# Development of Platform Selection Tool for Offshore Decommissioning in Malaysia

by

Syarafina Binti Ahmad Termizi

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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Universiti Teknologi PETRONAS
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**CERTIFICATION OF APPROVAL**

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

______________________________________

(Dr. Noor Amila Wan Abdullah Zawawi)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
DECEMBER 2013

## 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.

SYARAFINA BINTI AHMAD TERMIZI

## ABSTRACT

Decommissioning of offshore structures is not a novel issue in the oil and gas industry. Malaysia is now dealing with ageing platforms that are waiting to be decommissioned. There are several alternatives of decommissioning such as “complete removal” and conversion to artificial reefs; “partial removal”, “remote reefing” and “topple in-situ”. Given quite a list of options, the decision to undertake the best option is challenging as the current method of comparative assessment of options using Best Practicable Environmental Option (BPEO) did not fully cover the technical aspect from structural competency point of view. Besides, BPEO is only implemented at the end of platform’s life. Therefore, the main goal is to develop a management decision making tool which is incorporated in the life cycle management of an oil field. A survey is conducted to solicit the verification of a group of ‘experts’ on pre-identified decommissioning criteria. The criteria were ranked accordingly through calculation of Relative Importance Index (RII), and a conceptual system is developed to complement the existing asset management system. In summary, this study could benefit the knowledge of offshore decommissioning planning through prioritization of decommissioning criteria.

**Keywords: decommissioning, criteria, decision making tool, Relative Importance Index**

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**ABBREVIATIONS AND NOMENCLATURE**

| | |
|---|---|
| API | American Petroleum Institute |
| BPEO | Best Practicable Environmental Option |
| EQA | Environmental Quality Act |
| MMS | Minerals Management Services |
| HLV | Heavy Lift Vessels |
| IMO | International Maritime Organization |
| PTS | PETRONAS Technical Standards |
| RII | Relative Importance Index |
| UNCLOS | United Nations Convention on the Law of the Sea |
| WSD | Working Stress Design |

# CHAPTER 1

# INTRODUCTION

## 1.1 PROJECT BACKGROUND

Strategically located in Asia Pacific Region and surrounded by South China Sea; Malaysia is blessed with numerous oil and gas reservoirs which significantly contributes to the nation's wealth and revenue. The first oil field was discovered in Miri back in 1910. Thereafter, the oil and gas industry has developed tremendously over time with about 28.35 billion barrels of oil (BBOE) recorded to date (History of Oil and Gas in Malaysia, 2013).

Fixed offshore platforms are used mainly for local oil and gas exploration. The abundant number of fixed platforms in Malaysia is due to the shallow water depths (depth < 200m). However, many of these platforms are approaching their design life. As stated in PETRONAS Technical Standards (PTS), the platforms are designed to have a service life of 30 years. According to Twomey (2010), there are around 249 offshore structures in Malaysia scattered around South China Sea in four regions: Peninsular Malaysia, Sabah, Sarawak, and the Malaysia Thailand Joint Authority. Among the numbers, 48% of the platforms already reached their design life of 25 years. The redundant platforms need to be decommissioned and removed without instigating any environmental problems. Despite the high percentage of 'expiring' platforms, Malaysia is still new in area of decommissioning with only a few of executed offshore decommissioning projects. In 2003, KETAM field showed Shell opting for complete removal. Meanwhile in 2004, Shell had its first local conversion of platform into artificial reef through decommissioning of BARAM 8 platform off coast of Miri, Sarawak. Recently in 2012, PETRONAS successfully facilitated the removal of SM4 and SMVA.

In order to decommission an offshore platform, there are several alternatives to be chosen. Options for decommissioning methods are complete removal, partial removal and rig-to-reef. For removed structures, the disposal options available are reuse, recycle or landfill disposal. Offshore decommissioning offers various options yet each of the options incurs considerably high amount of money with certain extent of complexity. As a result, the selection of option has never been easy. Hence, this research provides a macro study on decision making selection tool for offshore decommissioning which could assist the management of decommissioning planning. By having the selection tool, the decommissioning criteria and alternatives will be analyzed as to recommend the best option for decommissioning of fixed offshore structures.

## 1.2 PROBLEM STATEMENT

Although there are abundant possible combinations of alternatives for decommissioning of oil and gas facilities, there will always be a problem and difficulties in selecting the best option. Decommissioning is a controversial issue with a number of conflicting stakeholders. It is difficult to solve unaided hence a proper management tool could reduce the complexity of decision making. To date, there is no published tool in Malaysia which proposes to assist in the selection process. At present, decommissioning method is chosen based on case-by-case study and comparative assessment between feasible options. The assessment follows PETRONAS's Best Practicable Environmental Option (BPEO) which evaluates the relative performance of each option with respect to technical feasibility, health and safety, environmental impact and cost. BPEO is only deployed at the end of a platform's life and is often subjected to less structured ranking of proposed decommissioning alternatives. Therefore, this research aims at developing a tool which complements the existing asset management system and subsequently aid decision makers to recommend decommissioning alternatives, earlier in the platforms' life cycle. An effectively planned decommissioning campaign in this context would entail that a platform operator to possess centralized and up-to-date knowledge about the structure and field.  A high level decommissioning database is one which is developed as an inventory, which also specifies the amount of decommissioning activity which should occur in a given year to optimize revenue and strategic operation decisions via prioritization of future projects.

Due to increasing number of platforms approaching their design life, the difficulties to manage the platforms to be decommissioned keep arising each year. In addition, the planning for decommissioning is a tedious process where it might take up years and millions of Malaysian Ringgit to complete the decommissioning campaign. A simple decision framework with quantified decommissioning criteria could ease the complexity of decision making as it could provide a baseline for selection process.

## 1.3 OBJECTIVES

As mentioned in Section 1.2 above, the aim of this research is to develop the selection tool for offshore decommissioning in Malaysia. In order to achieve the main goal, two objectives have been outlined which are as follows:-

- To identify and quantify the structural pre-decommissioning criteria for existing fixed offshore structures which complements the existing asset management system
- To develop a local decommissioning prioritization system for fixed offshore structures which is relatively structured and accounts for uncertainty

Therefore, at the end of this project, the predetermined objectives are expected to be achieved within the given scope and time frame as per next discussion.

## 1.4 SCOPE OF STUDY

In order to ensure this research is well focused and remains on its right track, the scope of study has been delineated. This study is applicable only to fixed offshore structures in Malaysia. This indicates that decommissioning of pipelines and plugging of well will not be included. Since decommissioning is a very wide scope, this research will focus mainly on the technical elements of the structures.

## 1.5 RELEVANCY AND FEASIBILITY OF THE PROJECT

This research could be of benefit to the oil and gas industry in Malaysia as it could help in providing a tool to aid in decommissioning decision making. This could be a stepping stone in decommissioning planning through a practicable decision framework which includes technical aspect of structures into decision making, on top of the BPEO practice. Besides, this tool could complement the existing asset management and aid the decision makers to recommend the best option for decommissioning prior to platform's end life. By having a tool prepared for the selection of decommissioning options, the planning time could be reduced hence optimizing the resources.

Apart from that, the research is relevant to the body of knowledge as it provides the ranking of pre-decommissioning criteria based on expert's evaluation. Fundamentally, the baseline of this study is justified by the insight of oil and gas experts hence proving the relevancy of this project to oil and gas industry.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 DECOMMISSIONING OF OIL AND GAS INSTALLATIONS

Decommissioning starts to take place when the end of design life of offshore platform is approaching. According to NTL 2010-G05 enforced by US Department of Interior Bureau of Ocean Energy, Management, Regulation and Enforcement (BOEMRE), platforms that have been idle for five or more years need to be decommissioned within five years. The long duration significantly reflects the tedious and complex process of decommissioning, as illustrated in Figure 1.

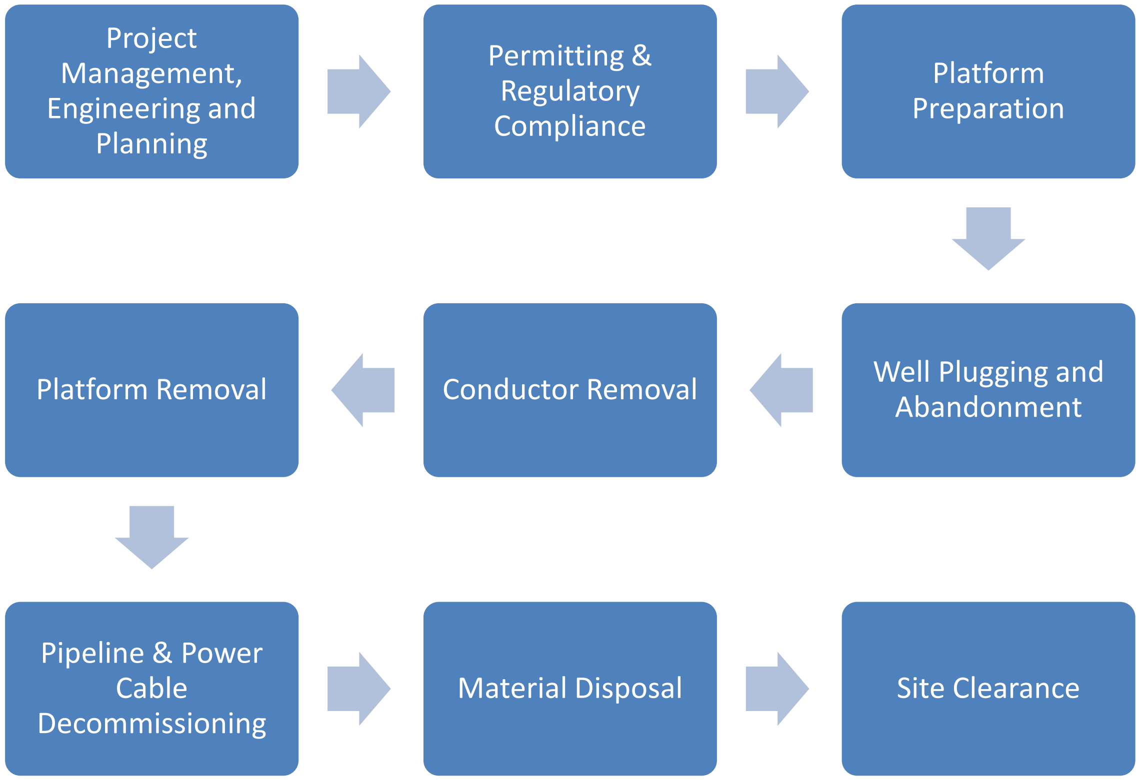



**Figure 1: Stages of Decommissioning (How Does Decommissioning Work?, 2012)**

Project management, engineering and planning is a multi-process procedure involving operational planning, engineering analysis and contracting. According to international practice, the planning commences three years before the well runs dry. Besides, the decommissioning method to be implemented is also decided in this stage. The method chosen will practically affect the following stages. For this research, we are aiming to provide a macro management tool which could aid the decommissioning planning.

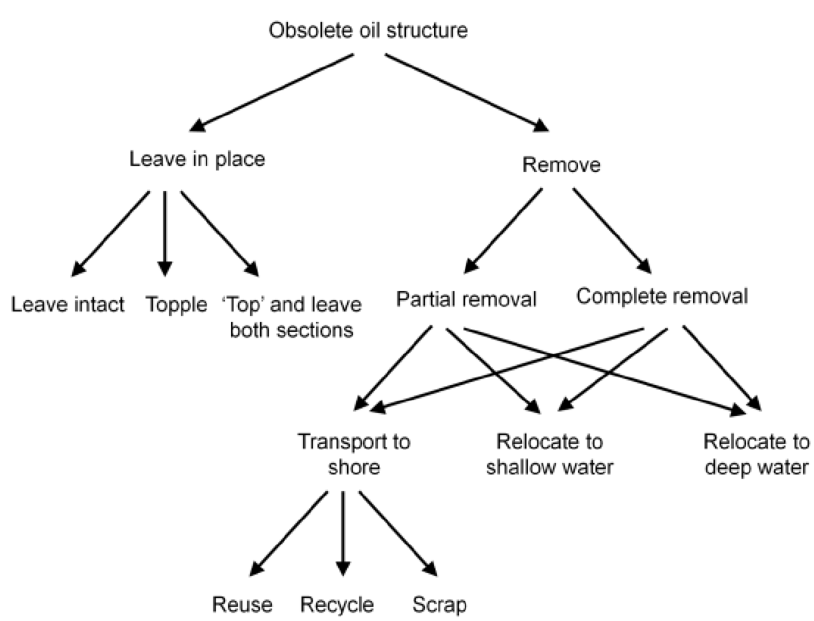
Permitting from various related parties is also an important stage in decommissioning. The permit must first be acquired from federal, state and local regulatory agencies. Failure in acquiring the permit from one agency might hinder the overall decommissioning progress. From operation perspective, decommissioning is more or less the inverse of platform installation which involves four main processes;

well plugging and abandonment (well P&A), conductor removal, topside and jacket removal (John,2009).

Rigless well P&A method is primarily used on shallow water platforms. It comprises of several processes such as wellbore cleaning, casing stubs plugging and as such. The plugs must be tagged to ensure proper placement or pressure-tested to verify integrity. For conductor removal, they are severed and removed using Heavy List Vessel (HLV). There are two available methods for conductor removal; explosive cutting and non-explosive cutting. However, according to Malaysian law, the use of explosive materials during platform removal is restricted due to environmental concerns. For Partial Removal method, conductors will be severed at the same elevation as the top of the jacket. On the other notes, topside and jacket is removed with HLV. Removal of topside follows the installation process in reverse sequence and subsequently will be sent to shore. Nonetheless, the removed jacket is subjected to variety of alternatives in which it can be sent to shore or left on the seabed. Further of this will be discussed in the next section.

## 2.2 DECOMMISSIONING OPTIONS

Decommissioning is a complex and costly engineering problem. It is always difficult for



decision makers to evaluate the available information for each decommissioning option with the possible outcome since each option has a mix of pros and cons attached to them. As pointed out by John (2009), fundamentally, all options include removal of deck and production facilities to the shore for storage, reuse or disposal while the only difference between the options is the handling of disused jackets. The jacket is either reused, recycled, converted to artificial reefs or disposed of in landfill. To actually remove a platform, two types of removal have been internationally practiced; complete removal and partial removal as part of conversion to an artificial reef. Since this research deals with decommissioning options, a firm understanding on each option is of pivotal element. Figure 2 briefly depicts the decommissioning options practiced worldwide (Booth, Fowler, & Macreadie, 2013).

Oil and gas equipment and piping will be sent to shore. Meanwhile, the remaining jacket and deck structures are subjected to onshore disposal, offshore disposal, reuse or conversion to artificial reefs. Nevertheless, the feasibility of each decommissioning method depends on several factors such as water depth, available resources and condition of structures to be decommissioned (Department of Resources, Energy and Tourism of Australia, 2008).

**Figure 2: Decommissioning Options**

Complete removal involves the severance of conductors and removal of jacket structure and platform materials to shore for disposal, reuse or recycling purposes. Complete removal is recommended through a guideline set by International Maritime Organization (IMO), where a platform structure of jacket weight less than 4,000 tonnes and located in water depth shallower than 100m needs to be completely removed.

Besides, in order to incorporate a decommissioning aspect in offshore installation, all structures installed after 1st January 1998 must be accompanied by a design that allows for complete removal. Complete removal follows a complete sequence of decommissioning stages as discussed in section 2.1, without leaving any structural members on the seabed. For the whole jacket removal, it comprises of several works which require proper management such as cutting, handling and loading (PROSERV OFFSHORE, 2009). It needs a detailed engineering study on jacket cut points because it will significantly determine the required crane and vessel capacity. In cases where the jacket is too large for a conventional HLV, jacket hopping removal which involves severing operation in different locations is found to be appropriate. Jacket will be made bouyant, lifted by HLV and towed to shallower water in order to facilitate the severing operation. This shows that complete removal not only requires extensive use of personnel and equipment to perform the operation, but a significant time and operational cost.

### 2.2.2 Partial Removal (Artificial Reefs)

Another type of removal is partial removal. Through this method, conductor and jacket are severed to at least 55m subsurface as to allow clearance for safe navigation (Wiegand, 2011). The severed parts are sent to shore for disposal, reuse or recycling purposes. Partial removal is considered as a part of conversion to artificial reefs as the remaining jacket could be converted to an articial reef. There are three methods of conversion to artificial reefs: partial removal, topple in place and remote reefing (John,2009). In partial removal, the severed section could be left on the seabed next to the remaining section, as illustrated in Figure 3. However, this method is only applicable if the platform was located at the designated artificial reef site. Partial Removal is usually considered as one of the best decommissiong methods as the severing operation can be done at a specified depth accessible by divers. Hence, selecting optimum location for jacket cut points is substantial in minimizing the diver's and cutting tool's onsite duration (PROSERV OFFSHORE, 2009).

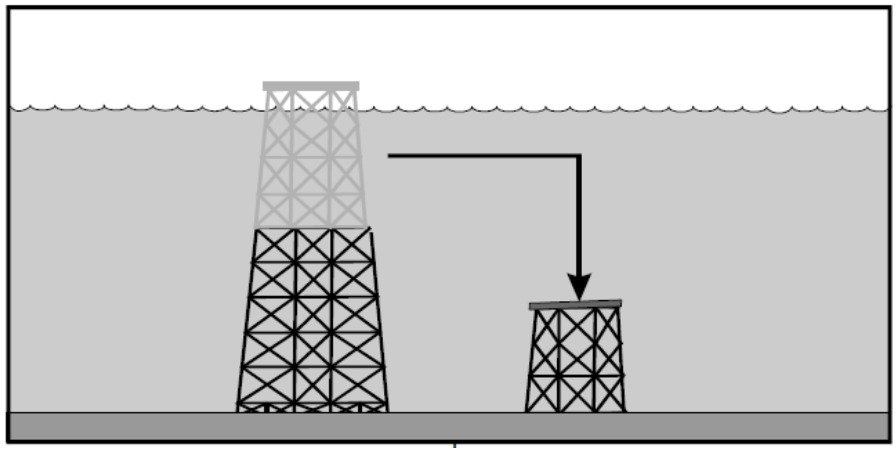


**Figure 3: Partial Removal**
**(Na K. , Wan Abdullah Zawawi, Liew, & Abdul Razak, 2012)**

The second method of toppling of the jacket in place is also dependant on the platform current location. Besides, it should comply to the minimum sea clearance for safe navigation. In order to ensure there is sufficent force to topple the jacket, tug with ample capacity should be selected. Hence the toppling force for each jacket section should be taken into major consideration. The other alternative for artificial reef is remote reefing. This option comes into picture when the platform is not located at designated reef site hence the removed jacket needs to be relocated at an appropriate reef site. It comprises of several engineering analysis such as the weight and bouyancy take-off. Since HLV will not be used in this option, towing of jacket structure to the predetermined site requires the determination of bouyancy required to upend and tow the jacket. The analysis comes together with a proper placement of bouyancy bags or tank to support the towing process. Futhermore, a proper tow route should also be analysed to identify any sea obstructions on the sea floor.

Regardless of the method chosen for conversion to artificial reefs, all of them are promoting sustainability through the preservation of marine environment. Over the years of platform's production, the structures becomes a habitat for sea creatures hence building up a whole new ecosystem. Figure 4 shows the marine life that have been attaching at the toppled jacket of Baram 8 in Miri, Sarawak. Therefore, by partially removing the structures, the habitat of ocean life could be conserved apart from improving the biodiveristy thus leading to better fishery exploitations. (Na, Wan Abdullah Zawawi, Liew, & Abdul Razak, 2012). At present, the trend of converting the decommissioned platform to artificial reefs is rising up especially in Gulf of Mexico. Conversion of platform structures to an artificial reef has been found to be appropraite for implementation in Malaysia due to its naturally shallow water depths (Wan Abdullah Zawawi, Liew, & Na, 2012).

**2.2.3 Disposal Options**

As previously discussed before, any decommissioning methods will still be sending the topsides and optionally jacket structures to shore. As illustrated in Figure 5, disposal options available for decommissioned structures are refurbishment and reuse, recycle or landfill disposal (Oil & Gas UK, 2012).

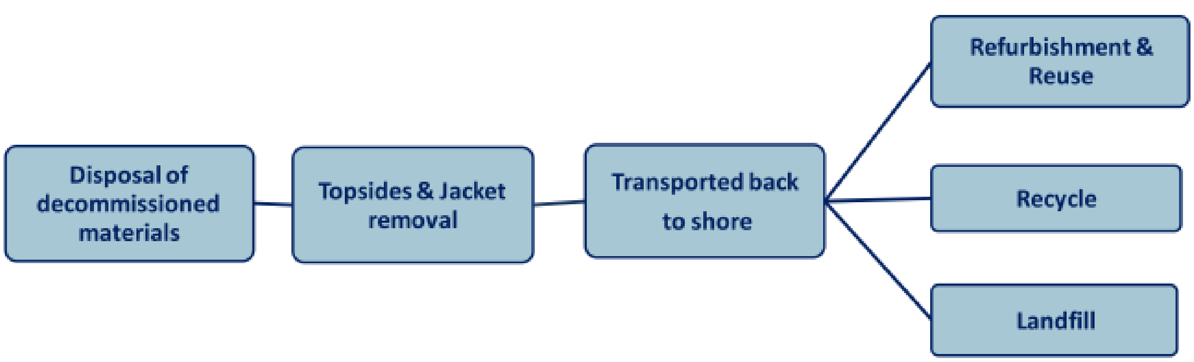



**Figure 5: Disposal Options for decommissioned materials**

Technically, reuse is an option that lengthens the life of the decommissioned structures by upgrading them to fit the new capacity. It has been recognized to be a cost and time effective solution for structures fabrication as it eliminates the need to fabricate a new one. According to Na (2012), reuse option could reduced up to 40-50% of the lead time-saving costs, based on current steel prices and fabrication charges of a new platform. It still retains the original state of material and helps to reduce the capital cost while shortening the time of construction and installation from a year or two to several months (Wiegand, 2011). In Malaysia, PETRONAS is also opting for reusing a refurbished platform in the development of Balai cluster. Hence, more of this option is expected to be seen in the coming years. In order to reuse any platform facilities, it requires additional considerations with respect to fatigue, material, inspection, removal and reinstallation (American Petroleum Institute, 2000). According to internationally practiced design code, API RP 2A-WSD, when structures are considered for reuse, inspection should be executed to verify suitability for the intended application and establish the condition of the structures. For example, structural conections having fatigue damage ratios of equal or more than 30% would impair the intended service of the platform hence should be upgraded or removed (American Petroleum Institute, 2000). In short, reuse option comes with thorough and detailed consideration in order to ensure that the refurbished platform could perform under its extended service.

Recycle comes into consideration when the structures did not pass the inspection or reuse option is found to be uneconomical. While reuse retains the original state of material, recycle is a reprocessing of an item into a new raw material. Wan Abdullah Zawawi (2012) states that recycling of steel scrap contributes to reduction of $CO_2$ emission and promotes a significant raw material and energy saving. In order to effectively manage the dismantling of offshore structures, yard must be of certain specification with adequate recycling facilities, such as good logistical access for distribution of recycled material and proper spillage control. To date, there are less than ten handling facilities that can cope with jacket recyling (Na K., et al, 2012).

As compared to the preceding two options, landfill disposal is normally considered when it comes to handling of non-recycable and hazardous materials. It might involve the process of burning and incineration of wastes hence higher emission of green house gases than the other disposal options (Oil & Gas UK, 2012). As this option involves several risks and drawbacks to the environment, it is always best to consider the option of reuse or recycle first, as outlined in waste management hierarchy in Figure 6.

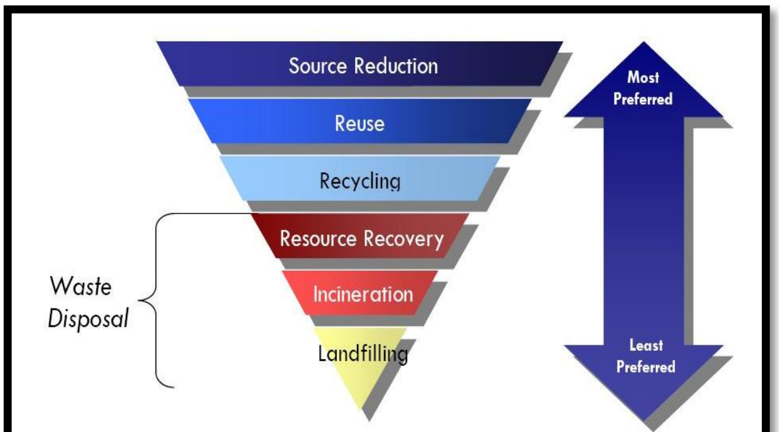



**Figure 6: Solid waste management hierarchy**

## 2.3 MALAYSIA REGULATORY FRAMEWORK

Regulations on decommissioning of offshore production facilies are pertinent to a number of international conventions and treaties. Besides, there are also several national legistlations governing decommissioning activities which are decribed below. In summary, all the legistations are enforcing on removal of oil and gas platform facilities to protect the safety of navigation, environment and other users of the sea.

### 2.3.1 International Regulations and Requirements

Malaysia's current standard industrial practice is governed by the previously mentioned legislations. The enforcement of removing disused offshore installations first gained attention into public international law during The 1958 Geneva Convention. It was stated Article 5(5) that the redundant installations must be entirely removed and the article was pertinent to all participating 57 state parties, including Malaysia (Hamzah, 2003).

Subsequently, the article was modified through UNCLOS 1982 in which it contained a more flexible provision, allowing for partial removal. The article 60(3) of UNCLOS 1982 states that,

‘Any installations or structures which are abandoned or disused shall be removed to ensure safey of navigation, taking into account any generallu accepted international standards established in this regard by the competent international oganisation. Such removal shall also have due regard to fishing, the protection of the marine environment and the rights and duites of other States. Appropriate publicity shall be given to the depth, position and dimensions of any installations or structures not entirely removed.’

Later, the scope of UNCLOS was widened with the mandate from IMO, which encompassed maritime safety, navigation and control of marine pollution (Department of Resources, Energy and Tourism of Australia, 2008). Futhermore, the cost, technical feasibility and risks of injury to associated personnel during removal are also taken into consideration. In IMO guidelines, it specifically mentioned that any disused structures installed after January 1998 that weighs lesser than 4000 tonnes and located in less than 100m water depths need to be entirely removed. Removal also needs to be performed in a way that it would not cause any adverse effects on the marine environement. Besides, new uses of platform and justification on leaving the platform on sea bed is emphasized. As pointed out by Hamzah (2003), IMO Guidelines and Standards specifically mentioned about convertion of redundant platform to artificial reefs, which are as follows:-

‘An installation or structure may be left wholly or partially in oace where it will serve a new use if permitted to remain wholly or partially in place on the sea bed (such as enhancement of a living resource)’

Nevertheless, it must be consistent with the established standards and does not interrupting navigation lanes. There are also several international requirements related to offshore decommissioning such as London Dumping Convention, Oslo Paris Convention (OSPAR) and London Convention & Decommissioning (1990).

### 2.3.2 Existing Malaysia Legislation

At present, there are only few regulations governing decommissioning activities in Malaysia such as which are  Environmental Quality Act 1994, Continental Shelf Act 1966, Exclusive Economic Zone Act 1984 and Merchant Shipping Ordinance 1952 (Bhoy, 2012). In EQA 1974, it basically concerns with the marine environment such as the prohibition of oil discharge into Malaysian water. Merchant Shipping Ordinance 1952 enforces on the safety of navigation. PETRONAS, as the custody of national petroleum resources, has developed draft of decommissioning guidelines for oil and gas installations. The basis of PETRONAS Decommissioning Guidelines comes from the previously mentioned international guidelines and the experiences learnt from KETAM and BARAM-8 decommissioning project executed by Shell (Bhoy, 2012). Besides, it is also stated in PETRONAS Decommissioning Guidelines that any removal shall be decided based on case-by-case decommissioning assessment.

## 2.4 PRE-DECOMMISSIONING CRITERIA

There are a lot of criteria need to be considered during decommissioning planning. A well-revised planning will significantly contribute to resources optimization and a better managerial procedures. Throughout the decommissioning stages, several criteria have been listed out as the main criteria which will structurally affect the course of decommissioning: platform integrity, platform type, resources and lifting management.

### 2.4.1 Platform Integrity

Existing platforms may be removed and relocated for continued use at a new site. Nevertheless, the platforms should be inspected beforehand to ensure that it is in an acceptable condition. Apart from that, the structures have to be reanalyzed and reevaluated for the use, conditions and loadings anticipated at the new site. Hence, the analysis of existing structures requires additional considerations with respect to fatigue, reserve strength ratio and structural integrity of connection and corrosion protection system. All structural connections should be inspected to insure that service damage does not impair the capability of the connection to carry design loads (American Petroleum Institute, 2000). Besides, the integrity of corrosion protection system should also be taken into consideration since it is crucial to check for the condition of protective coatings. In summary, the results of platform integrity will significantly determine the method of decommissioning whether it is acceptable for reuse or better for scrapping.

### 2.4.2 Platform Type

Platform type focuses on the features of platform such as the platform location, water depth and number of piles. According to IMO guidelines, platforms installed in water depth less than 100m is feasible for complete removal. This verifies why the water depth is of pivotal consideration since it could affect the option of decommissioning. Apart from that, the environmental condition surrounding the platform location such as wave climate, determine the complexity of decommissioning execution process. Hence, this proves that water depth and platform location is a essentially important in decommissioning planning. Besides, if the option of reuse were to be considered, it is important to look into platform characteristic so it will match the new proposed facilities.

### 2.4.3 Resources

One of the fundamental consideration in pre-decommissioning planning is the availability of resources for project execution. As previously discussed, removal operation will require extensive use of vessels and cranes. Nonetheless, the availability of those vessels are limited and needed booking years in advance (How Does Decommissioning Work?, 2012). Apart from that, vessel transporation has been proven to be contributing to the highest factor for cost estimation of decommissioning (Abd Rahim & Wan Abdullah Zawawi, 2013). Hence, vessel hire should be considered in decommissioning planning. Besides that, the decision to convert the structures to artificial reefs or to transport them to shore is greatly influenced by the location of nearest yard and artificial reef zone. If the structures were decided to be scrapped, then the location of hazardous waste treatment plant should be highlighted.

### 2.4.3 Lifting Management

Regardless of the option chosen for decommissioning methods, lifting of structures is an inevitable operation. The lifting process requires the utilization of crane vessels in which the capacity of vessel is determined by jacket weight, topside weigth and pile weight. Lifting management plays a significant role during the mobilization and demobilization process. The structures may be lifted in one piece, modular section, or in small pieces, depending on the capacity of barges and cutting management of structures (How Does Decommissioning Work?, 2012). All of these relate to the weight of aforementioned structures. Besides, during the lifting process, the integrity of lift points should be checked to avoid any calamity during operation.

## 2.5 DECISION MAKING SELECTION TOOL

At present, offshore decommissioning in Malaysia is done on case-by-case basis with the decommissioning of Ketam and Baram-8 as the baseline. Following the removal of those two platforms, few other offshore platforms (SM-4 and SMV-A) were decommissioned by PETRONAS. A Best Practicable Environmental Option (BPEO) Assessment Study was conducted to evaluate the decommissioning options with high consideration of environmental, health and safety impacts. Nevertheless, the assessment is conducted only at the end of platform life. Hence, this study proposes to have a selection system incorporated in the platform life cycle, which will lead to optimization of costs and improved productivity.

For this research, it involves a multi-criteria decision framework which is based on ranking of scores. The scores reflect the siginificance of each criterion to decommissioning activities. The criteria are ranked by the experts in decommissioning field, in which the ranking of importance could optimize complex trade-offs between different stakeholders. Relative Importance Index (RII) Method is used to rank the pre-decommissioning criteria in which it uses weighted scores to compare the relative importance of the criteria under study. From the five-point Likert scale used for this study, it was then converted to relative importance indices to obtain the ranks of the different criteria. These rankings made it possible to cross compare the relative importance of the factors as perceived by the three groups of respondents (Chan & Kumaraswamy, 1997).

This method has been widely used in numerous research to determine the relative importance index of factors. Gunduz, Nielsen, and Ozdemir (2013) used Relative Index Method to quantify and rank the delay factors for construction projects in Turkey. Works by Gunduz et. al is similar to this research as it also solicit expert's evaluation to verify the pre-identified delay factors in construction, in which the factors are extracted from literature research and studies. Apart from that, RII method was utilized to investigate and rank the major barriers and solutions to the use of Public-Private Partnerships (PPP) in Nigeria (Otairu, Umar, A. Zawawi, & K. Pakir, 2013). The same method was adopted to this study for the analysis of data collected from the questionnaire survey, within various groups as classified according to the role of respondents in decommissioning activities. As a result, a rapid and transparent outcome could be produced in which different stakeholders will have their own say in the decision making process.

## 2.4 REVIEW OF RELATED WORKS

Offshore decommissioning is not a novel issue around the globe. There are numerous decommissioned projects that had been executed before. Therefore, there are several works that used to compare between several decommissioning methods through ranking of criteria, which is closely related to this research. According to a study conducted by Robert and Velazquez for US Minerals Management Services (MMS-Department of Interior) in November 2000, there are several issues influencing the decommissioning methods which are safety, technical feasibility, environmental impact, permitting, disposal option, cost and scheduling. The study compared all the issues concerned between three decommissioning options; complete removal, partial removal and remote reefing.

**Table 1: Decommissioning Method Evaluation (Robert & Velazquez, 2001)**

| | Complete Removal | Partial Removal | Remote Reefing |
|---|---|---|---|
| Safety | (1) | (5) | (3) |
| (5) | *5* | *25* | *15* |
| Technical feasibility | (1) | (5) | (3) |
| (4) | *4* | *20* | *12* |
| Environmental impact | (1) | (5) | (3) |
| (4) | *4* | *20* | *12* |
| Permitting requirements | (5) | (2) | (3) |
| (3) | *15* | *6* | *9* |
| Disposal Option | (1) | (5) | (4) |
| (3) | *3* | *15* | *12* |
| Cost | (1) | (5) | (4) |
| (2) | *2* | *10* | *8* |
| Schedule | (1) | (4) | (5) |
| (1) | *1* | *4* | *5* |
| **Rank total** | **(11)** | **(31)** | **(28)** |
| **Weighted total** | ***34*** | ***100*** | ***73*** |

Referring to Table 1, issues that influence decommissioning method selection were categorized and ranked in order of importance from 1 to 5, with 5 being the most important. Using all the ranked issues, each decommissioning method was compared with the other two and ranked 1,3 and 5 with 5 being the best case method. The ranking for each method was then multiplied with the weighted value for each task. The resulting numbers, as written in italics, were added to obtain the total score. The decommissioning method with highest score is considered to be the best option to be chosen. Hence, from Table 1, it has been found out that partial removal is the most preferable option, followed by remote reefing. Complete removal is identified to be the least preference method as its complexity is rather high in all issues, except for a straightforward permitting issue (Robert & Velazquez, 2001). The study is closely related to this research as it identifies the criteria influencing decommissioning methods and compare their significance to each decommissioning option. The method used to evaluate the options was also based on weighted scores. However, it did not technically focus on the structural aspect of the structures hence comes the objectives of this research which is to fill in those gaps.

As aforementioned in section 2.3, PETRONAS is using Best Practicable Environmental Option (BPEO) Assessment to determine the most feasible decommissioning method for a particular structure. Essentially, it comprises of four main criteria that significantly affect the selection of decommissioning option, which are environment, health and safety, technological feasibility and cost. Figure 7 depicts the BPEO concept. The relative performance of each decommissioning option with respect to the four criteria will be assessed hence the most feasible option could be identified (PETRONAS Research & Scientific Services Sdn. Bhd, 2006).

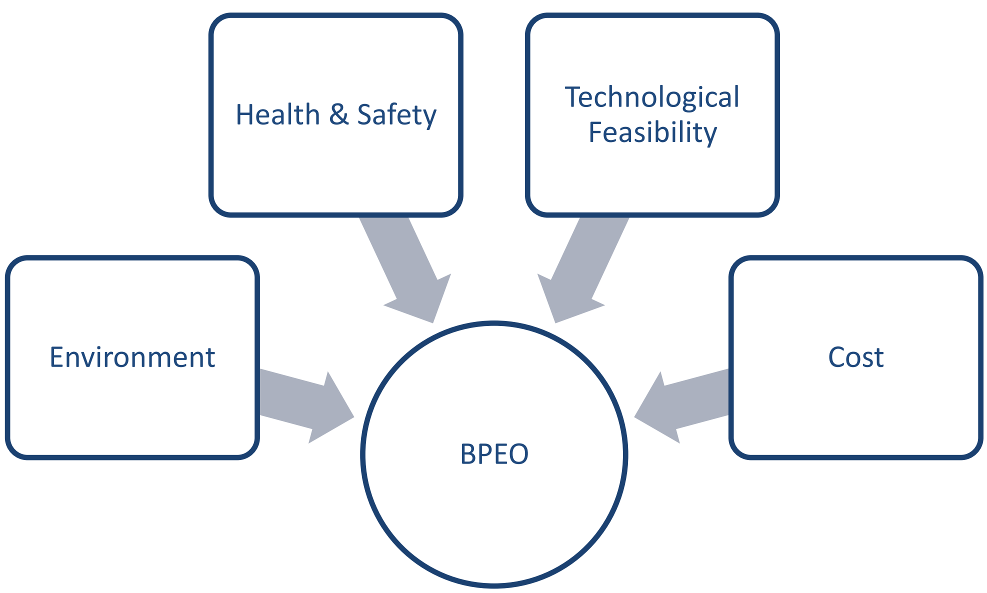


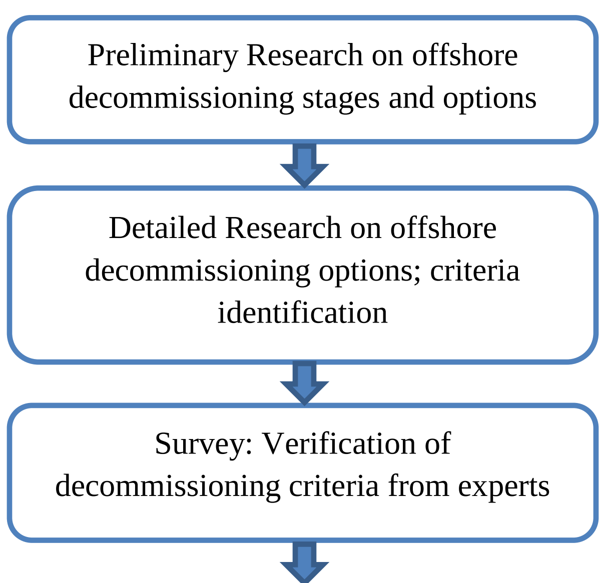

**Figure 7: BPEO Concept**

Similar to the work done by Robert and Velazquez, PETRONAS uses the comparative assessment to select the most practicable decommissioning option. On top of that, BPEO is deployed only at the end of platform's life. Hence this research aims at developing a tool to complement the asset management system in which the decommissioning planning could be incorporated throughout the platform's life cycle, instead of the end of platform's life.

# CHAPTER 3

# METHODOLOGY

## 3.1 RESEARCH METHODOLOGY



In order to accomplish the objectives set for this study, the decommissioning criteria are identified from literature research and executed decommissioning projects. Subsequently, the pre-identified criteria are listed out in form of decision framework, which are then classified into main criteria and sub-criteria. A set of questionnaire is distributed to the appointed expert groups in decommissioning planning, which are project manager, contractor and consultant. The respondents are asked to rank the criteria in order of their relative importance during the planning of pre-decommissioning. Then, the results are ranked and several analysis have been done to test the reliability and cohesion of those judgments. Further recommendations are also provided for better improvement of this research.

## 3.2 PROJECT ACTIVITIES

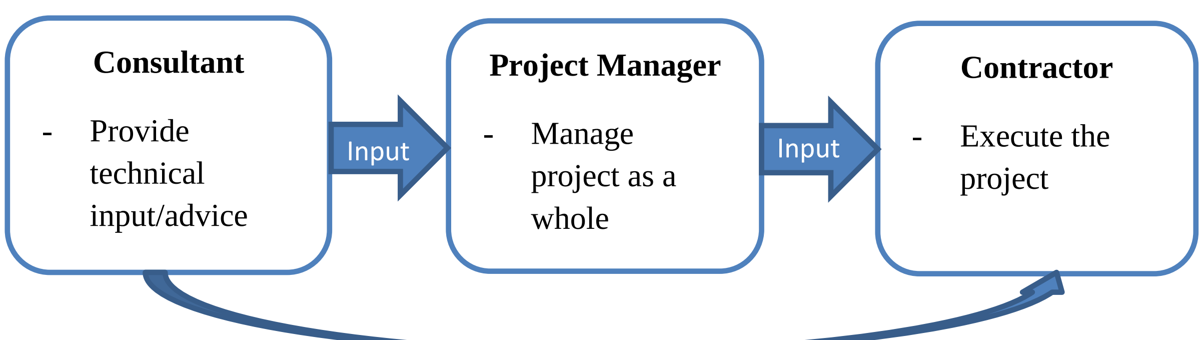
As previously depicted in methodology flowchart, the analysis of decision making requires data collection of decision makers' preferences through survey. The survey was done based on a set of questionnaire targeted to involved experts in offshore decommissioning area.

### 3.2.1 Survey

The respondents was approached to answer a set of questionnaire hence to develop priorities among the listed criteria. The questionnaire uses the Likert scale of 1 to 5 with 1 being the most important and 5 being the most redundant factor. The criteria provided in the first questionnaire are extracted from the eligible standards and literature readings on decommissioning, especially from PETRONAS Technical Standards (PTS) and API RP-2A WSD Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms. Hence, the opinion of experts is needed to justify the relevancy of the listed criteria apart from to provide a room for them to address any other important criteria. Once the responses from all respondents have been received, the findings will be summarized for result analysis. The set of first questionnaire is as attached in Appendix 1.

### 3.2.2 Stakeholders (Respondents)

The respondents are chosen based on their involvement in decommissioning and expertise in structural integrity. As discussed in section 2.1, decommissioning activities start with project management, engineering and planning. Three groups have been identified as the major stakeholders during those managing and planning stages, which are project managers, consultant and contractor. The relationship between the groups are depicted in Figure 8:



Inspection

**Figure 8: Basic relationship between stakeholders in project planning (Abdullah Zawawi, 2013)**

A) Consultant

Consultants are the ones responsible for the structural aspects of offshore structures. In the flow of decommissioning project management, they will be providing technical input and advice to the managing team. Among the notable consultant is PETRONAS Group Technical Solution (GTS).

B) Project Manager

Standing as the certified owner of oil and gas activities in Malaysia, PETRONAS is responsible for any projects related to oil and gas, which includes decommissioning project as well. PETRONAS has its own management team, Petroleum Management Unit (PMU) which is accountable in managing the platforms in Malaysian water. During decommissioning, project manager will be receiving technical input from consultant and they are obliged to prepare the execution plan for contractor. Execution plan describes the schedule of decommissioning and the equipment and labor required to perform the operation (How Does Decommissioning Work?, 2012). In order to ensure the project is well executed, the interaction between project manager and both consultant and contractor has to be well-communicated.

C) Contractor

Contractors will be in charge of executing the decommissioning project. It is important to include the involvement from contractor in decommissioning planning because similar to the consultant, they are also expert in technical works in which they could turn the decommissioning plan into executed project.

### 3.3 DATA ANALYSIS

In order to analyze the result, Relative Importance Index (RII) is used to rank the criteria. All the numerical scores obtained from the questionnaire were transformed to relative importance indices to determine the relative ranking of the factors. The relative importance index (RII) was evaluated using the following expression, as in Eq. (1):

$$RII = \frac{\sum W}{(A*N)} \qquad (1)$$

where;

W= weighting given to each criteria by respondents (ranging from 1 to 5)

A= highest weight (ie: 5 in this case)

N= total number of respondents

The RII value had a range of 0 to 1, with 0 not inclusive. Higher value of RII indicates the more important the criteria is.

For correlation test, Spearman's Rank Correlation (ρ) test has been used. It is a non-parametric test which measures the strength of association between two variables. For this study, Spearman's method is used to investigate for correlation or agreement between groups of respondents. Spearman's (ρ) ranges between +1 to -1. The description of such range is as follows:-

(ρ) of +1 indicates a perfect association between groups

(ρ) of 0 indicates no association between groups

(ρ) of -1 indicates a perfect negative association between groups

The closer (ρ) is to zero, the weaker the association is.

In order to test for internal consistency in judgment, Cronbach's alpha method is utilized. It is the method used to check for internal inconsistency estimate of reliability of test scores. The value of alpha will be derived from the test scores, in which it has its own acceptability ranges. Further of this will be discussed in Chapter 4.

## 3.3 KEY MILESTONE & GANTT CHART

**Table 2: Key Milestone for Research Project**

| | FYP 1 | | | | | | | | | | | | | | FYP 2 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activities/Week | 1 | 2 | 3 | 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 |
| Selection of Project Topic | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Research Work | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| • *develop understanding of project background* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| • *problem identification and objective establishment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| • *literature review on decommissioning options and stages* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Extended Proposal Defence | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | |
| Further Research on Criteria of Decommissioning | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Proposal Defence | | | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | |
| Development of Framework for Decommissioning Criteria | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Interim Draft Report | | | | | | | | | | | | | ■ | | | | | | | | | | | | | | | | |
| Submission of Interim Report | | | | | | | | | | | | | | ■ | | | | | | | | | | | | | | | |
| Data collection by survey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Result analysis and checking | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Progress Report | | | | | | | | | | | | | | | | | | | | | | ■ | | | | | | | |
| Purpose recommendation for future works | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pre-SEDEX | | | | | | | | | | | | | | | | | | | | | | | | | ■ | | | | |
| Submission of Draft Report | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | | | |
| Submission of Dissertation (soft bound) | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | | |
| Submission of Technical Paper | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | | |
| Oral Presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | |
| Submission of Project Dissertation (hard bound) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ |

■ key milestone

### 3.4 TOOLS REQUIRED

**Table 3: Software Required for Research Project**

| Software | Description |
|---|---|
| Microsoft Office ( Word, Excel, Powerpoint) | For documentation and presentation purposes. Microsoft Excel is used for result analysis. |
| PQStat | To do the analysis for reliability check and correlation test |

Table 3 shows the software required at this point of preliminary research stage. Microsoft Office Word and Microsoft Office Excel are used for documentation and presentation purposes. Besides, Microsoft Excel is mainly used for result analysis and calculation of RII. For reliability and correlation test, PQStat software is used which provides a more understandable interface in analyzing the result.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Criteria Identification

Before the commencement of survey, the criteria of pre-decommissioning were first proposed from the eligible standards and literature review. The survey comes in as the validation of those identified criteria through expert group elicitation. Figure 9 outlines the listed criteria in a form of decision framework. The main goal is to prioritize the pre-decommissioning criteria of fixed platforms in Malaysia. Four major indicator of pre-decommissioning have been identified which are: platform integrity, resources, lifting management and platform type; in which sub-criteria subsequently follow each one of them. The first questionnaire follows the Likert scale of 1 to 5 with 1 being the most important and 5 being the least. The listed criteria need to be ranked with regards to its significance and any additional factors could be separately included by the respondents in the questionnaire as well.

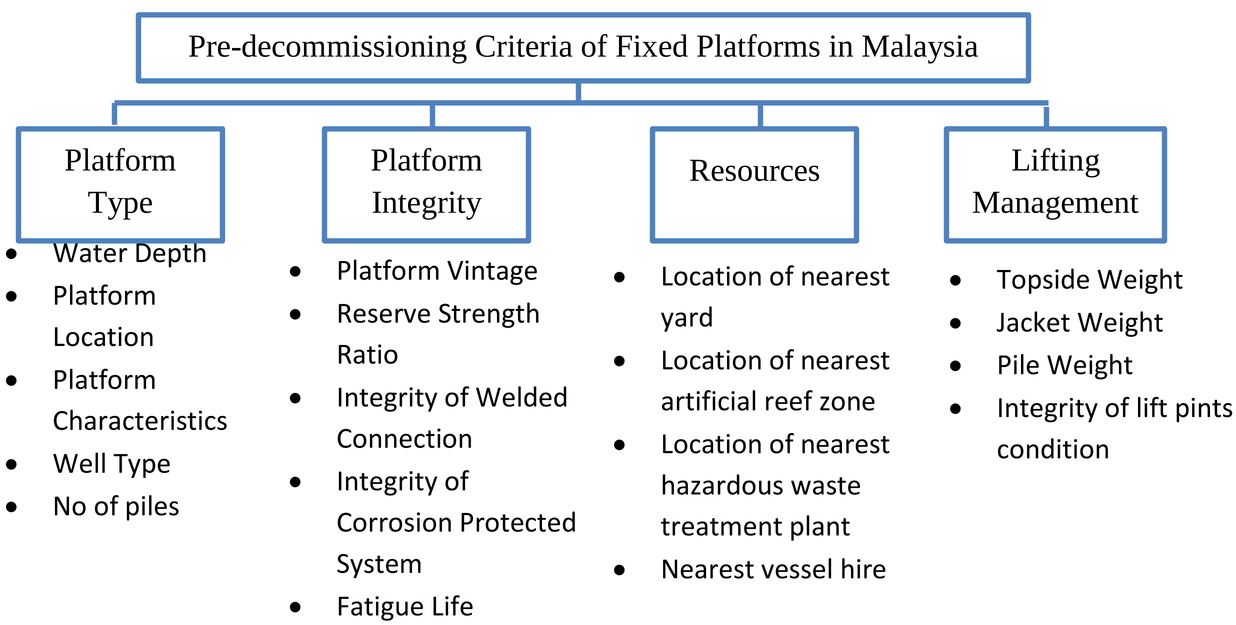



**Figure 9: Pre-decommissioning Criteria of Fixed Platforms in Malaysia**

### 4.2 Relative Importance Index (RII)

From the questionnaire, the findings have been analyzed and ranked. The ranking is established by using the method of Relative Importance Index (RII). The scoring was done based in Likert Scale of 1 to 5, with the following descriptions:-

**Table 4: Likert Scale of the conducted survey**

| Scale | Description |
|---|---|
| 1 | Very High Importance |
| 2 | High Importance |
| 3 | Medium Importance |
| 4 | Low Importance |
| 5 | Very Low Importance |

Since the scale of 1 is regarded as the most important criteria, the lower the RII value will indicate a greater importance to decommissioning. Listed below is the rank of sub-criteria in accordance to their importance level.

**Table 5: Rank of Important Criteria for Pre-decommissioning**

| Sub-criteria | RII | Rank |
|---|---|---|
| Nearest vessel hire | 0.029 | 1 |
| Topside Weight | 0.267 | 2 |
| Jacket Weight | 0.333 | 3 |
| Platform Characteristics | 0.343 | 4 |
| Location of Nearest Yard | 0.371 | 5 |
| Integrity of Welded Connection | 0.433 | 6 |
| Water Depth | 0.457 | 7 |
| Pile Weight | 0.500 | 8 |
| Location of Nearest Artificial Reef Zone | 0.543 | 9 |
| Platform Vintage | 0.567 | 10 |
| Platform Location | 0.600 | 11 |
| Reserve Strength Ratio | 0.600 | 12 |
| Well Type | 0.629 | 13 |
| Location of Nearest Waste Hazardous Treatment Plant | 0.629 | 13 |
| Fatigue Life | 0.633 | 15 |
| Integrity of lift point | 0.633 | 15 |
| Integrity of Corrosion Protection System | 0.733 | 17 |
| No of Piles | 0.800 | 18 |

From the results, vessel hire (RII=0.029) ranked as the most important criteria of pre-decommissioning. This is indeed relevant considering that transportation is the biggest factor in cost estimation of decommissioning (Abd Rahim & Wan Abdullah Zawawi, 2013). Hence, if the decision to decommission a platform were to be made, vessel hire needs to be prioritized above other criteria, as the availability of vessel is limited and the booking will take years in advance (How Does Decommissioning Work?, 2012). Then, the rank followed by topside and jacket weight. The rank is found to be appropriate since the size and weight of structures is closely related to the required capacity of vessels or barges for transportation and lifting purposes.

The average RIIs are then calculated for each group in order to evaluate the ranking of mean criteria.

**Table 6: Mean RIIs from sub-criteria**

| Main Criteria | Rank | Sub-Criteria | RII | Mean RII |
|---|---|---|---|---|
| Platform Type | 1 | Platform Characteristic | 0.343 | 0.566 |
| | 2 | Water Depth | 0.457 | |
| | 3 | Platform Location | 0.600 | |
| | 4 | Well Type | 0.629 | |
| | 5 | No of Piles | 0.800 | |
| Platform Integrity | 1 | Integrity Welded | 0.433 | 0.593 |
| | 2 | Platform Vintage | 0.567 | |
| | 3 | RSR | 0.600 | |
| | 4 | Fatigue Life | 0.633 | |
| | 5 | Integrity Corrosion | 0.733 | |
| Resources | 1 | Nearest vessel hire | 0.029 | 0.393 |
| | 2 | Loc. Nearest yard | 0.371 | |
| | 3 | Loc. AR zone | 0.543 | |
| | 4 | Loc. Hazard TP | 0.629 | |
| Lifting Management | 1 | Topside Weight | 0.267 | 0.433 |
| | 2 | Jacket Weight | 0.333 | |
| | 3 | Pile Weight | 0.500 | |
| | 4 | Integrity of lift point | 0.633 | |

**Table 7: Ranking of Main Criteria from Mean RII**

| Main Criteria | Mean RII | Rank |
|---|---|---|
| Resources | 0.393 | 1 |
| Lifting Management | 0.433 | 2 |
| Platform Type | 0.566 | 3 |
| Platform Integrity | 0.593 | 4 |

Table 6 describes the cluster of sub-criteria according to their respective group. The average RIIs in each group gives the ranking of main criteria, as shown in Table 7. In summary, Resources is the most significant main criteria of pre-decommissioning, followed by Lifting Management, Platform Type and Platform Integrity. This ranking correlates with the ranking of sub-criteria as previously discussed.

Since we have three groups of respondent for this survey, it is a good practice to evaluate the ranking based on the group's preference. The ranking is done according to the group of main criteria.

1) Contractor

**Table 8: Ranking of Criteria from Contractor**

| Sub-criteria | RII | Rank |
|---|---|---|
| Nearest vessel hire | 0.200 | 1 |
| Integrity of Welded Connection | 0.200 | 1 |
| Topside Weight | 0.300 | 3 |
| Jacket Weight | 0.350 | 4 |
| Location of Nearest Yard | 0.400 | 5 |
| Platform Type | 0.450 | 6 |
| Well Type | 0.450 | 6 |
| Reserve Strength Ratio | 0.467 | 8 |
| Platform Location | 0.500 | 9 |
| Pile Weight | 0.500 | 9 |
| Water Depth | 0.500 | 9 |
| Location of Nearest Artificial Reef Zone | 0.600 | 12 |
| Location of Nearest Waste Hazardous Treatment Plant | 0.600 | 12 |
| Integrity of lift point | 0.600 | 12 |
| Platform Vintage | 0.600 | 12 |
| Fatigue Life | 0.667 | 16 |
| Integrity of Corrosion Protection System | 0.800 | 17 |
| No of Piles | 0.850 | 18 |

2) Consultant

**Table 9: Ranking of Criteria from Consultant**

| Sub-criteria | RII | Rank |
|---|---|---|
| Topside Weight | 0.10 | 1 |
| Jacket Weight | 0.10 | 1 |
| Platform Type | 0.20 | 3 |
| Nearest vessel hire | 0.20 | 3 |
| Pile Weight | 0.20 | 3 |
| Location of Nearest Yard | 0.30 | 6 |
| Integrity of lift point | 0.30 | 6 |
| Water Depth | 0.40 | 8 |
| Location of Nearest Artificial Reef Zone | 0.40 | 8 |
| Reserve Strength Ratio | 0.60 | 10 |
| Integrity of Welded Connection | 0.60 | 10 |
| Location of Nearest Waste Hazardous Treatment Plant | 0.60 | 10 |
| Platform Location | 0.70 | 13 |
| Platform Vintage | 0.70 | 13 |
| Integrity of Corrosion Protection System | 0.70 | 13 |
| Fatigue Life | 0.70 | 13 |
| Well Type | 0.80 | 17 |
| No of Piles | 0.80 | 17 |

3) Project Manager

**Table 10: Ranking of Criteria from Project Manager**

| Sub-criteria | RII | Rank |
|---|---|---|
| Platform Type | 0.20 | 1 |
| Platform Vintage | 0.20 | 1 |
| Nearest vessel hire | 0.20 | 1 |
| Topside Weight | 0.20 | 1 |
| Water Depth | 0.40 | 5 |
| Fatigue Life | 0.40 | 5 |
| Location of Nearest Yard | 0.40 | 5 |
| Jacket Weight | 0.40 | 5 |
| No of Piles | 0.60 | 9 |
| Integrity of Corrosion Protection System | 0.60 | 9 |
| Location of Nearest Artificial Reef Zone | 0.60 | 9 |
| Pile Weight | 0.60 | 9 |
| Platform Location | 0.80 | 13 |
| Integrity of Welded Connection | 0.80 | 13 |
| Location of Nearest Waste Hazardous Treatment Plant | 0.80 | 13 |
| Integrity of lift point | 0.80 | 13 |
| Well Type | 1.00 | 17 |
| Reserve Strength Ratio | 1.00 | 17 |

From the results, the pattern of ranked criteria can be observed. Vessel hire and structures weight still scored among the top five ranks even from different background of experts. According to the calculated RII, consultant and project manager tends to give out many tied ranks due to similar RII value. This is due to limited number of respondents from both groups. On the contrary, RIIs for contractor are more varied, resulting in a more proper ranking of criteria. Therefore, it is most recommended to have more number of respondents from each identified groups to have a better consensus on the ranking.

There are slight variance for the lowest five ranks observed from the three groups of experts. Integrity of corrosion protection system, platform vintage and fatigue life scored the lowest five from contractor and consultant's preferences. However, those three criteria were given a better rank by project manager group. The difference in correlation between groups of experts will be discussed in the next section.

### 4.3 Spearman's Rank Correlation Test

In order to examine the agreement in ranking of the pre-decommissioning criteria between groups of respondents, the Spearman Rank Correlation test was conducted. The Spearman Rank Correlation (ρ) is a statistical test to check a hypothesis of no association between pairs of measurement from two populations (Umar, Wan Abdullah Zawawi, Khamidi, & Idrus, 2013). The guidelines in categorizing the strength of association between two populations are as listed below (Dusick, 2012).

**Table 11: Strength of correlation for Spearman's coefficient**

| Ranges of ρ | Strength of correlation |
|---|---|
| $0.9 < \rho \leq 1$ | Very strong |
| $0.7 < \rho < 0.89$ | Strong |
| $0.5 < \rho < 0.69$ | Moderate |
| $0.3 < \rho < 0.49$ | Moderate to low |
| $0.16 < \rho < 0.29$ | Weak to low |
| $\rho < 0.16$ | Too low to be meaningful |

Hence from the results, Spearman's test was conducted to measure the agreement between contractor, consultant and project manager, which is as summarized in Table 9.

**Table 12: Spearman's coefficient between groups of experts**

| | Spearman's ρ (or rs) | | |
|---|---|---|---|
| | Contractor vs Consultant | Contractor vs Project Managers | Consultant vs Project Managers |
| Main Criteria | 1.000 | 0.949 | 0.949 |
| Platform Type | 0.351 | 0.000 | 0.821 |
| Platform Integrity | 0.866 | -0.500 | -0.866 |
| Resources | 0.949 | 0.949 | 1.000 |
| Lifting Management | 0.949 | 1.000 | 0.949 |
| **Average** | **0.823** | **0.479** | **0.570** |
| Strength of correlation | strong | moderate to low | moderate |

Therefore, from the results, it can be concluded that contractor and consultant have almost similar view in ranking the criteria. This is due to their technical expertise in structural aspects of offshore structures. However, if both consultant and contractors were to be compared with project managers, the association is fairly moderate mainly due to discrepancies in professional viewpoint.

### 4.4 Reliability Test

After the results of survey have been obtained, it is crucial to check for the reliability of the results. Cronbach's alpha is the method used to check for internal inconsistency estimate of reliability of test scores. The value of alpha will be derived from the test scores, in which the ranges of acceptability are as shown in Table 5.

**Table 13: Ranges of Internal Consistency using Cronbach's Alpha**

| Cronbach's alpha | Internal Inconsistency |
|---|---|
| $\alpha \geq 0.9$ | Excellent |
| $0.7 \leq \alpha < 0.9$ | Good |
| $0.6 \leq \alpha < 0.7$ | Acceptable |
| $0.5 \leq \alpha < 0.6$ | Poor |
| $\alpha < 0.5$ | Unacceptable |

Hence, the values of alpha for internal consistency have been calculated for each category, which lead to the following results:-

**Table 14: Overall Cronbach's Alpha Coefficient**

| Cronbach's Aplha | Number of Items |
|---|---|
| 0.57 | 22 |

Table 11 displays the overall alpha obtained from the reliability analysis. The result yields value of 0.57, which indicates poor internal consistency among the twenty two items (criteria) as ranked by the respondents. This means that the respondents are not entirely consistent while giving the judgment hence resulting in a poor reliability score. The greater the consistency in responses among items, the higher coefficient alpha will be. Besides, the poor consistency result is verified by the moderately low correlation between raters. Due to different interest in decommissioning activities, they might view the importance of criteria differently hence the poor Spearman's correlation. In order to solve the inconsistency in the survey, it is recommended for second survey to be followed up. The findings from first survey could be included. Thereon, the respondents will have a direction to give a proper judgments and feedback for second questionnaire hence the consistency could be improved.

The main reason why the inconsistency existed in the findings is due to different background and role in decommissioning. Therefore, the respondents might prioritize the criteria differently. Yet in decommissioning planning, it is important that everyone has their say to decide upon the feasible option. Regardless of the slight inconsistency, this approach could directly involve the stakeholders in the decision process hence optimizing complex trade-offs through voting theory from the stakeholders. As the outcomes, a relatively transparent and understandable result could be obtained to reach the consensus among stakeholders.

Therefore, according to the predefined objectives, the target of identifying the criteria and decommissioning have been accomplished. From the questionnaire, the criteria were ranked and prioritized accordingly.

### 4.5 Additional Criteria

From the questionnaire, experts were given a space to address any other important criteria in decommissioning. Hence, the list of newly addressed criteria is summarized in Table 15 below.

**Table 15: Additional Criteria as addressed by experts**

| Additional Criteria | Degree of Importance (1 being the most, 5 being the least) |
|---|---|
| Economics<br>- Fiscal regime is always a key decision making factor whether decommissioning should be executed or otherwise | 1 |
| Platform Strategic Location<br>- If the platform is functioning as a hub, the decision to decommission may defer even though the field is no longer producing or not economic. The platform could be used for security of supply or evacuation of oil and gas. | 3 |
| Environmental Impact<br>- Access the environmental impact of decommissioning activities such as onshore impact and seabed disturbance. | 2 |
| Health and Safety<br>- The proposed decommissioning activities should be carried out in the safest manner. For example, the risk of personnel injury and death should be assessed | 1 |
| Well Plugging and Abandonment<br>- Damaged wells may require special intervention techniques which could be too costly to decommission hence affecting the decommissioning decision | 2 |
| International, National, State and Company Legislation Requirement<br>- The compliance to these requirement should be taken into consideration | 1 |
| Decommissioning technology and technique<br>- For cost and man-hour optimization | 1 |

| | |
|---|---|
| Residual Responsibility<br>- Responsibilities transferred to other parties to manage the residual | 1 |

The additional criteria is found to be relevant to the study of decommissioning since the factors of health and safety, environmental impact and cost are well addressed, as the ones stated in BPEO concept. However, due to limited scope of this research, the focus would be more on technical feasibility rather than the other factors. Besides, for better improvement of this research, these additional criteria could be added up during the formulation of second survey.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

Decommissioning revolves around a complex framework with several alternatives available hence the decision making to choose the best option is often tricky. This research aims to develop a tool to assist in identifying and prioritizing the pre-decommissioning criteria of fixed offshore structures during the lifecycle of a platform. It covers the decommissioning a possibility of removal, leave in place or conversion of structures into artificial reefs. Sets of questionnaire were distributed to the respective experts in decommissioning planning in order to integrate their opinions and judgments into decision consideration. The scores from survey were analyzed using Relative Importance Index (RII) Method, and from the finding, the feasibility of equipment and facilities are highlighted as the most important criteria. The correlation between groups of respondents has been found to be moderately low, verified by the poor internal consistency in judgment, which could be improved through implementation of second survey. In summary, the objectives of identifying and prioritizing the criteria of decommissioning have been achieved. Hence, this study provide a technical baseline for decommissioning of fixed offshore structures. It covers only the technical feasibility aspect of decision making. Therefore, for further improvement of this research, it is recommended to widen the scope into other aspect of BPEO which are cost, environmental impact and health & safety. The involvement from the related parties such as the environmentalist, legal bodies and technical team will give a better consensus on decommissioning decision making.

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# *APPENDIX 1*

# Pre-Decommissioning Decision Aid Toolkit for Fixed Offshore Structures in Malaysia

## Initial questionnaire

Thank you for agreeing to participate in this survey on the priorities of the pre-decommissioning criteria of fixed platforms in Malaysia.

This questionnaire round is the first of two rounds of the survey. Please try to answer all questions. You will have the opportunity to revise your answers with subsequent round of the survey.

**For the purpose of this survey, the alternatives are; leave in place (mothball), scrapping, recycling, reuse and reefing.**

In these surveys, you will be asked to develop priorities among the listed criteria. Most of the questions can be answered with only a single selection. Where appropriate, a space is also provided for you to comment on the underlying reasons for your responses.

The following questions might be helpful in guiding your assessment of the value of each indicator:

- Is the indicator useful for guiding policy that aims to provide an effective asset management system?
- Is the indicator helpful in prioritising strategies for the strategic planning of overall local decommissioning operations?

Once we have received responses from all panellists, we will collate and summarise the findings and formulate the second questionnaire. You should receive this in the next month.

We assure you that your participation in the survey and your individual responses will be strictly confidential to the research team and will not be divulged to any outside party.

Below, is a list of criteria currently used commonly to plan decommissioning activities. Please rate each of the indicators in terms of its value in providing information about the 'recommended' alternative for fixed offshore structures in Malaysia.

**1 indicates it is *most important* and 5 indicates it is *least important* or redundant.**

| | **Criteria** | **Rating (1=most important, 5=least important)** |
|---|---|---|
| 1 | Platform type | |
| 2 | Platform integrity | |
| 3 | Resources | |
| 4 | Lifting management | |
| 5 | Field economics | |
| 6 | Platform strategic location | |

Are all the criteria relevant? If we had to limit / expand the number of criteria, which ones, from the previous list of 5 would you choose to keep / add on to?

A space is provided for you to briefly explain the reason for your ranking if you wish. This additional information is optional, and could help us understand the reasons some indicators are valued over others.

| | **Indicator** | **Rating (1 – 5)** | **Reason** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

Below is a list of considerations currently used commonly to plan decommissioning activities. Please rate each of the indicators in terms of its value in providing information about the ‘recommended’ alternative for fixed offshore structures in Malaysia.

**1 indicates it is *most important* and 5 indicates it is *least important* or redundant.**

| | **Indicator** | **Rating (1=most important, 5=least important)** |
|---|---|---|
| | **Platform type** | |
| 1 | Water depth | |
| 2 | Platform location | |
| 3 | Platform characteristics* | |
| 4 | Well type | |
| 5 | No of Piles | |

*platform characteristics to match the proposed new facilities (for reuse)

Are all the indictors relevant? If we had to limit / expand the number of indicators, which ones, from the previous list of 5 would you choose to keep / add on to?

A space is provided for you to briefly explain the reason for your ranking if you wish. This additional information is optional, and could help us understand the reasons some indicators are valued over others.

| | **Indicator** | **Rating (1 - 5)** | **Reason** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |

Please rate each of the indicators in terms of its value in providing information about the 'recommended' alternative for fixed offshore structures in Malaysia.

**1 indicates it is *most important* and 5 indicates it is *least important* or redundant.**

| | **Indicator** | **Rating (1=most important, 5=least important)** |
|---|---|---|
| | Platform Integrity | |
| 1. | Platform vintage | |
| 2. | Reserve Strength Ratio | |
| 3. | Integrity of welded connections | |
| 4. | Integrity of corrosion protected system | |
| 5. | Fatigue life | |

Are all the indictors relevant? If we had to limit / expand the number of indicators, which ones, from the previous list of 5 would you choose to keep / add on to? You can rank up to 7 indicators that you think are important.

A space is provided for you to briefly explain the reason for your ranking if you wish. This additional information is optional, and could help us understand the reasons some indicators are valued over others.

| | **Indicator** | **Rating (1 - 5)** | **Reason** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

| | | | |
|---|---|---|---|
| 6 | | | |

Please rate each of the indicators in terms of its value in providing information about the 'recommended' alternative for fixed offshore structures in Malaysia.

**1 indicates it is *most important* and 5 indicates it is *least important* or redundant.**

| | **Indicator** | **Rating (1=most important, 5=least important)** |
|---|---|---|
| | Resources | |
| 1. | Location of nearest yard | |
| 2. | Location of nearest artificial reef zone | |
| 3. | Location of nearest hazardous waste treatment plant | |
| 4. | Nearest vessel hire | |

Are all the indictors relevant? If we had to limit / expand the number of indicators, which ones, from the previous list of 5 would you choose to keep / add on to? You can rank up to 7 indicators that you think are important.

A space is provided for you to briefly explain the reason for your ranking if you wish. This additional information is optional, and could help us understand the reasons some indicators are valued over others.

| | **Indicator** | **Rating (1 - 5)** | **Reason** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

| | | | |
|---|---|---|---|
| 6 | | | |
| 7 | | | |

Please rate each of the indicators in terms of its value in providing information about the 'recommended' alternative for fixed offshore structures in Malaysia.

**1 indicates it is *most important* and 5 indicates it is *least important* or redundant.**

| | Indicator | Rating (1=most important, 5=least important) |
|---|---|---|
| | Lifting Management | |
| 1. | Topside weight | |
| 2. | Jacket weight | |
| 3. | Pile weight | |
| 4. | Integrity of lift points condition | |

Are all the indictors relevant? From the previous list of 5, which would you choose to exclude / add on to? You can rank up 7 indicators that you think are important.

A space is provided for you to briefly explain the reason for your ranking if you wish. This additional information is optional, and could help us understand the reasons some indicators are valued over others.

| | Indicator | Rating (1 - 5) | Reason |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

| | | | |
|---|---|---|---|
| 6 | | | |
| 7 | | | |

If you have any further suggestions for indicators that you believe could be important for the proposed system, please list below (optional):

End of Survey. Thank you