Sustainability Applied To Offshore Accommodation Modules

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Abstract
Current issues of increasing material scarcity, environmental awareness and the willingness to explore more sustainable technologies are opening the way for the offshore industry to improve the sustainability of offshore accommodation modules. The objective of this paper is to investigate if Design for Disassembly is an appropriate method to increase the sustainability of Offshore Accommodation Modules. A method is developed from literature and tested on Self-installing Platforms. The case study delivered a flexible and connectable module system for accommodations. Life Cycle Analysis will determine environmental benefits in material and energy use. Functional assessment promises added functionality in terms of flexibility in use, maintenance, upgrading and remanufacturing. First reasoning about costs suggests lower life cycle costs and lower transformation costs.

Keywords:
Sustainability, Design for Disassembly, Offshore Accommodation Modules, Life Cycle Analysis

1 INTRODUCTION

The offshore industry has a 100-year history in the oil and gas sector with notable achievements but also unavoidable associated risks and pollution of the sea and the atmosphere. Issues of energy security, environmental awareness and the willingness to explore more sustainable energy technologies are now driving industrial developments of tidal, wave and wind energy facilities. Materials are furthermore becoming scarce and more costly, enlarging the need for sensible material use. The sustainability in terms of embodied and operating energy of the offshore platforms themselves is therefore becoming an important issue.

This paper addresses an opportunity to enhance the sustainability of offshore platforms and particularly of their accommodation modules by applying concepts and techniques of Design for Disassembly (DfD).

2 DESIGN FOR DISASSEMBLY AND OFFSHORE PLATFORMS

2.1 Sustainability

The term sustainability is nowadays very popular amongst designers and architects. From the first generally accepted definition by Brundtland [1] the term has had many uses and connotations, which has given the term a plethora of meanings [2].

The way to reach sustainability is also very diverse. Representing the environmental impact in a single footprint is often used to provide a visual overview of the severity of the strain on the biosphere's capacity [3]. Methods such as the 'sustainable emissions and resource usage' method focus on limiting the use of resources and the production of emissions to an acceptable level [4]. Methods that merely try to limit use of materials and production of emissions have some limitations. The continuous extraction of finite materials can hardly be called sustainable and the restricted use of materials seems a negative way to approach the challenges that lie ahead.

Many methods agree reconciliation of natural, social and financial benefits is needed to create truly sustainable products [5, 6, 7]. One method that is widely used within all sorts of organisations is the 'Triple Bottom Line' method [6, 8] (figure 1). The 'Cradle to Cradle' method also shows that taking all three factors into account can indeed in many cases be beneficial [7].

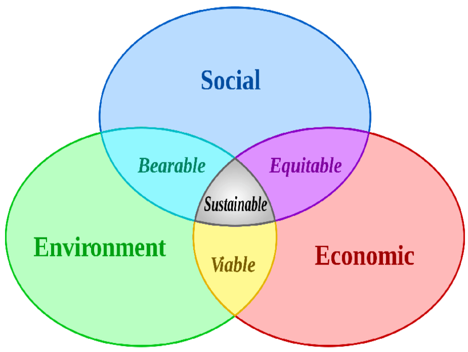

Figure 1: Visual representation of the triple bottom line [9]

Reuse of materials, components and systems is an important aspect to achieve more sustainable products and buildings [10, 11]. Reuse is furthermore one of the most preferable end-of-life scenarios [12, 13].

2.2 Disassembly benefits

Non-destructive disassembly is needed to safeguard the reuse potential of systems, components and materials. Design for Disassembly facilitates reuse and recycling at what was seen as the end of the lifecycle [14].

DfD has already been used for several decades in the automotive, consumer electronics, computer and other industries [15], but in other areas it is relatively new. In the construction sector DfD has been in focus for some decades with different results on aesthetics and acceptance [16, 17].

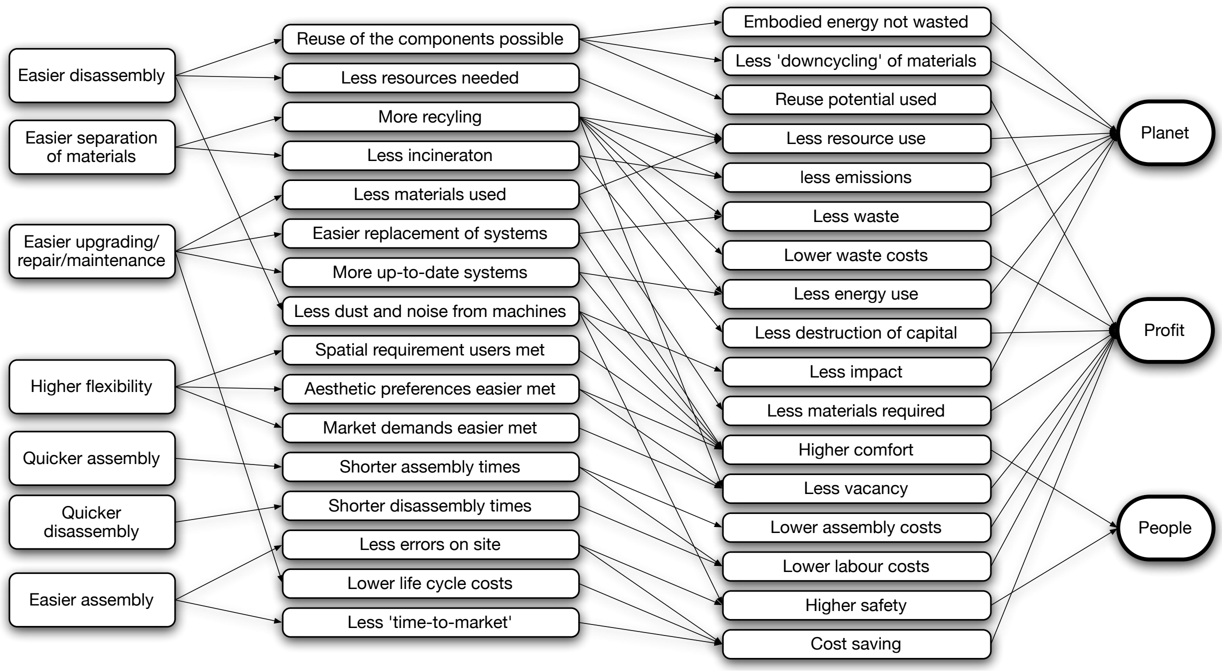

Figure 2: Connections between Design for Disassembly benefits and Triple Bottom Line [6] categories.

There are many benefits to DfD, not only for the planet, but also for people and profit. Benefits from disassembly include shorter disassembly times [16, 18], lower disassembly costs [16, 19] and less impact on the direct environment [16].

Easier disassembly in many cases also means a simplification of products [19], which has benefits for assembly times [18], assembly costs [19] and the number of on-site errors [16].

During the use phase of the products the benefits include easy upgrading [11, 20] and flexibility in spatial layouts [16].

Ease of repair and maintenance furthermore improves quality and saves costs by saving materials [16, 19]. Ease of upgrade, repair and maintenance also means that aesthetic preferences are easier to meet and that the service life of the building is extended [14, 16, 21].

Because parts, components and systems are non-destructively removed, they can be reused in the same or in other buildings [11, 14, 16, 21]. Reuse of components reduces resource use [11, 16, 22] and preserves the energy embodied in the materials [14, 16 23]. Furthermore reuse of the components reduces the amount of waste and prevents the destruction of capital [20].

Figure 2 summarises the benefits in a visual scheme to provide overview how the benefits link to the triple bottom line [6] categories.

2.3 Designing for Disassembly

The disassemblability aspects need to be taken into account from the start of the design process to optimise the results [24]. Systems, components and parts need to be independent form one another and have to be exchangeable to ensure that they do not cause unwanted effects in the disassembly process.

These criteria are therefore the main performance criteria of the transformation capacity. To reach this in the functional, technical and physical domain there are eight aspects that are important [25] (figure 3):

- Functional independence: Different functions should be independently changeable.
- Systemisation: Groups of functions have to be clustered in systems
- Hierarchy: Components and parts that are changed more often should be lower in hierarchy than more fixed ones. For example the load bearing structure should be high in the hierarchy.
- Base element specification: One element acts as an intermediary between the parts in a component and the higher order components
- Life cycle coordination: Coordination between material and functional life cycles ensures correct specification of hierarchy, assembly sequences, etc.
- Assembly sequences: Parallel assembly sequences ensure independent change of components.
- Type of connection: Dismountable connections allow for disassembly without disturbing other parts.
- Geometry: An open geometry allows for independent removal of assemblies.

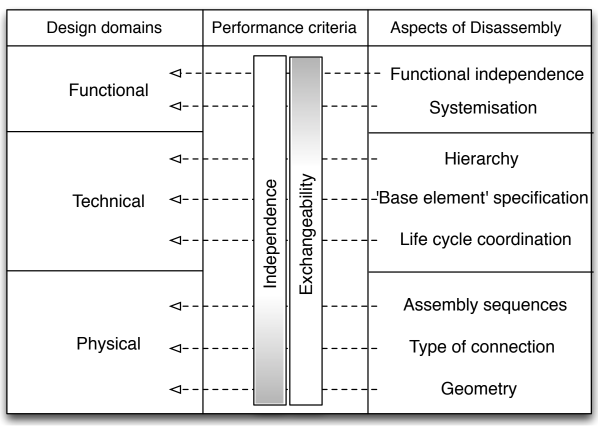

Figure 3: Relation of DfD aspects to design domains [25]

The high flexibility of assemblies and components and the high independence of systems allows for flexible uses of the structure without committing to one floor plan, one aesthetic appearance or one use scenario.

2.4 Design process

In the offshore industry many rules and regulation are in use to guard the safety of employees and environment. These extensive rules differ from one country to another and for example have different demands about layouts. Especially the accommodations of the platforms are subject of changing standards [26-31]. Current design process often takes the most stringent rules and the peak occupancy to design the accommodations.

This leads in many cases to over-dimensioning of accommodations in terms of number of cabins and size of recreation and mess room. To prevent waste of energy and materials, the accommodations need to be adjusted to changing demands over time. Therefore Design for Disassembly needs to be implemented in the design process of offshore accommodation modules.

This research about Design for Disassembly aspects led to a method that is used in the case study design and that is updated constantly according to new insights from the thorough evaluation of the iterative accommodation design.

3 ACCOMMODATIONS ON OFFSHORE PLATFORMS

3.1 Case study choice

The case study needs to take flexible requirements into account where a fixed design is currently in place. The case study choice therefore is to investigate a Self-installing Platform (SiP) (figure 4).

(a) (b)

Figure 4: (a) SiP for marginal gas field (b) Self-installing substation and accommodation platform for 80-turbine offshore wind farm.

These designs have or could have a 'table-top' design with all accommodations on top of the main deck. Different use is thus possible after its operational lifetime. Hull based design with enclosed accommodations are for example more difficult to update for a new function.

The platforms have different functions, but all have significant operating costs per day. Every day without operating thus presents major costs. Fast and flexible transformation has therefore the potential to account for large savings.

3.2 Life Cycle impacts

The current life cycle impacts are investigated with the Life Cycle Analysis method 'ReCiPe' [32]. The Life Cycle Analysis (LCA) of an offshore drilling rig focuses on the platform itself and in particular of the accommodation modules:

- The functional unit is taken as: "Provide a safe living area in an offshore environment for 100 people for 1 year".
- The use phase of the platform is only taken into account with regard of the accommodations. For example the drilling operations are therefore outside the scope of the analysis.
- The life cycle impacts of the inventory are mainly taken into account up to the second level of inventory (all materials and processes). Third level inventory (capital goods, such as the harbour or factory) was allocated to the platform where needed.
- Phases of the current life cycle are taken as; production, transport, use, maintenance and end-of-life.
- In the production phase general information about steel manufacturing is used to account for the steps leading up to the production.
- End-of-Life scenario was taken as dismantling in Asia, with reuse of the steel in Europe.
- Normalisation was used in the LCA to compare the impacts to an outside reference.
- Weighting factors are not applied to the outcomes of the LCA, but could be used in later comparisons.

The LCA reveals the impacts of the different phases and of the different parts of the platform. Highest normalised impacts are found on human toxicity, freshwater ecotoxicity, marine ecotoxicity and metal depletion (figure 5). The analysis shows that the accommodations are a relatively small part of the overall impacts, but nonetheless present a substantial impact on the environment. The major causes of the toxicity are linked to manufacturing and coating of the steel. The metal depletion is linked to the use of the steel itself.

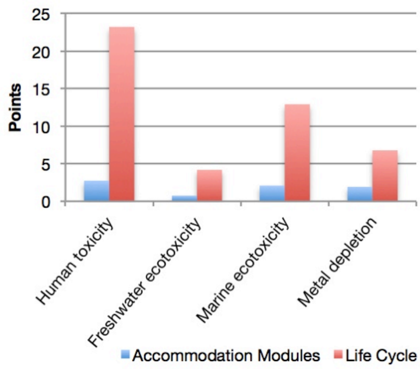

Figure 5: Four highest normalised impacts

Energy use of the platform is dominated by the heating and power usage in the use phase of the platform (figure 6). Design for disassembly could contribute to some savings in the overall energy reduction, but additional energy solutions are needed for substantial energy savings. The disposal phase and the transport of the modules are of interest, because design for disassembly could greatly reduce the energy use there. This gives directions for possible solutions for the redesign.

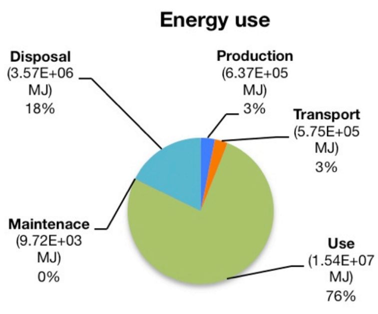

Figure 6: Energy use of the overall platform per life cycle phase

3.3 Disassembly limitations

Further analysis of the accommodations reveals problems with disassemblability of the current accommodations. Especially functional dependences, irreversible connections, sequential assembly sequences and stuck geometries are found. This provides valuable input for the redesign of the accommodations.

3.4 Design requirements

The new design of the accommodations has a large amount of requirements to generate a flexible design that can fulfil the different functional and layout changes over the lifetime. The requirements take into account;

- The applicable rules and regulations
- Safety regulations
- Inside environment
- Choice of materials
- Conditions on sites
- Spatial requirements over time
- Functional requirements of the different rooms.
- Demands per life cycle phase, including transport and commissioning

The requirements of the accommodations furthermore take the following scenarios into account:

1) Minimum oil and gas facility platform: unmanned: accommodations on host platform; 0 people [33]
2) Minimum oil and gas facility platform: manned: accommodations on Self-installing Platform; 12 people [33]
3) Offshore wind farm self-installing temporary or permanent substation/maintenance facilities for medium wind farm: maintenance of 80 wind turbines and the substation: 32 people [34]
4) Offshore wind farm self-installing temporary or permanent substation/maintenance facilities for large wind farm: maintenance of 175 wind turbines and the substation: 70 people [35]

This results in a requirements document that is used during the design phase.

3.5 Method application

The scenarios and requirements show that a flexible design is needed to meet the requirements of the accommodations. Especially upsizing the accommodations and flexible floor plans are important factors in ‘standard proofing’ the accommodation modules. Ease of transport is important for lower costs and higher flexibility of upgrading. Units that can be non-destructively removed furthermore ensure the reusability of the accommodations. Life cycle analysis shows that maximising reuse by remanufacturing and minimising transport can reduce the overall impacts. This is used as input for brainstorm sessions to generate design concepts.

3.6 Initial Design

Offshore platform often get their materials, food and other products with supply ships and some products are already transported in containers on these ships. This provided the idea to use containerised modules with standard container sizes. The standard container size could allow for cheap transport with standard container ships and for easy handling by standard cranes. Furthermore a standard 20’ container can satisfy the spatial requirements of the 9.5 - 12 m^2 per cabin that several relevant rules and regulations prescribe [26-31].

3.7 Design development

The detailed design indeed uses containerised units with standard intermodal dimensions that can be added together to form the accommodations. Shipping the containers in a standard container ship was however found to impose high structural demands that would increase the weight of the units. An external structural frame is therefore added to reduce the structural demands of the units.

The platforms and ports are often far apart, reducing the benefit of standard container ships. Because many of the benefits of standard container handling still hold true for this system, this solution provided an optimum between low weight and ease of transportation.

Using modules with the dimensions of standard 40’ containers for hallways means that 5 containerised units of 8’ wide can be used next to each other per hallway-module. In the scenarios the number of cabins was maximally 35, which means that four decks are needed. If larger accommodations are required, upsizing will be achieved by expanding sideways: using more than four accommodations decks is not custom in practice. The structural frame provides the structural strength to carry the top layers (figure 7).

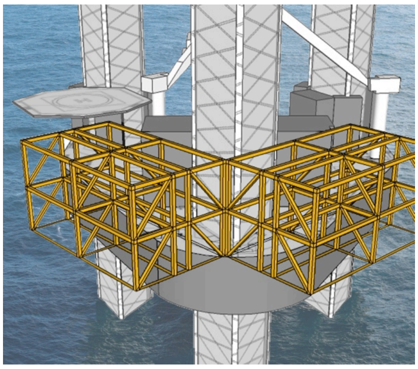

Figure 7: 3d model of the structural frame on a jack-up platform

Design features of the accommodation system are:

- Division between the decks provides extra flexibility because the top and bottom decks can be removed for maintenance or replacement separately.
- The frame can be added and removed in the width of 5 units, providing additional deck space when accommodations are removed.
- The modules can be attached to each other and the frame with twist lock connections (figure 8) that are also used in shipping containers.
- The sidewalls can be removed to combine the units into larger spaces. The functions of the units can therefore change, for example from cabins to recreation room and vice versa (figure 9).
- The connections for ventilation, lighting, water and fire detection are placed in the lowered ceiling. The connections for power, internet, television, communications and sewage are under the floor.
- The panels of the ceiling and floor can be individually removed to access the connections.
- The cables, pipes and ducts go the short side of the cabins and are connected to the hallway modules with demountable connections for fast assembly and disassembly.
- The hallway provides a ‘central street’ with the main ducts and pipes (figure 10).
- The sides of the lowered ceiling are part of the structure of the units and provide an airtight division to increase fire safety.
- The walls connected to the units have flexible seals to provide high gap-tightness and good sound insulation.

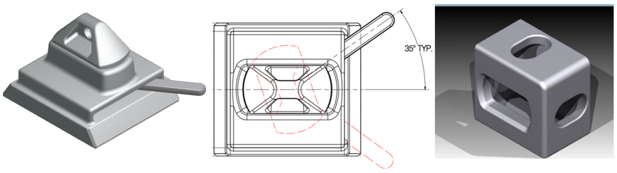

Figure 8: Twist lock connection for containers. [36]

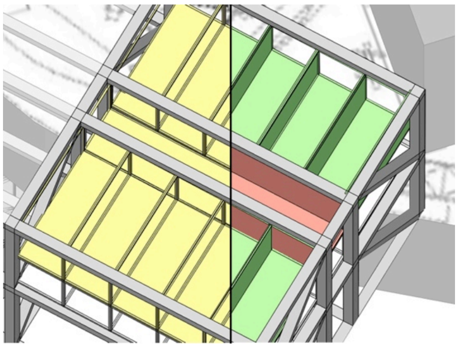

Figure 9: Two possible uses of the containerised modules: open and closed floor plan

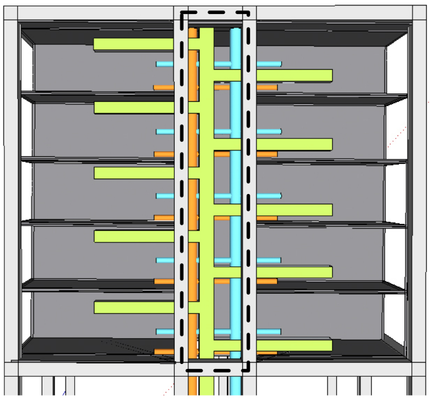

Figure 10: Connections through 'central street'

4 LIFE CYCLE BENEFITS

4.1 Environmental impact

Life Cycle benefits in the environmental impact of the accommodations are needed to improve the sustainability of the accommodations. First indications on the differences in environmental impact are:

- The transportation of the overall platform will be reduced with the more flexible design. Therefore the impacts due to transport will be reduced as well.
- The demountable connections make the accommodation fit for remanufacturing, which will reduce waste and increase the use of the embodied energy.
- The steel frame is also demountable and therefore fit for remanufacturing and use in another platform. This minimises the need for newly manufactured steel and reduces the impacts caused by manufacturing.

Added measures such as environmentally friendly coating reduce the impacts even further.

The comparison between the current case and the redesign will be made in more detail in a Life Cycle Analysis later in the research process.

4.2 Life Cycle Costs

Rough estimates of production, transport and installation costs will be compared to the current case. Due to the high operating costs per day, the costs of adapting the units are likely to be lower than in the current costs.

Reuse of the units can furthermore provide a saving in the manufacturing costs of new accommodations and the elimination of scrapping needs provides savings in end of life transport costs. The costs of industrially producing the standardised modules is likely to cost the same or less. Overall life cycle costs of the redesign are therefore assumed to be lower. A network of remanufacturers might be needed to ensure this reuse of parts, components and systems.

4.3 Life Cycle Functionality

The functionality of the accommodations increases in the redesign. Benefits include easier maintenance, higher flexibility and easier upgrading. The higher flexibility in spatial layout and possibility to remove parts of the structural frame and accommodations furthermore allows for a more versatile use of the platform.

5 SUMMARY

This paper describes the benefits of Design for Disassembly applied to the accommodations on board offshore platforms. It is shown that there are many advantages and that offshore platform can benefit from the use of Design for Disassembly. The research resulted in a method that is applied in accommodation design. The results are shown and the coming research steps are explained. Finally the potential benefits are mentioned.

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