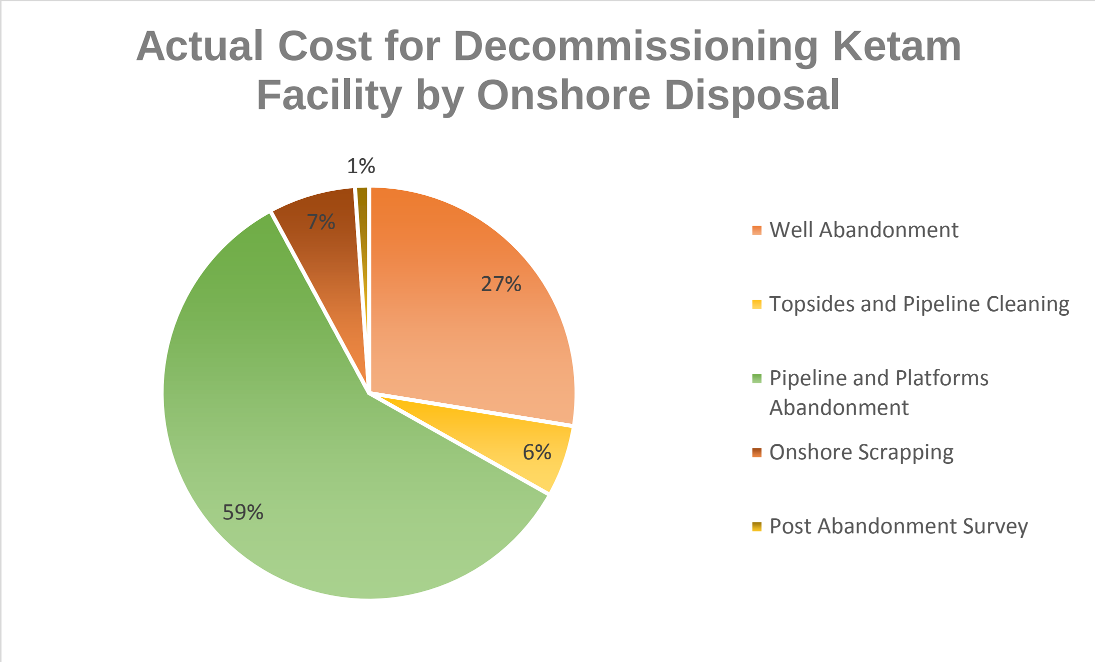


Figure 5 Actual Cost for Decommissioning Ketam Facility by Onshore Disposal

Thus, various cost element of well plugging and abandonment which represents a big percentage of the total decommissioning cost must be critically investigated and it is crucial to have a further study on the impact of well plugging and abandonment cost inflation on the overall decommissioning cost estimate so that the platform owners can have more accurate cost estimation for decommissioning of their offshore platforms to avoid cost overrun and the possibility of project abandonment.

1.3 Objectives

The objectives of this research are:

i) To evaluate key factors in determining total costs to plug wells.
ii) To compare the methodology of cost estimation
iii) To estimate well plugging and abandonment total cost by using the best options of research methodology.

1.4 Scope of research:

A good cost estimate must be adequate for the required phase of the project.

a) A clear definition of scope of work is required.
b) A basis of estimate (BOE) of suitable definition for the project phase is prepared.

Thus, this research will cover only the well plugging and abandonment phase which use rig-less abandonment method. Two key factors are taken into consideration to develop the cost estimates based on the available data are well depth and number of wells per platform.

Chapter 2: Literature Review

2.1 Overview of Decommissioning

Offshore oil and gas decommissioning is a growing activity globally. Much growth has been seen in the Gulf of Mexico market due to the 2010 NTL idle iron regulations and an abundance of redundant offshore installations. Asia-Pacific is gearing up for increasing activity as more comprehensive guidelines and regulations are made. The rest of the world is also growing, with offshore platforms, subsea installations and wells requiring decommissioning due to age. (Reportbuyer., 2014)

Jamieson, A., (2013) reports that high or inaccurate estimates of future decommissioning cost has become a source of growing concern among the oil and gas operators nowadays. Exact decommissioning costs are really difficult to calculate as there are many unknowns and fluctuations that includes estimated risks, material change in condition, market volatility, industry experience, loss of key personnel, supply chain inflation, technical data and information management systems.

The Oil and Gas UK Decommissioning Insight Report (2013), has been expanded to predict decommissioning spend over the next decade to 2022. In the survey, twenty seven (27) operators responded to the call for data on decommissioning expenditure and activity between 2013 and 2022.

Based on the results, total forecast expenditure on decommissioning from 2013 to 2022 is £10.4billion. 44% of this expenditure is to be made in the northern North Sea at £4.6billion where wells plugging and abandonment is the largest category of expenditure totalling £4.5billion.

This signifies 43% of the total forecast decommissioning expenditure from 2013 to 2022. In the central and northern North Sea, the average forecast for wells plugging and abandonment expenditure is £4.8million per platform well, £10.1 million per subsea development well and £8million per subsea exploration and appraisal well.

Apart from that, in the southern North Sea and Irish Sea, the average estimates for wells plugging and abandonment expenditure is £3.5million per platform well and £6.6million per subsea well. Because of that, one of the major cost components of a decommissioning project is clearly the well plugging and abandonment of platforms.

2.2 Well Plugging and Abandonment

According to Twomey (2009), abandonment is typically applied to wells and involves a full process of plugging the well, and, usually, the removal of any equipment that protrudes above the seabed. Besides, all wells shall be abandoned in a manner to assure down-hole isolation of hydrocarbon zones, protection of freshwater aquifers and clearance of sites in order to avoid conflict with other uses of the OCS, and avoidance of migration of formation fluids within the wellbore or to the seafloor. (Proserv Offshore., 2010).

Apart from that, planning and operations are two distinct phases in the well plugging process. The planning phase of well plugging includes the data collection, preliminary inspection, selection of abandonment methods (including consideration of using either rig methods, rig-less methods, or coiled tubing methods, or a combination of these three methods). Proserv Offshore (2010) has investigated plugging and abandoning wells by using both a contracted platform rig, and rig-less techniques, and has determined that rig-less methods are significantly more cost-effective compared to other methods. Rig-less technology is commonly employed in shallow waters since it is the low cost option, and there are no limitation on its use in deep water operation. Rig-less methods which are developed in the 80's are currently being used in the majority of the plugging and abandonment activities in the Gulf of Mexico. A small rental crane would be hired to give assistance with rig-less equipment spread set-up and breakdown, as well as tool, cement, and equipment handling assistance during plugging and abandonment operations. Furthermore, in the rig-less method, a load spreader spans the top of a conductor, providing a base to launch tools, plugs, and other equipment down-hole. Primarily, this load spreader is the main economic savings mechanism because the plugging process will take slightly less time than with a rig methods, and the load spreader is significantly economical and can be set-up and broken down faster than a platform rig.

Meanwhile, the operational phase involves the well entry preparations, filling the well with fluid, removal of down-hole equipment, cleaning out the wellbore, plugging casing stubs, plugging of annular space and placement of surface plugs and placement of fluid between plugs. Figure 4 below provides a graphic view of the typical wellbore configuration.

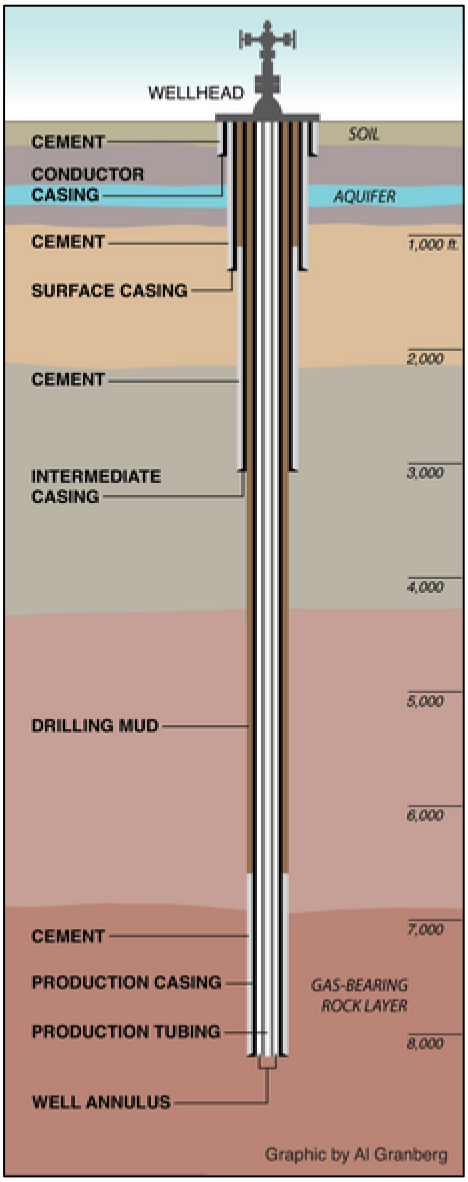


Figure 6 Schematic View of the Typical Wellbore Configuration

Adopted from ProPublica, Anatomy of Gas Well

2.3 Cost estimation

Cost estimating is a critical element in any acquisition process and helps decision makers evaluate resource requirements at milestones and other important decision points. It drives affordability analysis and is the basis for establishing and defending budgets. Cost estimates are important to determine and communicating a realistic view of likely cost and schedule outcomes that can be used to plan the work necessary to develop, produce, install and support a program. (Government Accountability Office. 2007).

In addition, the cost assessment guide prepared by the US Government Accountability Office stressed that cost estimating provides valuable information to help determine whether a program is feasible, how it should be designed, and the resources needed to support it. Too, cost estimating is essential for making program, technical, and schedule analyses and to support other processes such as selecting sources, evaluating technology changes, analysing alternatives, and performing design trade-offs and satisfying statutory and oversight requirements.

Focusing more on well plugging and abandonment cost, the most important factors in determining the costs are the time required to complete the operation, which depends on the difficulty of each well. The difficulty of each plugging and abandonment procedure is tied to the complexity of the well. The average cost of plugging each POCSR well by complexity category is shown in Table 3 below. The cost will increase as the level of complexity increases.

Table 3 Average Well Plugging and Abandonment Costs by Well Type

Well Type (Level of Complexity)	Average Cost/Well
Low cost well (3 days to plug and abandon)	$96,489
Med low cost well (4 days to plug and abandon)	$128,652
Med high cost well (5 days to plug and abandon)	$160,815
High cost well (8+ days to plug and abandon)	$257,304

Assumptions:

1. Costs do not include cost of conductor removal.
2. All costs include shipment and airfare associated with mob/demob of rig-less equipment from GOM.

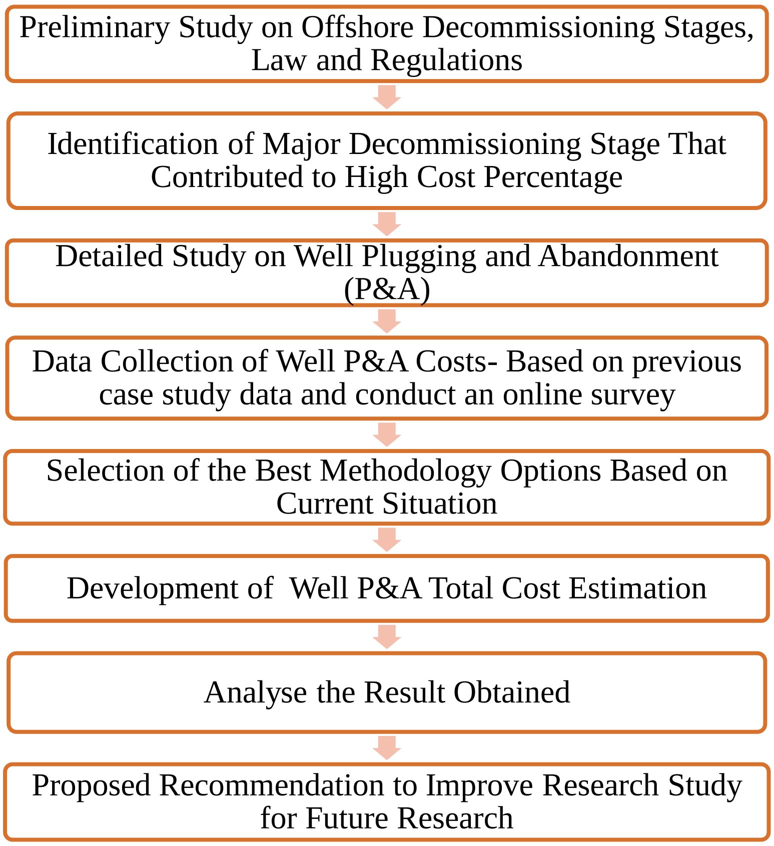
Adopted from Proserv Offshore. (2010). *Decommissioning Cost Update for removal Pacific OCS Region Offshore Oil and Gas Facilities.*

Well depth is also one of the cost factor. Deeper wells involve longer tripping times and may include additional cement volumes. Apart from that, the number of wells per platform is one of the important factors that contribute to the total cost for well plugging and abandonment. The higher the number of wells, the higher the total cost.

Chapter 3: Methodology

3.1 Research Methodology

3.1.1 Research flow



3.1.2 Cost Estimating Approach

The two basic methods of cost estimation are referred to as the "top-down" and the "bottom-up" approaches. The top-down approach uses historical data from decommissioning projects to estimate the cost for future projects after normalizing for cost factors. Meanwhile, bottom-up approach which is also referred to as Work Breakdown Structure project task are broke down into discrete and identifiable units and the cost of each unit are estimated and added together to obtain the overall cost estimate for the project. For this research purposes, both method is used and compared for suitable use. The first method was by conducting an online survey (bottom-up approach) to obtain data from experienced company who have done decommissioning project. While, the second method used was regression analysis (top-down approach) whereby historical data is gathered and analysed.

3.1.2.1 Survey

In order to obtain the most appropriate data, well plugging and abandonment work breakdown structure is first identified. Activity decomposition highlights the primary activities of a well plugging and abandonment project in an organized way by breaking the activities into progressively smaller sections. Estimates are based on decommissioning knowledge of the experienced engineers and project managers and the survey should require them to estimate the cost of each task in the work breakdown structure. The cost of each unit are added together to obtain the overall cost estimate for well plugging and abandonment. The final output is to develop a total cost template for the above. The following hierarchy shows the activity breakdown under each stages of well plugging and abandonment planning and operational phase.

Figure 7 Well Plugging and Abandonment Work Breakdown Structure

3.1.2.2 Regression analysis

Regression model is adopted using past project attribute data. This can be applied to decommissioning cost estimation as the cost of decommissioning platforms in POCSR has previously studied and published. The decommissioning cost presented in the report were developed by Proserv Offshore based on information obtained from Mineral Management Service files, oil and gas operators, third party contractors and Proserv's own decommissioning project experiences.

The goal of each cost estimation method is to estimate fixed and variable costs and to describe this estimate in the form of $Y = f + vX$. That is, Total mixed cost = Total fixed cost + (Unit variable cost × Number of units)

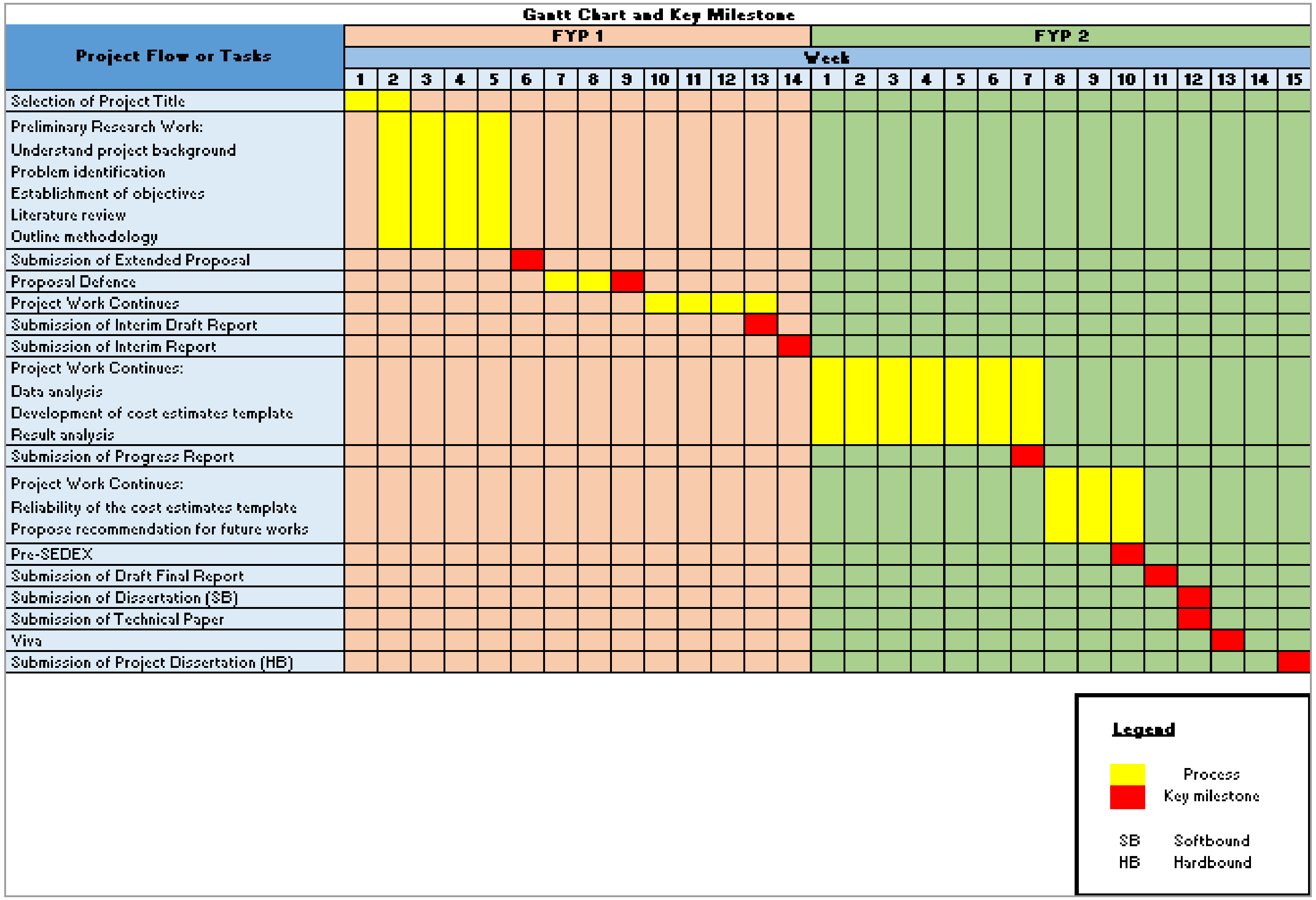
Regression analysis is similar to the scatter graph method in that both fit a straight line to a set of data points to estimate fixed and variable costs. However, regression analysis is more likely to produce the most accurate estimate of fixed and variable costs, assuming there are no unusual data points in the data set. Regression analysis uses a series of mathematical equations to find the best fit of the line to the data points and thus provide more accurate results than the scatter graph approach.

Moreover, regression analysis is a statistical technique used to measure the extent to which a change in one variable (independent variable) is accompanied by a change in some other variable (dependent variable). When only one independent variable is involved, the techniques is called simple regression analysis while when two or more independent variable are involved in the analysis, the technique is called multiple regression analysis.

Linear regression models the relationship between an activity (x), and the total cost (y) by fitting a linear equation to the data. Linear regression uses all data points in deriving the cost equation. A linear regression line has an equation in the same arrangement as the other methods of estimating costs: $y = M\mathbf{x} + C$, where **x** is the independent variable (the activity) and y is the dependent variable (total cost).

Rather than running these calculations by hand, computer software is used for this research. Though there are numerous software programs that generate linear regressions, including Microsoft Excel, this research used IBM SPSS Statistics software to perform the regression analysis.

3.2 Gantt Chart and Key Milestone



Chapter 4 : Findings

4.1 Results

4.1.1 Survey

An online survey with the link www.surveymonkey.com/s/Decommissioning-Cost-Estimation-Study has been distributed to potential respondents that have experience in decommissioning of offshore structures in Malaysia including among the offshore structures operators and contractors. Also, the survey has been posted publicly at decommissioning group through Linked In. However, there was no response or feedbacks on the survey after being posted one month. This may be due to the fact that the individuals could not give their estimate because they were not directly involve in the decommissioning project, particularly in well plugging and abandonment. Also, decommissioning of offshore platforms is still very new in Malaysia. There are possibilities that they have data but it is not yet ready for sharing and to become transparency between the operators, governmental bodies, the public and shareholders. The author has decided to proceed with the second options of methodology, the “top-down” approach of cost estimation.

4.1.2 Regression analysis

Regression model is adopted using past decommissioning project attribute data. However, there are no published data available for Malaysia platforms particularly for well plugging and abandonment phases. Therefore, the author has decided to look at data of more matured platforms such as in Pacific OCS Region, where there are more active decommissioning activities took place in that region.

In the Pacific OCS Region, twenty-three oil and gas production facilities have been installed in Federal waters. All of these facilities are situated off the coast of California. Twenty-two of these facilities produce oil and gas, while the other is a processing facility. The decommissioning cost estimates for individual platforms are based on a decommissioning scenario that was developed by the OFDC for these 23 Pacific OCS oil and gas platforms. Table 4 below shows the estimated well plugging and abandonment (Rig-less) cost for each platform in the POCSR.

Table 4 Well Plugging and Abandonment Cost per Platform (Rig-less Well P&A)

Platform	No of Wells	Average Well Depth (1000 ft)	Plugging and Abandonment Cost (million $)
A	52	2.5	5.2
B	57	2.5	5.7
C	38	2.5	3.9
Edith	18	4.5	2.1
Ellen	61	6.7	7.1
Elly	0	0	0
Eureka	50	6.5	6.2
Gail	24	8.4	3.4
Gilda	63	7.9	7.9
Gina	12	6	1.5
Grace	28	0	4.3
Habitat	20	12	2.7
Harmony	34	11.9	7.1
Harvest	19	10	3.7
Henry	23	2.5	2.5
Heritage	48	10.3	10.2
Hermosa	13	9.5	2.5
Hidalgo	14	10.7	3
Hillhouse	47	2.5	4.8
Hogan	39	5.4	5.1
Hondo	28	12.7	5.1
Houchin	36	5.1	4.8
Irene	24	9.8	4.2

The above data is further used in this research to regress the plugging and abandonment cost on number of wells and well depth. Because of data limitation, this research will only analyse two factors that contributes to the well plugging and abandonment cost which is the well depth and number of wells. The platform complexity is not evaluated.

By using IBM SPSS Software, the data is analysed and below results is obtained.

Table 5 Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Average Well Depth (1000 ft), No of Wells[b]	.	Enter

a. Dependent Variable: Plugging and Abandonment Cost (million $)

b. All requested variables entered.

Table 6 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.918[a]	.843	.826	.8992252

a. Predictors: (Constant), Average Well Depth (1000 ft), No of Wells

Table 7 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	78.445	2	39.223	48.506	.000[b]
	Residual	14.555	18	.809		
	Total	93.000	20			

a. Dependent Variable: Plugging and Abandonment Cost (million $)

b. Predictors: (Constant), Average Well Depth (1000 ft), No of Wells

Table 8 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.836	.760		-2.417	.026
	No of Wells	.127	.013	.976	9.739	.000
	Average Well Depth (1000 ft)	.303	.062	.494	4.929	.000

a. Dependent Variable: Plugging and Abandonment Cost (million $)

4.2 Discussion

4.2.1 Regression Analysis

Based on the model summary, the adjusted R square value is 0.826. Therefore, about 82.6% of the total variability in the total cost is explained by the model. There is no redundancy in the independent variables (number of wells and average well depth) because there is no big discrepancy between the R square and adjusted R square.
The key thing in the ANOVA table above is the F test statistic. F value obtained is not zero, therefore it can be concluded that the independent variables (number of wells and average well depth) chosen did help to predict the dependent variables (plugging and abandonment cost).

By referring to the coefficient table, a two factor regression can be derived;

$TC = 0.127NW + 0.303WD – 1.836$

Where TC = Plugging and Abandonment Cost (Million Dollars)

NW = Number of Wells

WD = Average well depth

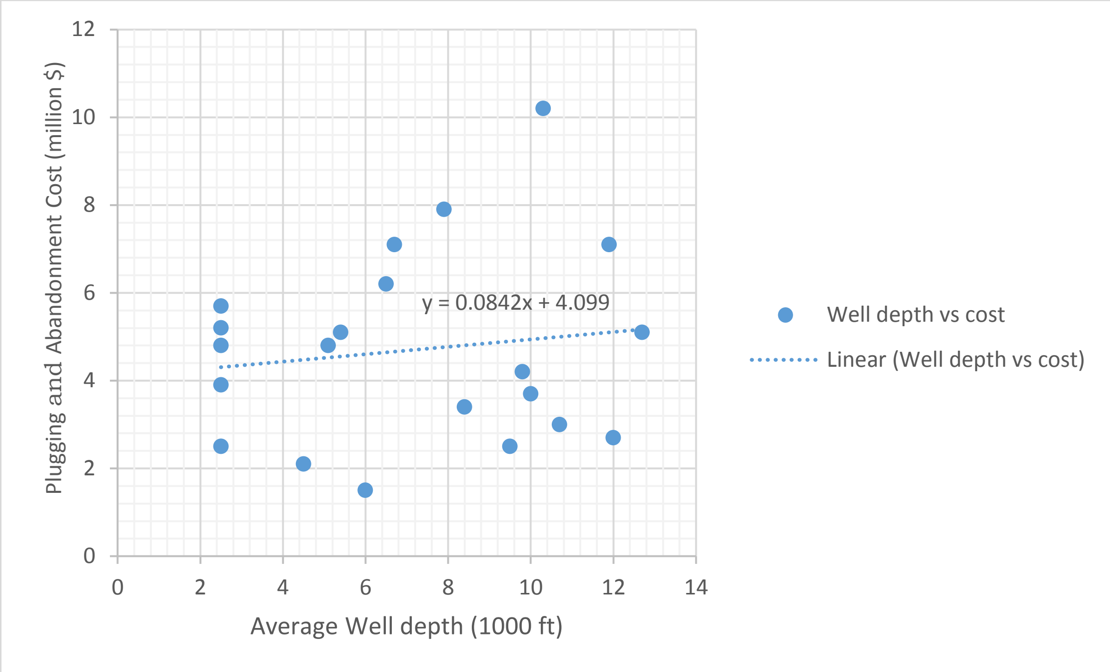


Figure 8 Graph of cost vs well depth

From the graph, we can see that deeper well depth will cost higher. This is due to deeper wells that involve longer tripping times and also will consume higher volumes of materials such as cement and cleaning fluids.

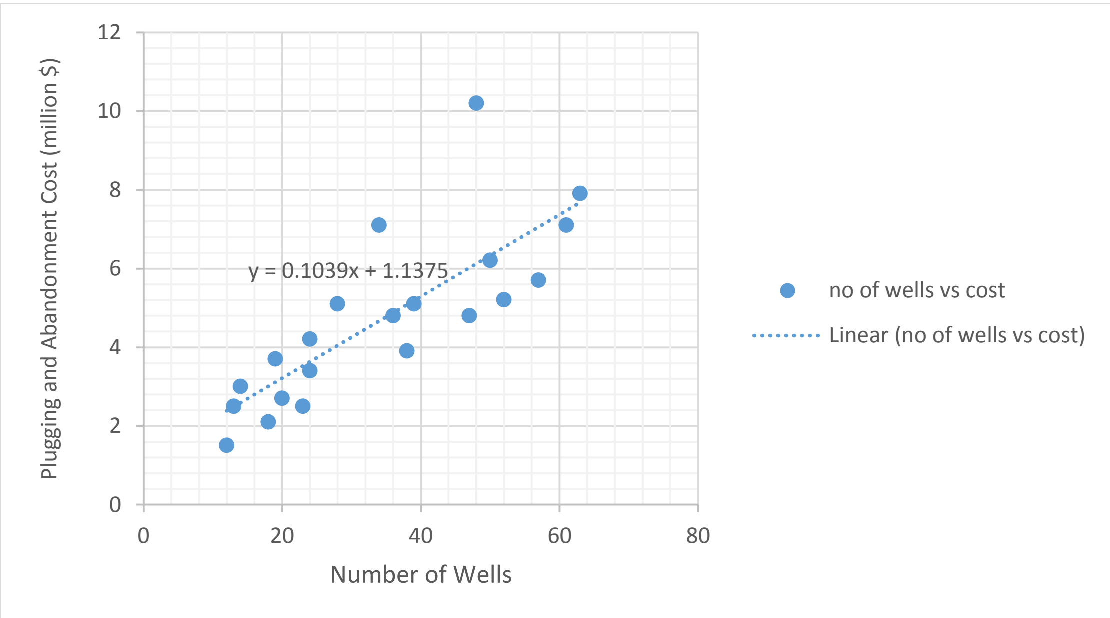


Figure 9 Graph of cost vs number of wells

According to the graph, higher number of well will cause the plugging and abandonment cost to be higher. The higher cost can be anticipated as there will be more well design to be reviewed, more inspection to be conducted such as wellhead and tree inspection to verify that the valves and gauges are operational, higher number of operational activities to be executed such as well entry preparation, removal of downhole equipment, wellbore cleaning, plugging open-hole and perforated intervals at the bottom of the wells, plugging casing stubs, plugging annular space, and placement of surface plugs.

Example

SM-4 Platform

The SM-4 or also called as SMJT-4 is a single pile wellhead platform with one (1) single well located in Samarang Field area in a water depth of about 10.5 m (34.45ft), approximately 50 km northwest of Labuan, offshore Sabah. The platform coordinate is E 1890280 and N 2037212. SM-4 well was drilled in November 1974 to a total depth of 8121 ft.

By using the cost equation derived, the total cost for SM-4 well plugging and abandonment is estimated to be;

TC = 0.127(**1**) + 0.303(**8.121**) – 1.836

= $ 0.752 million

= $ 752,000

= RM 2,406,400 (At exchange rate of 3.2)

SM-4 is a small platform with minimum facility. Therefore, the well plugging and abandonment cost for each platform is expected to be very much lower than Ketam which has cost RM 16.4million.

Moreover, platform decommissioning plugging and abandonment costs can vary widely due to other factors such as location and type (complexity) of the facility, transportation and disposal options. The cost equation developed in this research uses data from off coast of California while SM4 Platform is located in Malaysia.

Although well depth and number of wells are key variables used in determining the plugging and abandonment costs for decommissioning, other factors may have major impact on the decommissioning cost. For instances, the costs of plugging and abandoning a well with deviation greater than 60 degrees will be much higher than the cost of plugging and abandoning a well with less or no deviation.

Besides, decommissioning project work is typically a combination of day rate and turnkey contracts which depend on market conditions and levels of competition, and it cannot be forecast with any reliability. If the work period is different than estimated, if the equipment and spread requirements are altered, or if the vessel day rates are not the same, the cost estimation will differ from the values reported. Also, decommissioning costs also fluctuate based on variations in real costs and inflation.

4.2.2 Quality of Cost Estimate International Cost Estimation Standards Applied to Decommissioning

Table 9 International Cost Estimate Standards

International Cost Estimate Standards

INCREASING PROJECT DEFINITION

AACE Classification Standard	ANSI Standard Z94.0	AACE Pre-1972	Association of Cost Engineers (UK) ACostE	Norwegian Project Management Association (NFP)	American Society of Professional Estimators (ASPE)
Class 5	Order of Magnitude Estimate -30/+50	Order of Magnitude Estimate	Order of Magnitude Estimate Class IV -30/+30	Concession Estimate Exploration Estimate Feasibility Estimate	Level 1
Class 4	Budget Estimate -15/+30	Study Estimate	Study Estimate Class III -20/+20	Authorization Estimate	Level 2
Class 3		Preliminary Estimate	Budget Estimate Class II -10/+10	Master Control Estimate	Level 3
Class 2	Definitive Estimate -5/+15	Definitive Estimate	Definitive Estimate Class I -5/+5	Current Control Estimate	Level 4
Class 1		Detailed Estimate			Level 5 Level 6

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Adopted from Reverse Engineering (2012)

Because this study falls under preliminary estimates, it can be classified as Class 3 quality standard with around 15% of accuracy.

Chapter 5: Conclusion and Recommendation

Offshore decommissioning is growing more complex and challenging. It has been very difficult to gather verifiable information on the current number, status of platforms and regional decommissioning projects in Malaysia. Besides, each offshore installation is unique and requires a specific evaluation, planning, risk assessment, environmental assessment and cost analysis. Sharing of decommissioning learning's, data and enabling more open discussion and transparency between operators, governmental bodies, the public and shareholder would be very useful as early detailed planning which is key to cost control and a successful decommissioning project also minimize end of life “surprises” for platform owners, governmental bodies, the public and shareholders.

Importantly, decommissioning should be treated as an ongoing part of the operation of an offshore field. Throughout the life of an oil or gas field there should be three parallel tacks; running operations, maintenance and decommissioning. At every single decision gate in the life cycle of the field, the consequences of the decision on future decommissioning costs and ongoing decommissioning build-up costs should be examined and considered. This would reduce the impact of a short term gain which may create a major decommission cost in the long term**.** This process would also create an early and continuous awareness of decommissioning as a significant part of the offshore oil and gas business and will lead to improved accuracy of cost estimates**.**

Way Forward

This research used historical data of decommissioning activity that took place off the coast of California at the Pacific OCS Region because they have made their data available and published. The author has identified that a survey is not suitable to be used at this situation at hand because there are so many technical activities involved in well plugging and abandonment and it is very difficult to find the best person to give their rough estimation and who are willing to disclose the data especially from the servicing company because they sees decommissioning as their potential revenue stream. If there will be a future research on this topic, it will be very helpful if the researchers can get local data to be used for regression analysis in order to have better cost estimation accuracy for Malaysian platform because the market condition, level of competition, local day rates, technology, vessel spread availability and inflation rate will be different from the Pacific OCS Regions.

References

Bemment, R. (2001). *Decommissioning Topic Strategy* (Bomel, Comp.). Berkshire, United Kingdom: Health and Safety Executive Offshore Division.

Humphreys, K. K., & Wellman, P. (Eds.). (1996). *Basic Cost Engineering* (3rd, Revised and Expanded ed.). Madison Avenue, NY: Marcel Dekker.

Jamieson, A., Dr (Ed.). (2013, March). *Decommissioning in the North Sea*. London, United Kingdom: Royal Academy of Engineering.

Kaiser, M. J., & Liu, M. (2014). Decommissioning cost estimation in the deepwater U.S. Gulf of Mexico – Fixed platforms and compliant towers. In *Marine structures* (37th ed., pp. 1-32). Retrieved from http://www.sciencedirect.com/science/article/pii/S0951833914000148

Morakinyo, A. A. (2002). *Towards Sustainable Decommissioning: Disused Offshore Installations And Pipelines*. The Hague, NY: Kluwer Law International.

Ostwald, P. F., & McLaren, T. S. (2003). *Cost Analysis And Estimating For Engineering And Management*. United States, America: Pearson Education.

Proserv Offshore. (2010). *Decommissioning Cost Update for removal Pacific OCS Region Offshore Oil and Gas Facilities, January 2010, Volume 1*. Houston: Minerals Management Service Department of Interior.

ReportBuyer. (2014, February 17). The Offshore Oil And Gas Decommissioning Market 2013-2023. Retrieved from http://www.sacbee.com/2014/02/17/6164468/the-offshore-oil-and-gas-decommissioning.html

Twomey, B. G. (2009). *Introduction to Offshore Asia Pacific* [Presentation]. Kuala Lumpur, Malaysia: Offshore Decommissioning Summit.

U.S. Government Accountability Office, Cost Assessment Guide: Best Practices for Estimating and Managing Program Costs--Exposure Draft, Exec. Doc., at 349 (2007).

Werngren, O. (Ed.). (2013). *Oil & Gas UK Decommissioning Insight 2013*. Retrieved from Oil &Gas UK website: http://www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/OP082.pdf