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A multi-criteria decision approach to decommissioning of offshore oil and gas infrastructure

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ABSTRACT

Thousands of the world's offshore oil and gas structures are approaching obsolescence and will require decommissioning within the next decade. Many nations have blanket regulations requiring obsolete structures to be removed, yet this option is unlikely to yield optimal environmental, societal and economic outcomes in all situations. We propose that nations adopt a flexible approach that allows decommissioning options to be selected from the full range of alternatives (including 'rigs-to-reefs' options) on a case-by-case basis. We outline a method of multi-criteria decision analysis (Multi-criteria Approval, MA) for evaluating and comparing alternative decommissioning options across key selection criteria, including environmental, financial, socioeconomic, and health and safety considerations. The MA approach structures the decision problem, forces explicit consideration of trade-offs and directly involves stakeholder groups in the decision process. We identify major decommissioning options and provide a generic list of selection criteria for inclusion in the MA decision process. To deal with knowledge gaps concerning environmental impacts of decommissioning, we suggest that expert opinion feed into the MA approach until sufficient data become available. We conducted a limited trial of the MA decision approach to demonstrate its application to a complex and controversial decommissioning scenario; Platform Grace in southern California. The approach indicated, for this example, that the option 'leave in place intact' would likely provide best environmental outcomes in the event of future decommissioning. In summary, the MA approach will allow the environmental, social, and economic impacts of decommissioning decisions to be assessed simultaneously in a transparent manner.

1. Introduction

The world's offshore oil and gas infrastructure is aging (Doyle et al., 2008), and the global community is rapidly approaching a decommissioning crisis. There are currently >7 500 structures built for the hydrocarbon industry (e.g. rigs, platforms, hereafter 'oil structures') located in offshore waters, ~85% of which will become obsolete and require decommissioning within the next decade (Parente et al., 2006). Most nations require complete removal of obsolete structures, which presents substantial engineering challenges and is estimated to cost the oil and gas industry in excess of 40 billion USD (Salcido, 2005). A large proportion of this cost will be passed on to the general public through tax concessions afforded to industry (estimated 30–70% in the UK, Ekins et al., 2006). These costs are likely to have wider socioeconomic impacts owing to effects on local and regional economies.

Policies of complete removal are based on the assumption that 'leaving the seabed as you found it' represents the most environmentally-sound decommissioning option. However, we now know that oil structures are capable of developing abundant and diverse marine communities during their production lives, with some structures supporting communities of regional significance (Macreadie et al., 2011). Examples include oil platforms in the northern Gulf of Mexico that support a commercially and recreationally important red snapper (*Lutjanus campechanus*) fishery (Gallaway et al., 2009), and platforms off southern California that support substantial juvenile populations of a declining rockfish species (*Sebastes paucispinis*, Love et al., 2006). In other cases, oil structures may provide important habitat to ensure connectivity of populations, as has been speculated for the cold-water coral, *Lophelia pertusa*, in the North Atlantic (Bell and Smith, 1999). Removal of such structures is unlikely to represent best environmental practice and recognition of this has resulted in some nations

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leaving obsolete structures in place as artificial reefs ('rigs-to-reefs', RTR). RTR programs are extremely controversial and debate regarding their validity is ongoing in most regions (e.g. OSPAR nations, Jørgensen, 2012; Macreadie et al., 2012).

While nations consider whether to leave oil structures in place or not, we argue a broader perspective is required to achieve optimal decommissioning outcomes. Oil structures are located in a wide range of ecosystems, from shallow coral reefs through to the deep-sea. Consequently, inhabiting communities differ greatly among structures, as do the surrounding communities and habitats. It is therefore unlikely that a single decommissioning option, complete removal or otherwise, will provide optimum environmental outcomes in all scenarios. Similarly, a single option is unlikely to optimize social or economic outcomes in all scenarios. For example, RTR options are more likely to optimize social values in the northern Gulf of Mexico, where obsolete structures support an important recreational fishery (Stanley and Wilson, 1990), than in the North Sea where recreational angling on oil structures is minimal (Sayer and Baine, 2002). Numerous decommissioning options are available which fall between the extremes of complete removal and 'leave in place' (Schroeder and Love, 2004). A case-by-case approach to decommissioning is required where the most suitable option is selected from the full range of alternatives, based on the unique decommissioning scenario.

Selection of optimal decommissioning options represents a complex decision-making problem. Decommissioning involves many environmental impacts that differ among alternative options and decommissioning scenarios (Cripps and Aabel, 2002). Environmental aspects of decommissioning also interact with financial and socioeconomic considerations, generating complex trade-offs. The quality of data used to evaluate the performance of options also varies greatly among considerations. Lastly, decommissioning decisions are extremely controversial because they affect a wide range of stakeholder groups with differing interests. Research into decision analysis indicates basic methods of decision-making (e.g. pros and cons comparisons) are unlikely to result in optimal decisions in such complex scenarios (Kiker et al., 2005). Basic methods tend to oversimplify decision problems, losing valuable information and failing to consider conflicting objectives in the process.

Borrowing from the field of decision analysis, we propose a multi-criteria approach for making decommissioning decisions that allows identification of the best performing option across numerous selection criteria, including environmental, financial, socioeconomic, and health and safety considerations. The approach is user-friendly and readily adaptable to specific decommissioning scenarios. We outline the main components of the approach, identify major decommissioning options and provide a generic list of selection criteria required for the decision process. Given the controversial nature of decommissioning decisions, we suggest a participatory method to decision-making that includes both technical experts and stakeholder groups. A method of expert elicitation is described that can be used to assist relative performance evaluations of alternative options until sufficient empirical data become available. Lastly, we identify research that will assist in refining the method for maximum benefit. Our aim is to provide a holistic and transparent approach for optimizing decommissioning decisions across the global range of decommissioning scenarios. We present information in a format that is accessible to environmental scientists, managers, and industry representatives not necessarily familiar with the technical aspects of multi-criteria decision support.

2. The multi-criteria approach to decommissioning

Multi-criteria decision analysis (MCDA) refers to a suite of methods developed to assist complex decisions, such as those required for decommissioning. These methods provide a structured and objective framework for comparing the performance of multiple options across numerous selection criteria. MCDA is particularly useful for environmental management decisions because it can incorporate the objectives of multiple stakeholder groups and handle a wide range of data types (Mendoza and Martins, 2006). MCDA has been successfully applied in forestry management (Kangas and Kangas, 2005), fishery management (Mardle and Pascoe, 1999), protection of natural areas (Brown et al., 2001), waste disposal (Merkhofer et al., 1997), and water use (Keeney et al., 1996). Oil companies are beginning to integrate MCDA into their decommissioning planning, for example Shell UK is currently using a participatory MCDA approach to develop recommendations for decommissioning of concrete storage cells in the Brent Field in the North Sea. However, the type of MCDA used is often unclear, and to our knowledge there are no studies available in the primary literature that investigate the general application of MCDA to offshore decommissioning (see Cripps and Aabel, 2002 for a case-study).

The type of MCDA should be chosen to suit the specific decision problem at hand. Most methods follow a general process: 1) decision objectives are defined, 2) selection criteria are established that reflect the objectives, 3) alternative options are identified, 4) the performance of each option is evaluated for each criterion, 5) criteria are weighted according to their importance, 6) criteria evaluations and weights are combined into an overall performance estimate for each option and 7) an option is selected based on overall performance (Ananda and Herath, 2009; Linkov et al., 2004). However, methods differ in the procedures used to execute each step and are only suitable for particular applications. A compromise must also be struck between the depth of analysis achieved and the comprehensibility of the process, particularly in scenarios involving non-technical stakeholder groups (Kangas and Kangas, 2005). Complex methods may exploit available data more completely and provide more comprehensive performance evaluations, but they are usually more difficult to understand and implement.

We propose the use of Multi-criteria Approval (MA) for decommissioning decisions. MA was specifically designed for decisions involving mixed datasets of low quality (Fraser and Hauge, 1998), and can incorporate both the qualitative (e.g. environmental impacts) and quantitative data (e.g. cost) involved in multi-criteria decommissioning decisions. Because MA is based on simple voting principles, it can also be easily understood by non-technical stakeholder groups, distinguishing it from the numerous mathematically-complex MCDA approaches available. Lastly, MA is known to favor conservative decisions that represent a compromise between vastly differing decision objectives (Kangas and Kangas, 2003). This characteristic minimizes the chance of selecting a poor option, and is likely to reduce conflict between stakeholder groups with opposing interests. The major components of an MA approach to decommissioning decisions are outlined below.

2.1. The decision matrix

A decision matrix is a two-dimensional array that lists alternative options on one axis and selection criteria on the other. It provides an explicit representation of the decision problem, and forces users to consider alternative options and selection criteria important to the decision. Once options and criteria have been agreed upon, the matrix is used to tabulate performance 'scores' for each option with respect to each criterion (see below).

2.1.1. Decommissioning options

Thirteen major decommissioning options for oil structures were identified from the literature (Fig. 1, Ekins et al., 2006; Lakhal et al.,