Parametric Study on the Elements of Cost Estimation for Offshore Platform Decommissioning

by

Labina Bongiria Patricia Kenyi

Dissertation submitted

In partial fulfilment of the requirement for the

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FINAL YEAR PROJECT DISSERTATION

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Civil Engineering

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CERTIFICATION OF APPROVAL

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Approved by,

Dr. Noor Amila Wan Abdullah Zawawi

UNIVERISIT TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this report, 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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LABINA BONGIRIA PATRICIA KENY

ABSTRACT

Decommissioning is the last stage in the life cycle of an offshore platform where wells are plugged and abandoned, the structures removed and the seafloor cleared of any debris resulting from the ongoing operations. This process calls for proper planning and cost estimation in order to have successful projects carried out. This study aims at identifying stage-specific assumptions in decommissioning cost estimation and also develop a parametric cost model of parametric range estimating of decommissioning costs using regression models, for early range estimation. To accomplish early cost estimate, secondary data from Gulf of Mexico was used to develop rough regression models that would be used to estimate decommissioning costs for well plugging and abandonment, conductor removal, and structural removal. Results from the regression analysis show that the regression models have a high ability to predict cost since the adjusted R square is more than 50% which means a big percent of variability in dependent variable is explained by the model. Moreover the average F-calculated (137.092) of the 3 elements is higher than the F tabulated (3.49) which means the models have a statistical significance and make a good prediction. Furthermore, the p-values are very low (<0.05) as the test for normality) which shows that the model coefficients are significant and show correlation between independent variables. In conclusion, these models will serve as a format to estimate cost before decommissioning is carried out.

Keywords: Decommissioning; Cost estimation; Regression models; Offshore platforms;

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LIST OF ABBREVIATIONS

ASCOPE:	Asean Council on Petroleum
BPEO:	Best Practical Environmental Option
UNCLOS	The United Nations Convention on the Law of seas
IMO:	International Marine Organization
GOM:	Gulf of Mexico
UKCS:	UK Continental Shelf
DB:	Derrick Barge
CERs	Cost Estimating Relationships
GAO	Government Accountability Office
U.S	United States
P & A	Plugging and Abandonment

CHAPTER 1
INTRODUCTION

This report will define Background, problem statement, Objectives and scope of study for the Final year Project with the title:” Parametric Study on the Elements of Cost Estimation for Offshore Platform Decommissioning”. In addition, the Literature Review and an explanation of the Methodology will be provided.

1.1. BACKGROUND

Generally, methods employed in platform removal utilize the same procedure of commissioning although the procedure is done in the reverse known in the removal industry as Reverse installation. But where facilities like the jackets are too heavy to be lifted, the jacket is cut into small pieces and placed on cargo barges to be transported onshore for disposal.

TOTAL PLATFORMS WORLDWIDE:		≈ 6500
U.S. WATERS:		4094
Gulf of Mexico:	4056	
California:	24	
Alaska:	14	
North Sea:		≈ 250
U.K. Waters	104	
Norwegian Waters	35	
Denmark Waters	23	
Netherlands Waters	56	
South America:		≈ 350
Africa:		≈ 340
Mediterranean & Red Seas:		≈ 150
Middle East:		≈ 700
Australia & New Zealand:		20
Far East & Indonesia:		≈ 650

Figure 1: Estimated worldwide statistics on platform installations through 1985

Adopted from Alexander Jr, W. L., Jackson, T. G., & Hardin, D. J. (1988, January). Engineering the Cost Out Of Platform Removals and Salvage.

In the UK Continental Shelf (UKCS), a report by Royal Academy Engineering Offshore Decommissioning (2013) shows that large production of oil and gas has been taking place since 1970s with a production peak in 2000. The report states that the infrastructure in the North Sea consist of a variety of different structures mainly production platforms which will require decommissioning in the next 30 years in a safe and responsible manner. The report furthers states that among these infrastructure include; 8 large concrete substructures, 31 large steel jackets, 223 other steel jackets, 380 subsea production systems, 21 floating production systems, 3000 pipelines and 5000 wells which represent an enormous engineering challenge.

The petroleum industry in the US. Gulf of Mexico (GOM) has been decommissioning offshore platform installations for many decades. Over 4500 structures have been removed in the GOM since 1973 (Kaiser, M. and Liu, M., 2014). The decommissioning activities are done in reverse state of the art installation where platforms are removed in reverse order from the way they were placed during commissioning. Sequence of operation, cost of equipment and availability of equipment influence the final selection of equipment and procedure to be used in decommissioning.

There is a broad similarity in the requirements for decommissioning shallow and deep water but difference lies in the industry experience especially deep water operations where experience is limited. According to Kaiser, M. and Liu, M., (2014), a total of 15 structures have been removed in the US. GOM in water depths greater than 400ft from 1990-2012 compared to more than 4000 structures removed in less that 400ft water depth (Kaiser, 201). This shows how complicated deep water operations are than decommissioning activities in shallow waters.

The South China Sea located North West of Sabah and Sarawak geographically separates Malaysia into two similarly sized regions. The petroleum reserves located below the seabed of the sedimentary basins in these regions constitute 68% of oil and 86% natural gas reserves which have led to the development of offshore structures. Due to the depletion of the Malaysian reserves in shallow waters, the need for deep water reserves has accelerated. It is observed that decommissioning in Malaysia and rest of the world has been infrequent but this trend is yet to reverse and in the next 20 to 30 years, decommissioning activities will increase as fields reach the end of their viable production lives.

In the Asia-Pacific Region, about 665 offshore oil and gas projects are currently in production across the region (Asia-Pacific Spends & Trends 2008-2017). Since October 2012, many of these fields are located in China (114), Australia (87), Indonesia (212) and Malaysia (110) with many of them expected to deplete in the coming decades, Estimates show that by 2022, about 450 fields that are in production phase will deplete.

Figure 2: Asia-Pacific Offshore field Map

Adopted from Asia-Pacific Spends & Trends 2008-2017

The Asia-Pacific Spends & Trends 2008-2017 report further estimate about 823 undeveloped fields are located in the Asia-Pacific region which are located in Australia(183), Malaysia (150), Indonesia (103) and China (77). These fields are considered marginal and as such, will not be developed soon. Whilst the unlikelihood of development, 456 new fields are estimated to be brought on-stream by 2017 (Asia-Pacific Spends & Trends 2008-2017).

It is observed that decommissioning in Malaysia and rest of the world has been infrequent but this trend is yet to reverse and in the next 20 to 30 years, decommissioning activities will increase as fields reach the end of their viable production lives.

Economic expenditures associated with decommissioning of offshore platforms has become an area of concern in the Malaysia petroleum industry as it is complicated and considerably more expensive then onshore work due to issues like logistics associated with working in waters of varying depths, weather conditions and isolated environments. As the search for more oil reserves increases, most of it is found in waters of great depths. When there are increases in water depth structure sizes required for operations increases, greater planning and execution time are required as projects are becoming further from the shore, all of these increase project costs and uncertainty (Kaiser, M. and Liu, M., 2014).

1.2. PROBLEM STATEMENT:

The decommissioning as the last stage in the life cycle of an offshore installation where facilities and platforms are removed, wells plugged and abandoned and the sea floors cleared of any obstructions still remains a total cost primary challenge for operators as seen in the North sea, where decommissioning cost estimate was £10 billion in 2005 which rose to £30 billion in 2010 (Mark MacArthur). From these figures, the estimates show a significant increase in cost over a short period of time.

From 1989 to 2012, about 15 structures in more than 400ft water depths were decommissioned in the U.S. Gulf of Mexico, but costs associated with the projects were not released publicly (Kaiser, M. and Liu, M., 2014). Also, no proper formats have been released that aid in cost estimation.

With decommissioning being in its infancy in Malaysia, we would conclude that there is lack of specialists in the area and availability of data is scarce. Also, Malaysia is among the countries in the world yet to have a comprehensive decommissioning data.

As such, these problems if not tackled can cause projects to be under funded leading to project abandonment. Also problems like inaccurate cost estimates can foster inaccurate business opinions as to exactly how and what removals are to be carried out. As such, this has led to a mounting interest in developing an early cost estimation that would serve as an effective initial measure to planning costs for offshore platform decommissioning, hence the necessity to explore into this topic.

1.3. PROJECT OBJECTIVES:

The objectives of the study are:

1. To identify stage-specific assumptions in decommissioning cost estimation.
2. To develop a parametric cost model of parametric range estimating of decommissioning costs using regression models, for early range estimation.

1.4. SCOPE OF STUDY:

The Scope of this study will cover parametric cost estimation technique to generate regression models for estimating future decommissioning costs. Also, site-specific assumptions will be made for three elements. These are;

- Well plugging and abandonment
- Conductor removal
- Structural removal

In this study, the use of secondary data from Gulf of Mexico (GOM) will be adopted in order to come up with regression model that will be used in roughly estimating costs and also serve as an effective initial measure to decommissioning costs in local environments. The model can also contribute as a quick forecasting tool of future cost rate in the design and planning of decommissioning campaigns.

1.5. THE RELEVANCY OF THE PROJECT

Cost estimation for decommissioning offshore platforms is closely related to the oil and gas sector in Malaysia. It is inarguable that the decommissioning industry of Malaysia is still in its infancy, but with a number of offshore platforms approaching the end of their production lives, its capacity outlook is evident. According Zawawi, Wan Abdullah, et al (2012), about 280 jacket platforms located off the coast of Malaysia are approaching the end of their lives. Hence, decommissioning activities will intensify in the near future and decommissioning costing will be required to determine the funding requirements and financial liabilities that will eliminate postponement and abandonment of projects since enough funds will be available in case of any cost surprises that would occur from decommissioning operations. Also, good business decisions will be made as to the best disposal method to be employed.

CHAPTER 2
LITERATURE REVIEW

2.1. DECOMMISSIONING OF OFFSHORE PLATFORMS

The life cycle of offshore platforms starts with exploration and ends with decommissioning. On a global scale, decommissioning in the oil and gas industry is still in its infancy and it's no longer new.

Decommissioning is a process where an operator of an oil and gas installations can plan, gain approval, and implement the removal, disposal, or reuse of an installation when it is no longer needed for its current purpose (Jahn Frank et al., 2008).

Regulatory agencies can cease production, abandon the field and decommission the offshore platforms when they see that the production life of a field has become uneconomical or producing low volume of oil. Several international agreements and regulations have been issued concerning the decommissioning activities of the disused offshore installations and relevant safety and pollution aspects (A. Della Greca, 1996). Existing regulatory and international agreements have been put in place to serve as a guideline for offshore facilities and structures so that safe operations, cost effectiveness and low environmental effects are achieved. A few of them are mentioned in the ASCOPE decommissioning guideline (2009) include;

- The United Nations Convention on the Law of seas (UNCLOS, 1982) which does not permit complete removal but rather partial removal to ensure navigation safety and protection of marine life or other activities that are carried out in such waters.
- The International Maritime organization (IMO, 1989) entered into force and now plays a role of Competent International organization. Its criteria requires complete removal of jackets weighing less than 4000 tonnes and are situated in waters less than 75 meters.

In Malaysia, decommissioning activities are forecasted to accelerate in the future with many jacket platforms approaching the end of their production lives (Zawawi, Wan

Abdullah, et al., 2012). And as such, a basic framework to assess the offshore decommissioning activities in Malaysia is vital, especially concerning the cost estimation which has become a major challenge.

2.1.1. DECOMMISSIONING PROCESS

There are fundamentally three common decommissioning options; complete removal, partial removal and reuse for other purposes (Jesse A. Andrawus et al., 2009). Complete removal means removing all elements of the installation entirely. Partial removal which is allowed under IMO guidelines for large structures denotes leaving some of the installation elements In-situ while re-use means to use the installations for other purposes like artificial reef.

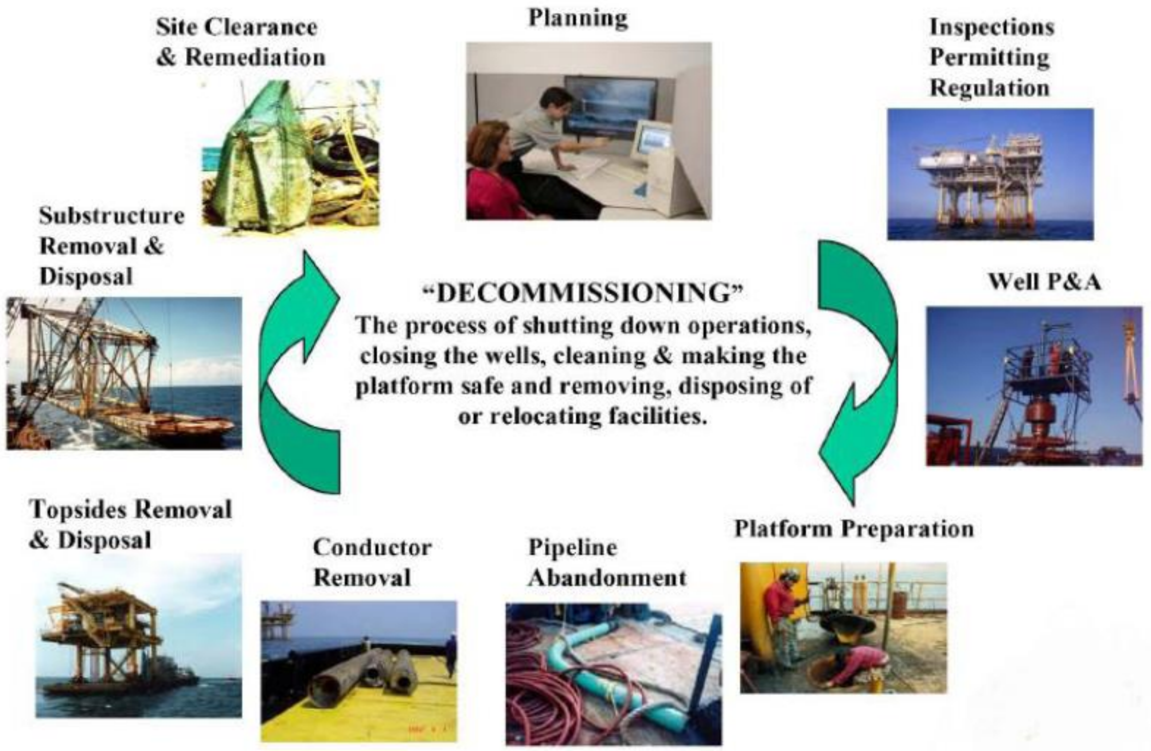


Figure 3: Decommissioning Process

Decommissioning process starts with wells being abandoned where zones are plugged with cement to protect offshore environment from hydrocarbon contamination.

Preparation of platform then follows where the topside is disconnected from the risers. The production system is then isolated from subsea wells and flushed to displace any fluids in excess. Facilities and deck are detached thereon and transported to onshore. Cut pieces of the deck are taken onshore and the jacket is then either transported to onshore by toppling or left in-situ to act as an artificial reef. The seafloor is then cleared of any debris. (ASCOPE Decommissioning Guidelines, 2009).

Decommissioning options can be categorized into two sections i.e. cutting method selection and disposal options (Alternatives). A little more information of the options are discussed in the following paragraphs.

Cutting method selection: There are various methods employed for jacket structures. Each of the methods possess advantages and disadvantages. The table below gives a summary of them.

Table 1: Cutting methods options

Method	Advantages	Disadvantages
Diamond wire cutting system	If no access to piles internally from top of pile to cut depth, then it is the best system	Expensive as it involves contracting sea divas to do the job
Explosive cutting system	Time effective	A threat to local marine life
Abrasive water jet cutting system	Reduces weight when pulling piles	Very expensive and lengthy process

The cutting methodology must be assessed carefully to address all impacts to the environment. This is usually done through Best practical Environmental Options (BPEO) which may be defined as a systematic approach to decision making in which all reasonable options are considered. The approach uses various factors for assessment which are illustrated in the figure below;

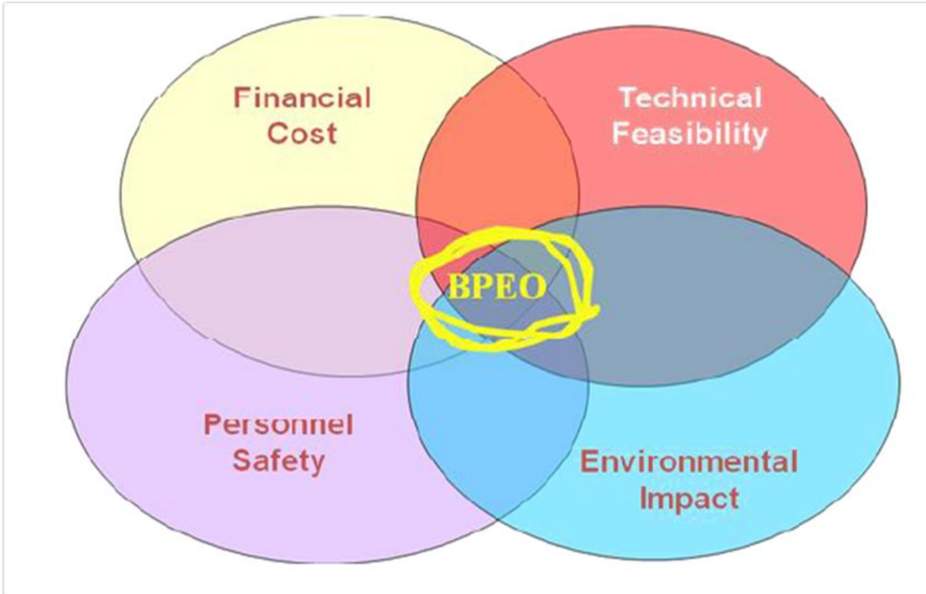


Figure 4: Factors to consider when using BPEO

Disposal options: The options include but not limited to leave in place, Partial removal, Full removal & disposal as an artificial reef, Full removal with deep water disposal, Full removal with onshore disposal. The figure below illustrates the options.

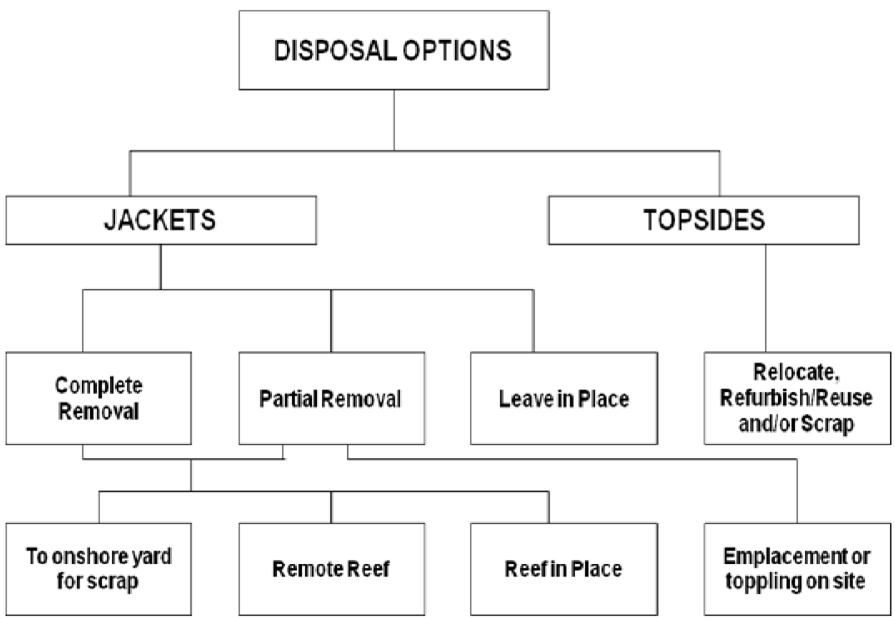


Figure 5: Disposal options

2.1.2. DECOMMISSIONING STAGES

There are roughly nine stages in the decommissioning process but only three will be discussed in this report as mentioned in the scope of work.

2.1.2.1. Well plugging and abandonment

When a well is no longer productive, plugging activities which could be permanent or temporary are carried with the intention of isolating and containing productive hydrocarbon intervals, and seal off leak paths that might allow the migration of formation fluids to the sea floor. This is done in order to protect and conserve the fresh water aquifers. Some techniques are utilized in plugging and abandoning wells and are usually based on regulatory standards and experience from industry. The process is usually accomplished without using a rig (Rigless technology) as it reduces costs significantly without conceding on the quality of abandonment results. Rigless technology is a common practice in shallow waters since low costs are incurred, and its use in deep water is not limited. Subsea wellheads are removed in wet tree wells, risers cut and pulled in permanent well abandonment, and equipment removed from the well in temporary abandonment. The plugging is usually done by squeezing cement into zones that renders production intervals incapable of producing. The cost of operations incurred depends on the time taken to plug and abandon wells. Subsea abandonment is generally expensive than dry or wet tree operations since the marine vessel spreads adds to the cost of operation.

2.1.2.2. Conductor removal

Conductors are generally removed using jacks and cranes. Usually they are cut at about 15ft below the mud line, then pulled up to expose a section of about 35ft and then cut using an appropriate cutting system like the mechanical cutting. An offshore platform crane lifts the cut section and places it on a deck where it is later transferred to a derrick barge to be transported onshore. The process is repeated until the conductor is entirely removed for each wellbore.

2.1.2..3. Structure removal

The process begins with the platform preparation done by cleaning and disposing fluids collected from pipes and production lines onshore. This is followed by deck removal in which topsides are removed in reverse sequence and the modules transported onshore by a moored vessel like a derrick barge. Lastly the jacket is removed by utilizing disposal options illustrated in **(Figure 5)** above. The selected option will depend on the lifting capacity of the derrick barge, availability of equipment and also cost.

2.2. DECOMMISSIONING COST ESTIMATION

In general, decommissioning of offshore platforms is a complex and costly process of both technical and non-technical activities. There are several alternative options that are weighed in order to select the best decommissioning strategy but COST of the different alternatives greatly influences the final decision. Prior to any decommissioning activity, it is vital to know the decommissioning costs and these cost estimates should be as accurate as possible in total and time structure to enable in planning of the decommissioning activities. Decommissioning costing may refer to decommissioning cost as a focal parameter into which all aspects with impact on decommissioning activities are anticipated, like approach and labor force (Vladimir Daniska, 2009).

The main purpose of decommissioning costing is to guide and inform the platform owners, shareholders, government and the public ensure that decommissioning funds will be available when needed, determine funding requirements on facility level and to act as a basis for industrial strategy and decommissioning activities when planning.

A report by Proserve Offshore (January, 2010) estimated cost whose cost analysis covers a list of items which include;

- Project Management, Engineering and Planning
- Permitting and Regulatory Compliance
- Platform Preparation
- Well Plugging and Abandonment
- Conductor removal

- Mobilization and Demobilisation of DB's
- Platform Removal
- Pipeline and Power Cable Decommissioning
- Materials Disposal
- Site Clearance
- Provisional Work and Weather Contingency Factors

These items are indicted in the figure below with platform removal having the largest percentage in terms of cost.

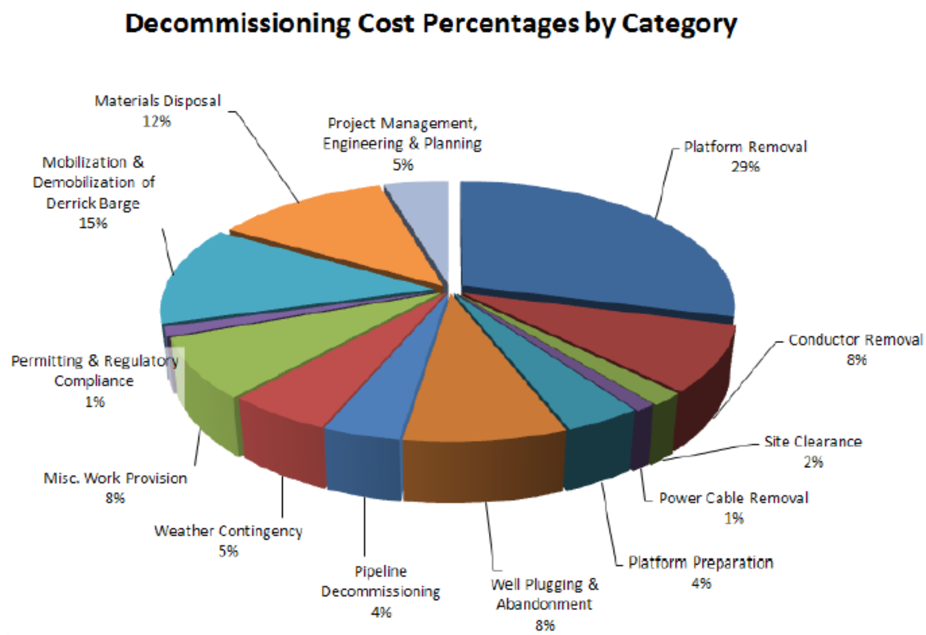


Figure 6: Decommissioning Cost Percentage by Category

Adopted from Proserve Offshore (January 2010). *Decommissioning Cost Update for Removing Pacific OCS Region Offshore Oil and Gas Facilities*

2.2.1. COST ESTIMATION APPROACHES

According to Vladimir Daniska (2009) in his overview of cost estimates, costs may be estimated in several ways which include;

- Bottom-up – site specific and most accurate

  Here project tasks are broken down into discrete units and the costs of each unit are estimated and added together, often with contingencies, to obtain the overall cost estimate of the project (Kaiser, M. and Liu, M., 2014)
- Specific analogy – based on known cost of an activity in prior estimates
- Parametric – based on historical databases of similar systems and structure

  Statistical methods are applied or regression models may be adopted using project attribute data (Kaiser, M. and Liu, M., 2014)
- Cost review and update – based on previous estimations of same or similar project
- Expert Opinion – based on consensus of specialists in an iterative process.

The most accurate is the bottoms-up estimates and most preferred because it’s based on evaluating of individual elementary decommissioning activities for which the site specific calculation data is developed.

Comparison of the commonly used cost estimation methods

Three Most Commonly Used Cost Estimating Methods Compared			
Method	Strength	Weakness	Application
1. Analogy	• Requires few data • Based on actual data • Reasonably quick • Good audit trail	• Subjective adjustments • Accuracy depends on similarity of items • Difficult to assess effect of design change • Blind to cost drivers	• When few data are available • Rough-order-of-magnitude estimate • Cross-check
2. Engineering build-up	• Easily audited • Sensitive to labor rates • Tracks vendor quotes • Time honored	• Requires detailed design • Slow and laborious • Cumbersome	• Production estimating • Software development • Negotiations
3. Parametric	• Reasonably quick • Encourages discipline • Good audit trail • Objective, little bias • Cost driver visibility • Incorporates real-world effects (funding, technical, risk)	• Lacks detail • Model investment • Cultural barriers • Need to understand model's behavior	• Budgetary estimates • Design-to-cost trade studies • Cross-check • Baseline estimate • Cost goal allocations

Figure 7: Comparison of cost estimating methodologies

Source: U.S GAO 2007

For this study, parametric method has been chosen as the most appropriate method because it provides timely estimate as long as sufficient data is available, quantitative outputs since quantitative inputs are used and consistent estimate format and documentation. This in turn generates quicker response to competitive business environments. The method is discussed below.

2.2.1.1. PARAMETRIC COST ESTIMATION TECHNIQUE

- Is a cost estimating technique that uses regression or other statistical methods to develop Cost Estimating Relationships (CERs) to establish cost estimates. The CERs provide logical and repeatable relationships between independent variables (parameters) and the dependent variable (cost) (Larry R. Dysert, 2008)

- CER is an equation used to estimate a given cost element using an established relationship with one or more independent variables. The CERs are based upon actual historical data from similar projects. The steps involved in the creation of the models are illustrated in the figure below.

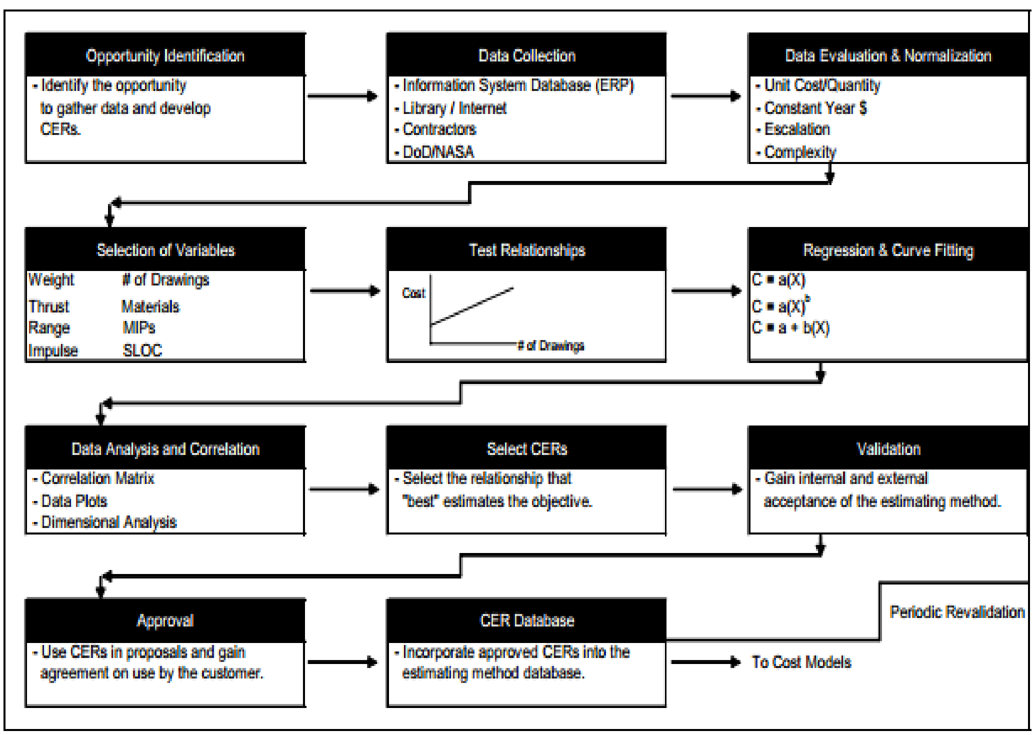


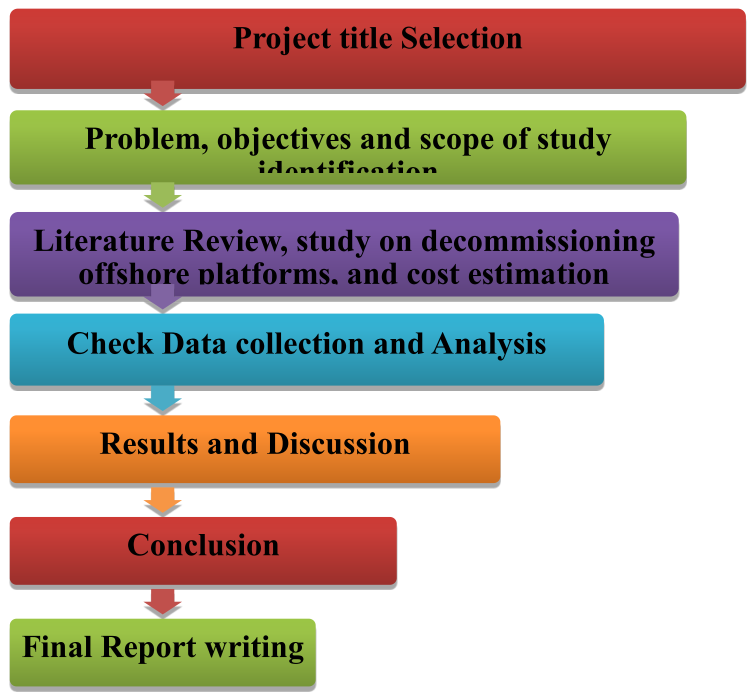
Figure 8: General CER develoment process

Source: Parametric Estimating Handbook – 4th Edition

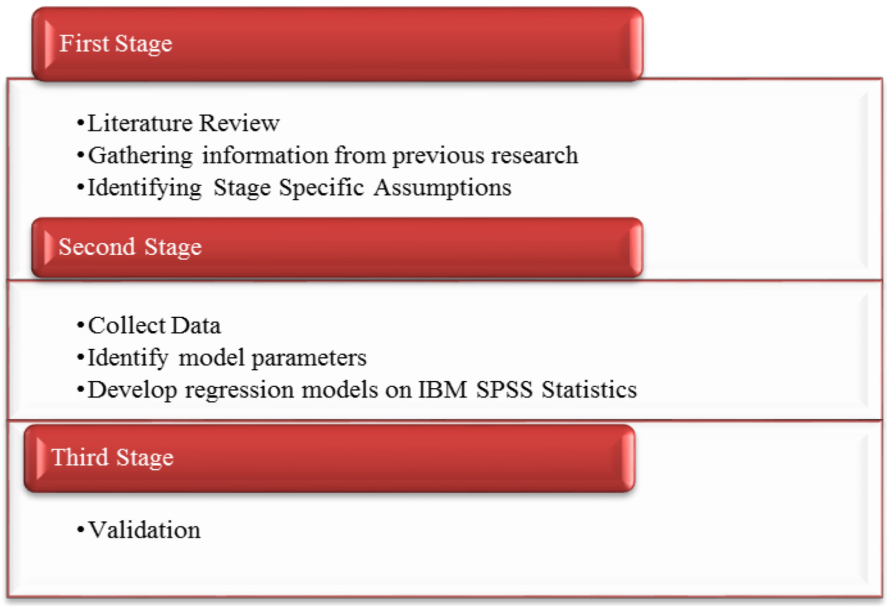
CHAPTER 3
METHODOLOGY

3.1. RESEARCH METHODOLOGY AND PROJECT ACTIVITIES

3.1.1. RESEARCH FLOW



Research Methodology



DEFINITION

In statistics, **regression analysis** is a statistical process for estimating the relationships between variables. It includes many techniques for modeling and analyzing numerous variables, when the emphasis is on the relationship between a dependent variable and one or more independent variables.

Regression models encompass the variable below:

- The **unknown constant**, denoted as **β**, which may represent a scalar or a vector.
- The **independent variables**, **X**.
- The **dependent variable**, *Y*.

A regression model relates the *Y* variable to a function of **X** and **β** in the formula below;

$$\mathbf{Y \approx f\,(X, \beta)}$$

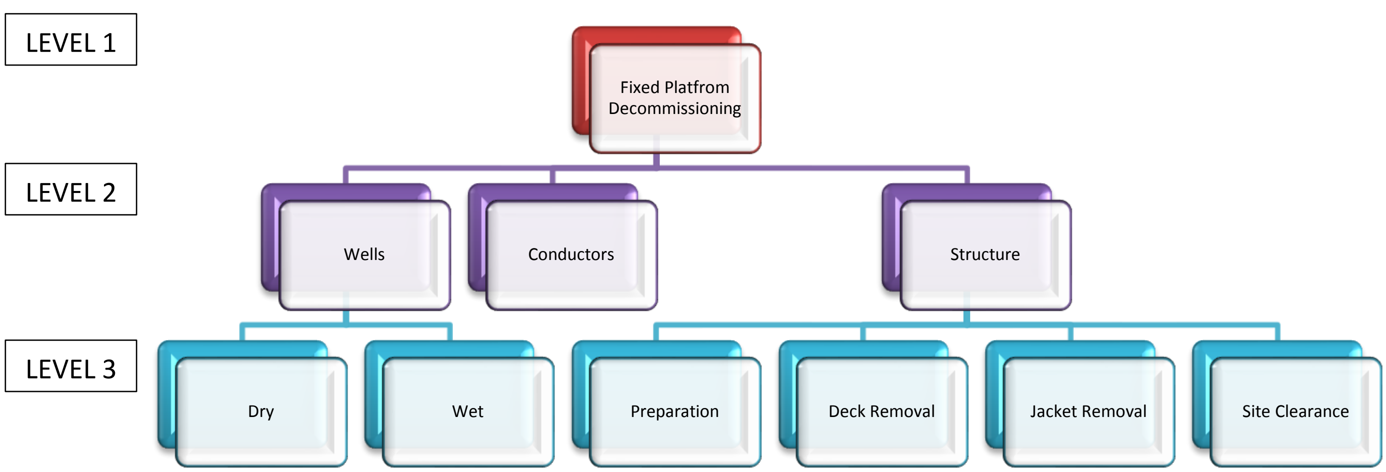
3.1.2. ARRANGEMENT

Decommissioning cost algorithms will be developed for fixed platforms across three stages of decommissioning which are;

- Well plugging and abandonment
- Conductor removal

- Structure removal

3.1.2.1 Table 2: WORK BREAKDOWN STRUCTURE



3.1.3. GENERAL ASSUMPTIONS

Assumptions in this study have been modified and generalized from those applied by Proserve engineers.

- The cost algorithms presented by Proserve engineers were considered to be accurate to ±20% circa 2009-2010. But in this study, the range is most likely to fall within ±30% of the expected values.

- The estimates will assume trouble-free conventional operations and weather and work contingencies. Operations that are unconventional like Tsunamis are not considered. Weather and work contingencies will be included to allow for possible modification processes, equipment costs and delays incurred.
- A general work contingency of 15% will be applied.
- Reverse Installation using DBs will be used to remove platforms.
- Platforms will be completely removed and disposed of at the shore.
- Mobilization/demobilization of derrick barges will be from Sarawak and if the lifting capacity is not met, then DBs from the nearest places will be mobilised
- Derrick barge mobilization/Demobilisation cost is not included in this study.
- Decommissioning total cost presented in the secondary data is in US dollars and will be converted to Malaysian Ringgit at a rate of 3.25600 i.e. 1USD = 3.25600MYR.

3.1.4. SITE-SPECIFIC ASSUMPTIONS IN DECOMMISSIONING COST ESTIMATION

Table 3: Stage-specific assumptions in decommissioning cost estimation

Decommissioning stage	Assumptions
Well plugging and abandonment	
Dry tree	• Well casings are grouted to the surface • 9-5/8" and smaller strings are pulled using jacks adopting rigless method • Water depths are from 95 to 1198feet
Conductor removal	• Abrasive cutting to be performed for severance operations • Conductors removed with casing jacks prior to arrival of DB • Conductors are cut into 40 feet-long segments • Conductors to be removed at a depth of 15

	feet below the mudline
Structure removal	• Complete removal of deck and jacket structure to shore using DBs with capacities ranging from 500 to 4000 tons • Jackets will be cut into sections ranging from 300 to 1600 tons • Most economical vessel spread and decommissioning method is selected • Single lift for platforms in <200 feet of water with 2000 ton DB • Water depth range from 95 to 1198ft • Number of legs range from 4 to 12 • Number of skirt piles range from 0 to 32 • Piles and skirt pile are severed abrasively • Platform preparation and site clearance activities are included in the estimate • No scrap value of steel • Piles to be removed at a depth of 15 feet below mud line

Source: Proserve Offshore, 2010

3.1.5. DECOMMISSIONING SCHEME

<u>Section 1: Well Plugging and Abandonment</u>

Requirements and Procedures

Well plugging and abandonment is one of the key cost elements of a decommissioning project and it requires wells to be abandoned in a form that ensures downhole cut off of hydrocarbon regions, prevention of formation fluids from migrating within the wellbore and to the seafloor, prevention of contamination of groundwater aquifers, site clearance to enable navigation activities or any other activities to take place on the sea and use of verified and tested equipment, quality plugging materials and trained personnel in accordance with industry standards.

Generally, the abandonment operation follows a step-by-step procedure that involves: Well preparations (this entails checking all valves on tree and well head to ensure that they are in proper condition and repairs to be made if problems are detected), Rig up on well (check all tubing and casing pressures and record them), filling the tubing and casing with fluid (to verify well integrity), removing down hole equipment, cleaning the well bore, utilizing squeeze cementing techniques or cement plugs to plug perforated intervals, plugging casing stubs and annulus and placement of surface plug with fluid filled between plugs.

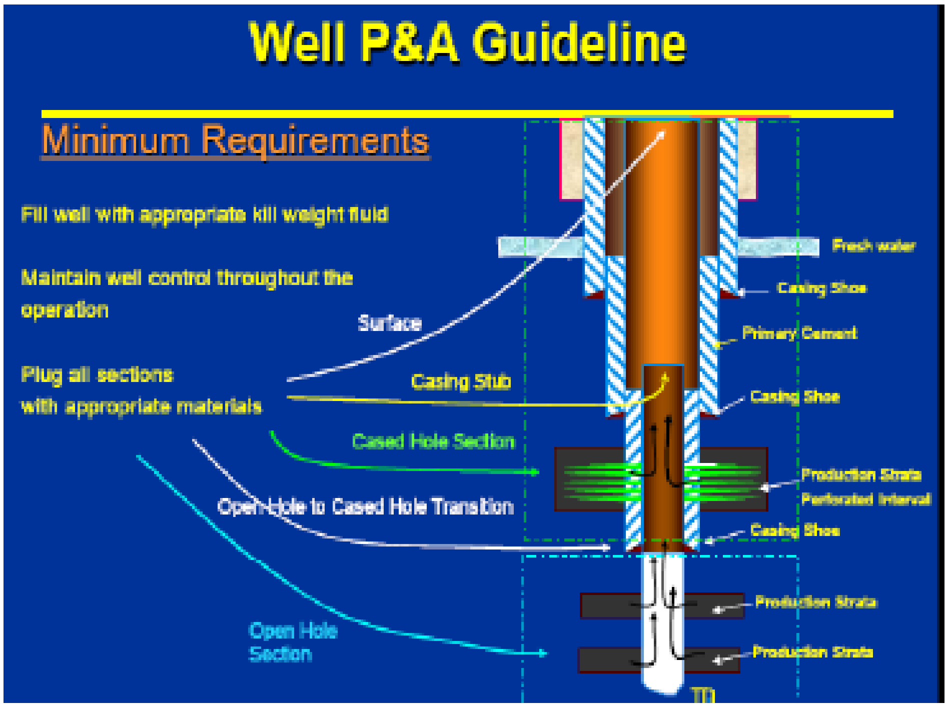


Figure 9: Well plugging and Abandonment minimum requirement

Adopted from ASCOPE Decommissioning Guidelines (2009).

Cost factors

The main factor is ascertaining costs to plug wells is the time taken to complete the process, which is dependent on the intricacy of individual wells and number of wells of each platform. Cost estimates for well plugging and abandonment are hinged on four cost categories that been used by Proserve. The categories will also be used in this study and are summarized below;

- A low cost well is one without pumps and sustained open hole pressures. It can be plugged in about two to three days.
- A medium low cost well is quite complex with some horizontal displacements having degree changes of 50^0 and below. Plugging a well of this type cane take about three to four days.

- A medium high cost well may encompass electric submersible pumps and has higher deviations in the range50^0 to 60^0. This kind of well can take about four to six days to plug.
- A high cost well is one that could have operational intricacies, severe dog legs with deviations of $60^0$and above. Plugging this well takes about six to ten days.

Another cost factor is well depth which is less substantial than well complexity. Well depth affects the number of trips made which makes deeper wells to have longer tripping times and thus, using up additional cement volumes which in turn increase service costs. In the below tables, average cost of well plugging by complexity and the total cost for well plugging and abandonment per platform are shown;

Table 4: Average well plugging and Abandonment costs by well type/Complexity

Well type	Average cost per well
Low cost well (3 days to plug and abandon)	RM284,900.00
Medium low cost well (4 days to plug and abandon)	RM418,890.91
Medium high cost well (5 days to plug and abandon)	RM523,613.64
High cost well (7+ days to plug and abandon)	RM837,781.82

Table 5: Well plugging and Abandonment cost per platform

Platform	Water Depth (ft)	Number of Wells to P&A (Rigless)	Rigless P&A Costs
A	188	52	RM17,058,392.38
B	190	57	RM18,639,154.34
C	192	38	RM12,699,494.02
Edith	161	18	RM6,796,665.57
Ellen	265	61	RM23,102,440.06
Elly	255	0	RM0.00
Eureka	700	50	RM20,218,079.90

Gail	739	24	RM11,190,116.61
Gilda	205	63	RM25,657,423.26
Gina	95	12	RM4,916,560.00
Grace	318	28	RM14,046,527.26
Habitat	290	20	RM8,650,111.01
Harmony	1198	34	RM23,016,637.95
Harvest	675	19	RM12,141,845.41
Henry	173	23	RM8,041,252.03
Heritage	1,075	48	RM33,345,855.14
Hermosa	603	13	RM8,270,357.22
Hidalgo	430	14	RM9,712,986.62
Hillhouse	190	47	RM15,561,674.30
Hogan	154	39	RM16,633,940.22
Hondo	842	28	RM16,753,005.63
Houchin	163	36	RM15,567,821.63
Irene	242	24	RM13,648,292.42
Average per well:			RM448,754.86
Average per Platform	188	33	RM14,594,288.39
Total		**748**	**RM335,668,632.99**

Section 2: Conductor removal

Requirements and Procedures

The conductor casing will be taken out at a depth of at least 15 feet below the mud line or to a depth that suits the uniqueness of the structure.

There are three dissimilar procedures employed in conductor removal. This covers Cutting, pulling and offloading. Cutting of the conductor casing necessitates the use of the best cutting method. The methods used can be explosive, abrasive or utilize diamond wire cutting system.

Cost factors and Assumptions

The factors considered in determining conductor casing removal costs are primarily water depth and number of conductors in each platform. The Conductors are the range of 0 to 65 while water depths span from 95 to 1198 feet.

In this study, the cutting technology to be utilized is assumed to be abrasive since it's the most commonly used method of severing conductors. Other approaches utilize explosives, but this could be very challenging and poses danger to the aquatic life.

Due to the large number of aquatic animals in the water, it's assumed that the conductors may be coated with marine growth and these will be removed as conductors are pulled.

The table below gives an estimate of the total removal cost of conductors. It is also essential to note that disposal costs are not included in these estimates.

Table 6: Total Conductor Removal Costs

Platform	Water Depth (ft)	Number of conductors	Removal Cost
A	188	55	RM13,536,523.70
B	190	57	RM14,097,802.75

C	192	43	RM10,799,155.66
Edith	161	23	RM5,373,578.67
Ellen	265	64	RM19,244,959.18
Elly	255	0	RM0.00
Eureka	700	60	RM37,282,111.68
Gail	739	24	RM15,833,758.69
Gilda	205	64	RM16,486,046.19
Gina	95	12	RM2,406,857.99
Grace	318	36	RM12,411,862.23
Habitat	290	20	RM6,725,391.73
Harmony	1198	52	RM51,593,664.32
Harvest	675	25	RM15,471,636.14
Henry	173	24	RM5,872,723.47
Heritage	1,075	49	RM44,210,384.77
Hermosa	603	16	RM9,247,948.42
Hidalgo	430	14	RM6,376,016.42
Hillhouse	190	52	RM12,973,678.52
Hogan	154	39	RM8,828,888.20
Hondo	842	28	RM20,645,455.95
Houchin	163	36	RM8,426,567.07
Irene	242	24	RM7,274,949.18
Total		**817**	**RM345,119,960.94**

Section 3: Structure removal

Requirements and procedures

Deck removal

The process of dismantling a platform starts with the removal of the deck/topsides. There are many decommissioning options employed in deck removal which include; Removal of modules together, removal as one whole piece, Removal in reverse order of installation or removal in small cut pieces. The option to be chosen depends on the entire design structure of one deck, but since the topsides vary in sizes, weight, functions and complexion, it's for this reason that none of the options is liable to be the most suitable in all cases. The weight of the topsides range between 448 and 1000 tons.

The removal options can be used depending on the lifting capacity and size of the DB especially when the entire deck is to be removed in one piece, this method is quicker and faster if the offloading site is big enough to accommodate such large pieces. On the other hand, removal of combined modules will require fewer lifts and thus reducing the DB time. Another method is by reverse installation which is one of the most common methods used in deck removal which involves demolishing in the reverse order in which they were installed. Also removal by small pieces involves cutting using mechanical means and the pieces mounted onto a DB. This method takes a longer time than reverse installation.

Jacket removal

The removal and lifting process of jackets is quiet expensive as it requires large and costly equipment. Weight and size of the facility have to be evaluated before taking them into consideration. In addition, attention has to be placed on method of lifting, method of cutting the main piles and skirt piles, diving requirements, transportation and the weather conditions of the water body. Bottom cuts of the jackets are made below the mud line approximately at 15 feet on the piles after the diving process which makes a major increment in the entire removal project. The jackets is then removed in sections or in a single lift especially for small structures.

In this study, the jackets weight range from 400 tons and 43, 000 tons and are located in water depths ranging from 95 feet to 1198 feet. Several removal options of jackets are employed which include; demolishing in-situ where the jackets are cut into sections especially for weights greater than 300 tons and single lift is another method used for jackets that may weigh less than 300 tons. The removal requires the use of heavy lift equipment like DB with lifting capacities to cater for the different weights.

Cost factors and assumptions

The platforms and other facilities are assumed to be removed at a depth of 15 feet below the mud line and modules will be removed in reverse sequence in which they were installed. Also the modules are assumed to be removed using DB's with 500, 2000 and 4000 lifting capacities. Also, all costs regarding the whole removal process for each of the platforms is included in the total platform removal cost of each platform as shown in the table below.

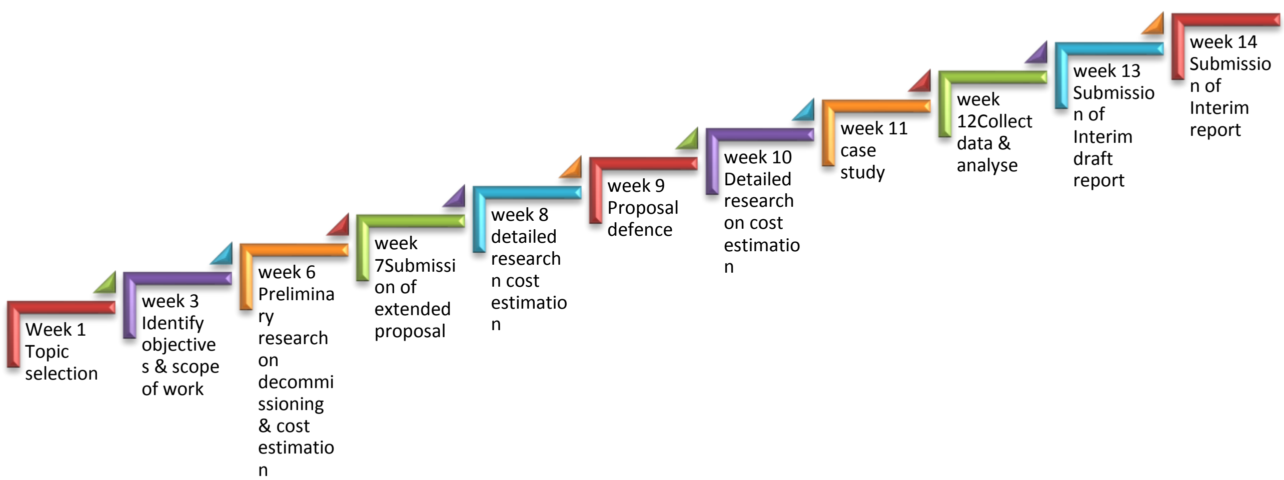
Table 7: Total Structure (Platform, Deck and Jacket) removal costs

Platform	Water Depth (ft)	Total number of piles	Platform Removal Cost
A	188	12	RM12,528,397.73
B	190	12	RM12,528,394.47
C	192	12	RM12,754,155.74
Edith	161	12	RM30,515,176.65
Ellen	265	8	RM19,335,443.42
Elly	255	12	RM21,756,780.85
Eureka	700	32	RM99,065,900.12
Gail	739	20	RM111,620,502.14
Gilda	205	12	RM18,053,852.52
Gina	95	6	RM5,454,871.22
Grace	318	20	RM24,619,299.76
Habitat	290	8	RM18,366,972.27
Harmony	1198	28	RM164,370,186.46
Harvest	675	28	RM107,696,185.34
Henry	173	8	RM10,913,083.10
Heritage	1,075	34	RM152,856,534.16
Hermosa	603	16	RM97,951,683.90
Hidalgo	430	16	RM80,168,717.55
Hillhouse	190	8	RM13,093,580.72

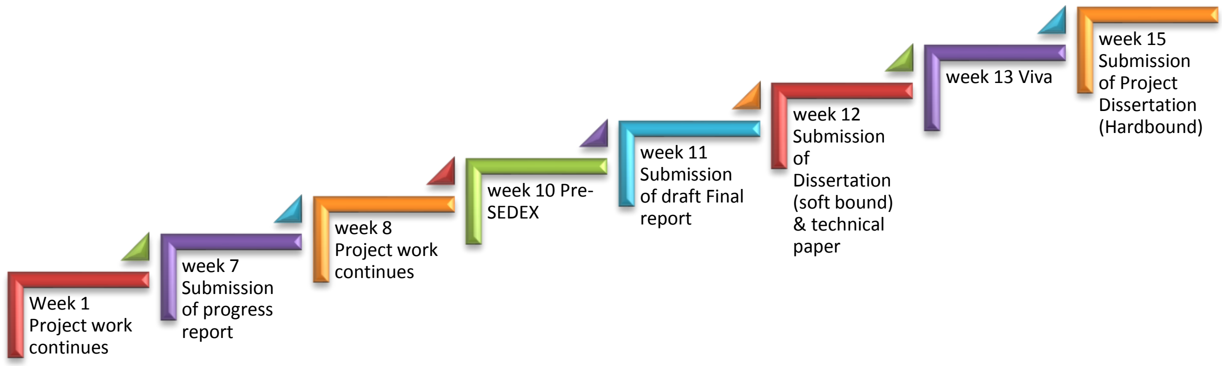
Hogan	154	12	RM26,330,467.77
Hondo	842	20	RM97,777,256.72
Houchin	163	8	RM25,543,407.91
Irene	242	8	RM19,525,154.26
			RM1,182,826,004.80

3.2 KEY MILESTONES

3.2.1. Final Year Project 1



3.2.2. Final Year Project 2


Week 1 Project work continues
week 7 Submission of progress report
week 8 Project work continues
week 10 Pre-SEDEX
week 11 Submission of draft Final report
week 12 Submission of Dissertation (soft bound) & technical paper
week 13 Viva
week 15 Submission of Project Dissertation (Hardbound)

3.3. GANTT CHART

		FYP 1														FYP 2														
No	Detail	1	2		4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Title Selection	■																												
2	Identify Objectives and Scope of work		■	■																										
3	decommissioning & cost estimation			■	■	■	■																							
4	Submission of extended proposal							■																						
5	detailed research on cost							■	■																					
6	Proposal defence									■																				
7	Detailed research on cost									■	■																			
8	case study										■	■																		
9	Collect data & analyse											■	■																	
10	Submission of Interim draft report													■																
11	Submission of Interim report														■															
12	Collection of data															■	■	■	■	■	■	■								
13	Developing cost factors															■	■	■	■	■	■	■								
14	Analysis using SPSS software															■	■	■	■	■	■	■								
15	Develop regression models															■	■	■	■	■	■	■								
16	Analyse results obtained															■	■	■	■	■	■	■								
17	Submission of progress report																					■								
18	Project work continues																					■	■	■						
19	Pre-SEDEX																								■					
20	Submission of Draft Report																									■				
21	Submission of technical paper and dissertation (Softbound)																										■			
22	Viva																											■		
23	Submission of project dissertation (Hardbound)																													■

CHAPTER 4
FINDINGS

4.1. RESULTS AND DISCUSSION
4.1.1. Table 8: Decommissioning cost factors

Decommissioning stage	Cost Factors	Table
Well Plugging and abandonment **Dry Tree**	Water depth, number of wells	5
Conductor removal	Water depth, number of conductors	6
Structure removal	Water depth, number of piles	7

4.1.2. Decommissioning algorithm

The key outputs from the regression analysis are the adjusted R^2 in the Model summary, the F-statistic and p-value in the ANOVA and the coefficients in the coefficient table.

Therefore, the R square tells the percent of the variability in the dependent variables explained by the variability in the independent variables. The model rarely explains 100% of the differences, it usually explains a certain percentage and the remaining percentage is the residual which is not explained by the model. A high value of R square suggests that the variation in the dependent variable is well explained by the regression model moreover the adjusted R square is preferred in reporting because it's more reliable since it takes into account the sample size of the variables. In addition, the F-statistic compares the difference between – groups' variance and it also takes into account the measure based on within-groups variance and lastly the coefficients is the most interesting part because it tells the relationship between the independent variable and the dependent variables through the coefficients.

4.1.2.1. Well Plugging and Abandonment

Table 9: Well P&A Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.946[a]	.895	.885	2,522,788.42126

In Well P & A, the R square is 89.5% and the adjusted R square is 88.5%. There is no much discrepancy between the two values which means that the independent variables are not redundant. A high discrepancy means that redundancy exists in the predictors. Therefore, these results mean that 88.5% of the variability in the cost is explained by the variability in Water depth and number of wells. As such, there is a strong correlation between the variables

Table 10: Well P&A ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1086750622596721.000	2	543375311298360.700	85.376	.000[b]
	Residual	127289228368901.080	20	6364461418445.054		
	Total	1214039850965622.000	22			

a. Dependent Variable: Cost

b. Predictors: (Constant), WD, NW

The result is written as F (2, 20) = 85.376 where 2 is the degree of freedom of the numerator and 20 is the degree of freedom of the denominator. The level of significance which is sometimes known as the p-value is 0.000 and is written as p<0.000. The p-value is less than 0.05 which signifies a strong equation. The calculated F (85.376) is way higher than the tabulated F (3.49) as shown in Appendix VI. This means that the model is very good since a statistical significance exists and as such, has high ability to predict accurate costs.

Table 11: Well P&A Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1416727.793	1340136.515		-1.057	.303
	NW	359836.285	31082.711	.838	11.577	.000
	WD	10606.425	1691.414	.454	6.271	.000

The coefficients of water depth and number of wells are 10606.425and 359836.285respectively.

In general, the coefficients in the regression model are interpreted as;

NW – for a 1 unit increase in the number of wells, the model predicts that the cost will increase by RM 359, 836.285 holding water depth fixed.

WD – For an additional foot in well depth, the model predicts that the cost will increase by RM 10,606.425 holding number of wells fixed.

Regression model

A two-factor regression model was developed from the data in Table 5 based on well depth and number of wells.

EA = 10606.425WD +359836.285NW – 1416727.793

Where by EA = estimated abandonment cost per well (RM/well), WD = water depth (feet) and NW = number of wells

Example

Platform Henry is located in 173ft water depth and in 1979 had 23 rigless wells. Unit cost to abandon a dry well is estimates as;

Using the cost equation derived, the total cost for Platform Henry plugging and abandonment is estimated to be;

EA = 10606.425(173) +359836.285(23) – 1416727.793 **= RM8, 694,418.29/Well.**

Actual abandonment cost **= RM8, 041,252.03/well**

4.1.2.2. Conductor Removal

Table 12: Conductor removal Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.967[a]	.935	.929	3,436,064.54668

a. Predictors: (Constant), NC, WD

Results in conductor removal show that R square is 93.5% and the adjusted R square is 92.9%. There is no discrepancy between the two values which means that there is no redundancy in the independent variables. Therefore, 92.9% of the variability in cost is well explained by the variability in number of conductors and Water depth. A stronger correlation exists between conductor removal variables than that of well P & A.

Table 13: Conductor removal ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3413587735081153.000	2	1706793867540576.000	144.563	.000[b]
	Residual	236130791379582.750	20	11806539568979.137		
	Total	3649718526460736.000	22			

a. Dependent Variable: Cost

b. Predictors: (Constant), NC, WD

The result show that F (2, 20) = 144.563 and its way higher than 3.49 (tabulated value in Appendix VI). This shows that a statistical significance that can relate between the variables exists, hence good predication. The P-value is p<0.000. As a test for normality, the value is less than 0.05 which means that the ANOVA is significant. The P-value is very low which shows that the equation is even stronger.

Table 14: Conductor removal Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-10478273.127	1775918.246		-5.900	.000
	WD	31188.136	2313.810	.770	13.479	.000
	NC	360746.007	39915.870	.516	9.038	.000

a. Dependent Variable: Cost

The coefficients of water depth and number of conductors are 31188.136 and 360746.007 respectively. Both values are positive which indicates that an increase in any of the units will increase the cost. A general interpretation would be;

WD – For 1 foot increase in well depth, the model predicts that the cost will increase by RM 31,188.136 holding number of conductors fixed.

NP - For a 1 unit increase in the number of piles, the model predicts that the cost will increase by RM 360,746.007 holding water depth fixed.

Regression model

ECR = 31188.136WD + 360746.007NC - 10478273.127

Where by ECR = estimated conductor removal cost (RM/conductor), WD = water depth (feet) and NC = number of conductors

Example

Platform Habitat installed in 1981 is located in 290ft water depth and has 20 conductors.

Using the cost equation derived, the total cost for platform Habitat conductor removal is estimated to be;

ECR = 31188.136(290) + 360746.007(20) - 10478273.127 = **RM5, 781,206.453/Conductor.**

Actual abandonment cost **= RM6, 725,391.73/Conductor**

4.1.2.3. Structure Removal

Table 15: Structure removal Model summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.974[a]	.948	.943	11,942,535.69883

a. Predictors: (Constant), NP, WD

b. Dependent Variable: Cost

Here, the R square is 94.8% and the adjusted R square is 94.3%. There is almost no difference in the values since the R square is very high, this means the model has a high prediction ability. Therefore, 94.3% of the variability in cost is well explained by the model.

Table 16: Structure removal ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	51726013417440808.000	2	25863006708720400.000	181.337	.000[b]
	Residual	2852483178355937.000	20	142624158917796.840		

Total	54578496595796752.000	22				

a. Dependent Variable: Cost

b. Predictors: (Constant), NP, WD

The results show that F (2, 20) = 181.337 which is about 52 times that of the tabulated value. This shows a good prediction since there is a statistical significance that can relate between the varibales. p<0.000 is less than 0.05 which is the test for normality. This means that the ANOVA is significant and can be used in predicting costs.

Table 17: Structure removal Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-14953078.146	5601845.205		-2.669	.015
	WD	135359.106	16164.614	.864	8.374	.000
	NP	744564.414	622439.171	.123	1.196	.246

The coefficients of well depth and number of piles are 135359.106 and 744564.414 respectively. Both values are positive which indicates that an increase in any of the units will increase the cost. A general interpretation would be;

WD – For 1 foot increase in well depth, the model predicts that the cost will increase by RM 135,359.106 holding number of piles fixed.

NP - For a 1 unit increase in the number of piles, the model predicts that the cost will increase by RM 744,564.414 holding well depth fixed.

Regression model

ESR = 135359.106WD + 744564.414NP – 14953078.15

Where by ESR = estimated structure removal cost (RM/structure), WD = water depth (feet) and NP = number of piles

Example

Gail is an 8 legged, 12 skirt piled platform located in 739ft water depth with a deck weight of 7,693 tons and jacket weight of 18,300 tons.

Using the cost equation derived, the total cost for platform Gail Structure removal is estimated to be;

ESR = 135359.106(739) + 744564.414(20) – 14953078.15**= RM99, 968,589.46/Structure.**

Actual abandonment cost **= RM111, 620,502.14/Structure**

A comparison between the estimated cost and actual costs in the examples show that there is little difference between the values. The estimated cost in well plugging and abandonment increases by 7.5% while conductor removal by 16.3%. Meanwhile the estimated cost in structure removal decreases by 11.7%. Due to these occurrences, a cost algorithm range of ±30% is allowed meaning that the estimated costs will fall above or below that value of the expected costs for complete removal of facilities

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

The report defined the Background, problem statement, objectives and scope of study for this final year project with the title "Parametric Study on the Elements of Cost Estimation for Offshore Platform Decommissioning." In addition, a literature review and an explanation of the methodology, Key milestones and Gantt chart of planned activities were provided.

Decommissioning as a whole is becoming complex and more challenging as the search for deeper wells continues, as such, it is going to be a big issue in Malaysia since many of the platforms are approaching the end of their production lives. In addition, each platform is unique in terms of size, weight, structure and therefore, requires specific evaluation to determine the cost. Hence, decommissioning cost estimate is a methodology which has the capability to develop reasonable data for decommissioning planning in Malaysia. But in order to achieve this, the regression models developed will aid in estimating costs for future use of any available platform installation regardless of its uniqueness for as long as it satisfies the assumptions mentioned in this study. Field data for Malaysian platforms would have been the best example to validate the results but due to scarcity of available data, this did not happen and as such, the data available from GOM was used for validation. Although Cost factors chosen in this research have ability to predict costs, decommissioning costs are affected by other factors like day rates, market conditions, location, inflation etc. hence, cost estimates will differ.

Factors affecting cost estimates

- Data collection errors
- Non-linearity of the x-y relationship
- Poor choice of cost driving parameters
- Presence of more than one cost driving parameter
- Inconsistent cost classification.

Limitations of using the parametric cost estimation technique.

- The main problem is sample size which according to statisticians, Parametric statistical procedures are more powerful but require a minimum sample size of about 30 (Pallant, 2007; Salking,2004). The sample size used in this study is 23 which is quite small and as such will not be able to give very accurate cost estimates.
- Also possibility of the regression coefficients having the wrong sign. For example a contradiction occurs where by a particular regression coefficient is negative yet it should be positive. This problem can be disconcerting as it is usually difficult to explain negative parameters

How to improve the accuracy in decommissioning cost estimation

Quality cost estimates are critical for economical, safe and in-time decommissioning and as such, up-front planning is necessary. Also the value of assumptions should not be underestimated, every cost estimates should be site specific. In addition, contingencies are an integral part of cost estimate, therefore, they should be included while estimating cost. Moreover, more data is needed to give more accurate result

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APPENDICES

APPENDIX 1
General raw Secondary data

	Platform	Field/Unit	Water Depth (ft)	Average Well	Total Weight (tons)	Year Install	Projected DB Lift
1	A	Dos Cuadras	188	2,500	3,457	1968	2,000
2	B	Dos Cuadras	190	2,500	3,457	1968	2,000
3	C	Dos Cuadras	192	2,500	3,457	1977	2,000
4	Edith	Beta/Beta	161	4,500	8,038	1983	2,000
5	Ellen	Beta/Beta	265	6,700	9,600	1980	2,000
6	Elly	Beta/Beta	255	0	9,400	1980	2,000
7	Eureka	Beta/Beta	700	6,500	29,000	1984	2,000
8	Gail	Sockeye/Sant	739	8,400	29,993	1987	4,000
9	Gilda	Santa Clara/Santa Clara	205	7,900	8,042	1981	2,000
10	Gina	Hueneme?pt Hueneme	95	6,000	1,006	1980	2,000
11	Grace	Santa Clara/Santa Clara	318	6,822	8,390	1979	4,000
12	Habitat	Pitas Point/Pitas Point	290	12,000	7,564	1981	2,000
13	Harmony	Hondo/Santa Ynez	1198	11,900	65,089	1989	4,000
14	Harvest	Pt.	675	10,000	29,040	1985	4,000
15	Henry	Carpinteria	173	2,500	2,832	1979	2,000
16	Heritage	Pescado/Sant a Ynez	1,075	10,300	56,196	1989	4,000
17	Hermosa	Pt. Arguello/Pt. Arguello	603	9,500	27,330	1985	4,000
18	Hidalgo	Pt. Arguello/Pt. Arguello	430	10,700	21,050	1986	4,000
19	Hillhouse	Dos Cuadras	190	2,500	3,100	1969	2,000
20	Hogan	Carpinteria	154	5,400	3,672	1967	500
21	Hondo	Hondo/Santa Ynez	842	12,700	23,550	1976	4,000
22	Houchin	Carpinteria	163	5,100	4,227	1968	500
23	Irene	Pt. Pedernales/Pt . Tranquillon	242	9,800	7,100	1985	2,000
				156,722			

APPENDIX 11

Average well plugging and Abandonment costs by well type/Complexity

Well type	Average cost per well (RM)	Average cost per well (USD)
Low cost well (3 days to	RM284,900.00	$ 87,500.00
Medium low cost well (4	RM418,890.91	$ 128,652.00
Medium hihg cost well (5	RM523,613.64	$ 160,815.00
High cost well (7+ days	RM837,781.82	$ 257,304.00

APPENDIX 111

Well plugging and abandonment

Platform	Average Well Depth (ft)	Number of Wells to P&A (Rigless)	Rigless P&A Costs (RM)	Rigless P&A Costs (USD)
A	2,500	52	RM17,058,392.38	$ 5,239,064.00
B	2,500	57	RM18,639,154.34	$ 5,724,556.00
C	2,500	38	RM12,699,494.02	$ 3,900,336.00
Edith	4,500	18	RM6,796,665.57	$ 2,087,428.00
Ellen	6,700	61	RM23,102,440.06	$ 7,095,344.00
Elly	0	0	RM0.00	$ -
Eureka	6,500	50	RM20,218,079.90	$ 6,209,484.00
Gail	8,400	24	RM11,190,116.61	$ 3,436,768.00
Gilda	7,900	63	RM25,657,423.26	$ 7,880,044.00
Gina	6,000	12	RM4,916,560.00	$ 1,510,000.00
Grace	6,822	28	RM14,046,527.26	$ 4,314,044.00
Habitat	12,000	20	RM8,650,111.01	$ 2,656,668.00
Harmony	11,900	34	RM23,016,637.95	$ 7,068,992.00
Harvest	10,000	19	RM12,141,845.41	$ 3,729,068.00
Henry	2,500	23	RM8,041,252.03	$ 2,469,672.00
Heritage	10,300	48	RM33,345,855.14	$ 10,241,356.00
Hermosa	9,500	13	RM8,270,357.22	$ 2,540,036.00
Hidalgo	10,700	14	RM9,712,986.62	$ 2,983,104.00
Hillhouse	2,500	47	RM15,561,674.30	$ 4,779,384.00
Hogan	5,400	39	RM16,633,940.22	$ 5,108,704.00
Hondo	12,700	28	RM16,753,005.63	$ 5,145,272.00
Houchin	5,100	36	RM15,567,821.63	$ 4,781,272.00
Irene	9,800	24	RM13,648,292.42	$ 4,191,736.00
Average per well:	6,814		RM448,754.86	$ 137,823.97
Average per Platform	6,814	33	RM14,594,288.39	$ 4,482,275.30
Total		**748**	**RM335,668,632.99**	**$ 103,092,332.00**

APPENDIX 1V

Conductor Removal

Platform	Water Depth (ft)	Conductors (ton)	Number of conductors	Removal Cost (RM)	Removal Cost (USD)
A	188	2,948	55	RM13,536,523.70	$ 4,157,409.00
B	190	3078	57	RM14,097,802.75	$ 4,329,792.00
C	192	2,339	43	RM10,799,155.66	$ 3,316,694.00
Edith	161	1,109	23	RM5,373,578.67	$ 1,650,362.00
Ellen	265	4,416	64	RM19,244,959.18	$ 5,910,614.00
Elly	255	0	0	RM0.00	$ -
Eureka	700	9,360	60	RM37,282,111.68	$ 11,450,280.00
Gail	739	3,931	24	RM15,833,758.69	$ 4,862,948.00
Gilda	205	3,648	64	RM16,486,046.19	$ 5,063,282.00
Gina	95	420	12	RM2,406,857.99	$ 739,207.00
Grace	318	2,866	36	RM12,411,862.23	$ 3,811,997.00
Habitat	290	1,480	20	RM6,725,391.73	$ 2,065,538.00
Harmony	1198	13,291	52	RM51,593,664.32	$ 15,845,720.00
Harvest	675	3,775	25	RM15,471,636.14	$ 4,751,731.00
Henry	173	1,214	24	RM5,872,723.47	$ 1,803,662.00
Heritage	1,075	11,319	49	RM44,210,384.77	$ 13,578,128.00
Hermosa	603	2,186	16	RM9,247,948.42	$ 2,840,279.00
Hidalgo	430	1,428	14	RM6,376,016.42	$ 1,958,236.00
Hillhouse	190	2,829	52	RM12,973,678.52	$ 3,984,545.00
Hogan	154	1,825	39	RM8,828,888.20	$ 2,711,575.00
Hondo	842	5,163	28	RM20,645,455.95	$ 6,340,742.00
Houchin	163	1,750	36	RM8,426,567.07	$ 2,588,012.00
Irene	242	1,546	24	RM7,274,949.18	$ 2,234,321.00
Total			**817**	**RM345,119,960.94**	**$105,995,074.00**

APPENDIX V

Structure Removal

Platform	Water Depth (ft)	Piles (ton)	Deck (ton)	Jacket (ton)	Total removal weight (tons)	Number of Jacket legs/piles	Number of skirt Piles	Total number of piles	Platform Removal Cost (RM)	Platform Removal Cost (USD)
A	188	600	1,357	1,500	3,457	12	0	12	RM12,528,397.73	$ 3,847,788.00
B	190	600	1,357	1,500	3,457	12	0	12	RM12,528,394.47	$ 3,847,787.00
C	192	600	1,357	1,500	3,457	12	0	12	RM12,754,155.74	$ 3,917,124.00
Edith	161	450	4,134	3,454	8,038	12	0	12	RM30,515,176.65	$ 9,371,983.00
Ellen	265	1,100	5,300	3,200	9,600	8	0	8	RM19,335,443.42	$ 5,938,404.00
Elly	255	1,400	4,700	3,300	9,400	12	0	12	RM21,756,780.85	$ 6,682,058.00
Eureka	700	2,000	8,000	19,000	29,000	8	24	32	RM99,065,900.12	$ 30,425,645.00
Gail	739	4,000	7,693	18,300	29,993	8	12	20	RM111,620,502.14	$ 34,281,481.00
Gilda	205	1,030	3,792	3,220	8,042	12	0	12	RM18,053,852.52	$ 5,544,795.00
Gina	95	125	447	434	1,006	6	0	6	RM5,454,871.22	$ 1,675,329.00
Grace	318	1,500	3,800	3,090	8,390	12	8	20	RM24,619,299.76	$ 7,561,210.00
Habitat	290	1,500	3,514	2,550	7,564	8	0	8	RM18,366,972.27	$ 5,640,962.00
Harmony	1198	12,350	9,839	42,900	65,089	8	20	28	RM164,370,186.46	$ 50,482,244.00
Harvest	675	3,383	9,024	16,633	29,040	8	20	28	RM107,696,185.34	$ 33,076,224.00
Henry	173	150	1,371	1,311	2,832	8	0	8	RM10,913,083.10	$ 3,351,684.00
Heritage	1,075	13,950	9,826	32,420	56,196	8	26	34	RM152,856,534.16	$ 46,946,110.00
Hermosa	603	2,500	7,830	17,000	27,330	8	8	16	RM97,951,683.90	$ 30,083,441.00
Hidalgo	430	2,000	8,100	10,950	21,050	8	8	16	RM80,168,717.55	$ 24,621,842.00
Hillhouse	190	400	1,200	1,500	3,100	8	0	8	RM13,093,580.72	$ 4,021,370.00
Hogan	154	150	2,259	1,263	3,672	12	0	12	RM26,330,467.77	$ 8,086,753.00
Hondo	842	2,900	8,450	12,200	23,550	8	12	20	RM97,777,256.72	$ 30,029,870.00
Houchin	163	150	2,591	1,486	4,227	8	0	8	RM25,543,407.91	$ 7,845,027.00
Irene	242	1,500	2,500	3,100	7,100	8	0	8	RM19,525,154.26	$ 5,996,669.00
									RM1,182,826,004.80	**$ 363,275,800.00**

APPENDIX VI

Table of critical values for the F distribution (for use with ANOVA):

How to use this table:

There are two tables here. The first one gives critical values of F at the p = 0.05 level of significance.
The second table gives critical values of F at the p = 0.01 level of significance.

1. Obtain your F-ratio. This has (x,y) degrees of freedom associated with it.
2. Go along x columns, and down y rows. The point of intersection is your critical F-ratio.
3. If your obtained value of F is equal to or larger than this critical F-value, then your result is significant at that level of probability.

An example: I obtain an F ratio of 3.96 with (2, 24) degrees of freedom.
I go along 2 columns and down 24 rows. The critical value of F is 3.40. My obtained F-ratio is larger than this, and so I conclude that my obtained F-ratio is likely to occur by chance with a p<.05.

Critical values of F for the 0.05 significance level:

	1	2	3	4	5	6	7	8	9	10
1	161.45	199.50	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.39	19.40
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14
10	4.97	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98
11	4.84	3.98	3.59	3.36	3.20	3.10	3.01	2.95	2.90	2.85
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49
17	4.45	3.59	3.20	2.97	2.81	2.70	2.61	2.55	2.49	2.45
18	4.41	3.56	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35
21	4.33	3.47	3.07	2.84	2.69	2.57	2.49	2.42	2.37	2.32
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.38	2.32	2.28
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.26
25	4.24	3.39	2.99	2.76	2.60	2.49	2.41	2.34	2.28	2.24
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.17
31	4.16	3.31	2.91	2.68	2.52	2.41	2.32	2.26	2.20	2.15
32	4.15	3.30	2.90	2.67	2.51	2.40	2.31	2.24	2.19	2.14
33	4.14	3.29	2.89	2.66	2.50	2.39	2.30	2.24	2.18	2.13