Application of 4D BIM for Evaluating Different Options of Offshore Oil and Gas Platform Decommissioning

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Abstract:

Offshore oil and gas platforms generally have a lifetime of 30-40 years, and decommissioning of offshore platforms is a major issue in the oil and gas industry. In the United States, 130 platforms on average are decommissioned and removed per year. In the North Sea, about 470 offshore installations will need to be decommissioned over the next 30 years. There are many possible options to decommission offshore oil and gas platforms, and each decommissioning option can be implemented with different methods and technologies. Therefore, it is necessary to have a clear understanding and in-depth evaluation of each decommissioning option before platform decommissioning. 4D building information modeling (BIM) has been commonly used in the building industry to analyze constructability and evaluate different construction or demolition plans. However, application of BIM in the oil and gas industry, especially for the platform decommissioning process, is still limited. This paper suggests and demonstrates the application of 4D BIM technology to simulate various offshore platform decommissioning options, thereby visualizing and evaluating different options considering the time required for decommissioning. Different offshore platform decommissioning options will be introduced in this paper. 4D BIM creation and representation of offshore oil and gas platforms will be discussed as well. This paper will also present an illustrative example of the proposed approach, which simulates and evaluates two decommissioning options of a fixed Jacket platform, namely Rig-to-Reef and Removal-to-Shore. The result shows that the proposed 4D BIM approach can improve the understanding of different decommissioning options, leading to better planning and execution for decommissioning of offshore oil and gas platforms.

Keywords: Offshore Platform Decommissioning, 4D BIM, Simulation

1. INTRODUCTION

There are now over 7000 oil and gas installations and platforms on the continental shelves of over 53 countries around the world (Parente et al., 2006). Offshore oil and gas platforms (OOGP) generally have a lifetime of 30-40 years, and decommissioning of offshore platforms is a major issue in the oil and gas industry. Between 2010 and 2014, Gulf of Mexico decommissioning generated approximately $9 billion in spending, regularly exceeding $1.5 billion per year. Over the next 30 years, almost all the 470 offshore installations in the North Sea’s UK Continental Shelf, such as platforms, will need to be decommissioned, according to the Oil & Gas UK’s Economic Report 2013 (Oil & Gas UK, 2013). 27 offshore oil and gas platforms in southern California will be decommissioned between 2015 and 2030 as the platforms will reach the end of their useful production lifetimes. In Malaysia, the decommissioning activities for fixed offshore platforms are expected to rise significantly. There are approximately 300 oil platforms in Malaysia, many of which are approaching the end of their service life. As the next decades will witness the big trend of OOGP decommissioning, evaluating different decommissioning options will be an unavoidable work.

1.1 OOGP Decommissioning Process

Before discussing the evaluation of different OOGP decommissioning options, basic understanding of the whole decommissioning process is needed. Based on the US Decommissioning Handbook, the general decommissioning
process for an OOGP has been summarized in Figure 1. When one OOGP reaches its end of economic life, its operators will firstly initiate discussion with the competent authority. The DECC (Department of Energy & Climate Change), for instance, is the competent authority for all the UK’s OOGP in the North Sea. The discussion will lead to the outline of the decommissioning process as well as the consultation plan with the related parts. All the possible decommissioning options will be proposed after the consultation and then the shortlisted options will be chosen by considering the similar historical OOGP decommissioning cases. In order to choose the feasible option, detailed evaluation of the shortlisted options should be conducted. The options’ evaluation usually focuses on environmental impact, technical feasibility, risk and economic analysis. For the evaluation of decommissioning options, explorations have already been done by some researchers. One of the latest studies is conducted by Henrion et al. (2015), which performed multi-attribute decision analysis for decommissioning of OOGP in southern California. Besides, Truchon et al. (2015) developed a strategic framework for identifying and evaluating sensitive ecosystem services in association with both human and environmental drivers to provide realistic (actionable) guidance in the selection of these decommissioning options. Following the evaluation of different options, the decommissioning program should be developed for the selected option. The program contains all the details of the decommissioning, including description of items to be decommissioned, removal and disposal methods, environmental impact assessment, interested party consultation, program management, supporting documents, and partner letter of support (Department of Energy & Climate Change, 2014). The developed program will be submitted to the competent authority to get the permission before execution. The last step of the OOGP decommissioning is the post-decommissioning, which includes debris clearance, final survey, close-out report and monitoring. This paper will focus on the option evaluation step (shaded in Figure 1), especially on applying 4D BIM technology to visualize the options.

![Process of the OOGP platform decommissioning](image)

Figure 1. Process of the OOGP platform decommissioning

1.2 4D Building Information Modeling (BIM)

4D BIM has been widely used in the building industry to analyze constructability and to evaluate different construction or demolition plans. Kassem et al. (2015) developed a 4D BIM tool compliant with Industry Foundation Classes (IFC) for workspace management in an interactive real-time manner, aided with analytic data from a centralized database. Han and Golparvar-Fard (2015) presented a new appearance-based material classification method for monitoring construction progress deviations at the operational-level by leveraging 4D BIM models and 3D point cloud models generated from site photologs using Structure-from-Motion techniques. The 4D BIM models were also used to continuously compare with the actual site monitoring data during the construction process so that the safety status of the related components can be visualized in real-time in the system as the conditions change and potential safety risks evolve (Y. Zhou et al., 2013). Hu et al. (2008) and Zhang and Hu (2011) also applied 4D BIM and other related technologies to manage the conflict and safety problems during the construction. Except the safety issues during the construction process, 4D BIM can also be used to monitor the process combined with remote sensing technology (Kim et al., 2013). Although the application of 4D BIM into the oil and gas industry is rare, a study with the goal of investigating the feasibility and benefits of 4D in supporting liquefied natural gas (LNG) construction projects had been conducted by Ying et al. (2015) to improve the construction process planning and control. However, no study has ever applied 4D BIM to evaluate OOGP decommissioning options. Some companies in the market, such as CONSTRUCTIVEMEDIA in Perth of Australia, can produce decommissioning animations with high quality, but its principle is different from that of 4D BIM. 4D BIM not only includes the detailed information of all the items on the platform, but also contains the time required for each decommissioning activity as well as their logical relationship.
The rest of this paper will be structured as follows. In Section 2, different OOGP decommissioning options will be discussed and summarized. Section 2 will also present the main evaluation procedures, which include the creation of 4D BIM model, development of the schedule for OOGP decommissioning options, and visualization of the decommissioning process. In Section 3, a case study will be used to illustrate the proposed workflow. This paper will be concluded in Section 4.

2. EVALUATION METHOD

2.1 Potential OOGP Decommissioning Options

There are many possible options to decommission OOGP, and each decommissioning option can be implemented with different methods and technologies. Reuse, recycling, and disposal are the three decommissioning options commonly used for all the OOGP around the world. According to the waste hierarchy (Figure 2), reuse has the top priority considering the sustainability as its energy consumption is relatively small compared to recycling (Zawawi et al., 2012) and more environmentally friendly than disposal. However, implementation of the same option varies among different places around the world given they follow different laws and policies. For example, in the North Sea, OSPAR Decision 98/3 requires that any platform should be completely removed for further consideration like reuse if its jacket’s weight is less than 10,000 tonnes in air (OSPAR Commission, 1998). Therefore, the Rigs-to-Reefs program, which allows obsolete, nonproductive OOGP to be converted to artificial reefs to support marine habitat, has never been applied in the North Sea. On the contrary, many states in the United States like Texas, California, and Florida currently implement the Rigs-to-Reefs program for some of their platforms in the Gulf of Mexico as well as the offshore southern California in the near future. Except the Rigs-to-Reefs choice, many other reuse choices have been studied by different organizations. One interesting example is the offshore residential plan developed by the Seastanding Institute (Zawawi et al., 2012) based on the disused platform. In addition, different sections of the platform can be refurbished and reused in other fields.

![Figure 2. Waste hierarchy (Hansen et al., 2002)](image)

For the recycling option of the OOGP decommissioning, the topsides, jackets and other subsea structures will be removed and transferred to a coastal factory for dismantling. All the separated pieces of the platform will then be marked and recorded for further recycling consideration. These work usually will be outsourced to a specific subcontractor by the operator of the platform. If the separated pieces could not be used for other uses, disposal will be considered.

For all the possible decommissioning options, Bernstein et al. (2010) has developed a tree by considering removal or not or partial removal, which only covers a small part of the potential options. Our paper summarizes all the OOGP decommissioning options by considering the platform as a whole or by sections and filling each consideration with options that has ever been studied before in both academic and industry fields (Figure 3). Two decommissioning options of a fixed Jacket platform, namely Rig-to-Reef and Removal-to-Shore, will be evaluated by applying the 4D BIM technology in this paper.
2.2 Evaluation Procedure

In order to evaluate OOGP decommissioning options with 4D BIM technology, a simple evaluation workflow is proposed (Figure 4). First, an OOGP BIM model will be created in Autodesk Revit. Then, the schedules for different decommissioning options as well as their methods are generated from the project management application namely Primavera. Finally, these two sections will be imported into the 4D simulation application namely Synchro Pro and combined by assigning the objects of the OOGP BIM model to the related tasks of the schedules for comparison. After the 4D BIM models of the OOGP decommissioning are created, the options and their methods can be evaluated. More details of the proposed workflow will be discussed in the following sections.

2.2.1 Creation of OOGP BIM Model

Currently, BIM models have been commonly used in the construction industry for various planning and analysis tasks. However, for OOGP, Autodesk Revit does not have enough related object-based families for the model creation. In order to perform the 4D decommissioning simulation, an OOGP BIM model was created in Revit based on an OOGP formatted in 3DMax. Elements, like pipes, from the System template in Revit were used to model the elements on the platform.

2.2.2 Schedules of the OOGP Decommissioning

As mentioned in Section 2.1, an OOGP have many options for decommissioning and each option can be implemented with different methods. For each decommissioning option in our proposed workflow, its schedule will be created in Primavera. The reason to use Primavera is that the 4D simulation software, Synchro Pro, can read the schedule files.
from Primavera automatically, making the whole evaluation process more efficient. In addition, the logics among the decommissioning steps should be reasonable. For example, when an OOGP is chosen to be removed to onshore for further consideration, topsides should be removed before the jacket and the modules on platform should also follow the planned sequence based on different calculation and analysis, like the lift trajectory optimization and duration estimate for each removal activity.

2.2.3 OOGP Decommissioning Options Simulation and Evaluation

Once the 3D OOGP BIM model and the decommissioning schedule of the OOGP are prepared completely, the decommissioning options can be evaluated by combining them with the 4D simulation application, namely Synchro Pro. The main work in this process is to assign the 3D model elements to the related activities. The automatic matching function in the Synchro Pro can make the model resource assignment very efficient. The last work is to visualize different decommissioning options for the OOGP and have a good understanding of each option to choose the most feasible one.

3. CASE STUDY

3.1 OOGP BIM Model

The model used in this paper is a fixed platform with steel jacket piled into the seabed, supporting a deck with space for about 30 modules including the production facilities, drilling rigs, crew quarters, and other modules (Figure 5). The height of this platform is around 450 meters from the bottom of the jacket to the top of the main mast on the platform.

![Figure 5. Overview of the OOGP BIM model](image)

3.2 The OOGP Decommissioning Options to be Evaluated

In order to verify the proposed workflow of OOGP decommissioning options evaluation using 4D BIM technology, Rig-to-Reef and Removal-to-Shore were selected for the prepared OOGP model. Different methods will be used for these two decommissioning options. Furthermore, whatever option is chosen for the model, its topsides will be removed to land before the handling of the steel jacket. For the topsides, reverse installation or single lift can be used for the decommissioning. For the steel jacket, offshore deconstruction, single lift, or topple in place for reef can be applied. Table 1 summarizes the two decommissioning options and illustration of each method.

![Figure 6. Schedule of Removal-to-Shore using T1+J2](image)
As presented in Table 1, there will be two methods for Rig-to-Reef and four methods for Removal-to-Shore, respectively. For Rig-to-Reef, the two methods combination are T1+J1 and T2+J1. For Removal-to-Shore, the four methods combination are: T1+J2, T1+J3, T2+J2, and T2+J3. Schedule for each method combination will be developed in the Primavera and Figure 6 shows the example of T1+J2 for the Removal-to-Shore option.

### 3.3 Simulation and Evaluation

The OOGP BIM model and the schedules of decommissioning options are imported into the Synchro Pro 4D simulation application, and are combined to form the 4D BIM Model of the OOGP by linking the 3D models to the related activity in the schedule. Then, with the help of the Play function in the Synchro Pro, each option can be simulated and visualized, not only the removal sequence but also the time cost for each option. Figure 7 shows some of the decommissioning simulation processes.

### Table 2. Estimate duration for each option with different methods

<table>
<thead>
<tr>
<th>Option</th>
<th>Method</th>
<th>Estimate Duration (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rig-to-Reef</td>
<td>T1+J1</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>T2+J1</td>
<td>10</td>
</tr>
<tr>
<td>Removal-to-Shore</td>
<td>T1+J2</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>T1+J3</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>T2+J2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>T2+J3</td>
<td>14</td>
</tr>
</tbody>
</table>

In addition to the simulation of the decommissioning process, the duration for each option and its method can also be simulated and evaluated after the assignment of time for each activity of any option. The duration can be calculated using Equation (1).

\[
\text{Option’s Duration} = \frac{\text{Modules’ Volume (m}^3\text{)}}{\text{Preparation Work Rate (m}^3\text{/day})} + \frac{\text{Total Lift Distance (m)}}{\text{Lift Speed (m/day})}
\]

So the exact time for different phase, for example, at what time the living quarter is under lift, is also visible. It provides a good reference for the project managers to not only understand the progress of the OOGP decommissioning but also develop a better resource plan, like the labor and equipment deployment. After simulating different methods of the two options, Rig-to-Reef and Removal-to-Shore, the duration for each option is summarized in the Table 2.
Figure 7. Different process of the OOGP decommissioning

4. DISCUSSION

4D BIM has been commonly used in the building industry. However, applications of 4D BIM in the offshore engineering of facilities such as OOGP and offshore wind farm are limited. This paper demonstrates the potential to use 4D BIM for simulating and evaluating different OOGP decommissioning options. As shown in the case study, 4D BIM can contribute to the evaluation of the OOGP decommissioning options by visualizing different decommissioning process as well as duration for each option. The visualization of the option can also help all participants reach an agreement on the understanding of different options during the evaluation and decision phase, which facilitates the communication among them. Finally, with more input of the required resources, like labor, equipment, temporary facilities and their cost, 4D BIM can be used develop a more accurate and detailed option simulation for OOGP decommissioning.

5. CONCLUSION

This paper presents and demonstrates a 4D BIM based workflow for evaluating different OOGP decommissioning options. With the help of 4D simulation application by combining the 3D BIM OOGP model and decommissioning schedule, which is developed in Primavera, Rig-to-Reef and Removal-to-Shore and their methods can be clearly
visualized. The visualization provides a good reference for project managers to plan and execute OOGP decommissioning. However, as the required resource data like labor, materials, equipment and temporary facilities information are still lacking, the proposed approach can only provide the visualization of different decommissioning options as well as the duration for each of them. In the future work, more resource plan problems of OOGP decommissioning will be studied and incorporated into the current visualization workflow to deliver a more holistic reference for the evaluation of OOGP decommissioning options.

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