Exploring an incremental pathway to the development of multi-use exploitation within offshore wind farms

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ABSTRACT: The North Sea is getting more crowded due to the increase in offshore wind farms (OWF). According to several researchers, this development causes pressure on the valuable area of current North Sea stakeholders, like fisheries and environmental organisations (Hooper and Austen, 2013; Lacroix and Pioch, 2011). However, the designated areas for OWF could potentially be used for secondary activities, also called "multi-use activities", such as mussel cultivation (Buck et al., 2010; Lagerveld et al., 2014), seaweed farming (Van den Burg et al., 2016), and nature development (Kamermans et al., 2018). In contrast, other researchers have shown the difficulties of multi-use exploitation within wind farms because exploitation uncertainties can lead to excessive insurance claims (Kannen, 2012; Wever et al., 2015). Because there is no clear multi-use policy by the government, stakeholders are developing individual strategies to increase the value of OWF and to find solutions for the spatial planning problem of the North Sea. This fragmented approach to multi-use resembles a 'prisoner's dilemma' in which all actors develop the safest plan for themselves. However, integrating business cases and jointly developing an integrated exploitation plan would be a better choice for all involved stakeholders. This research investigates the potentially best multi-use businesses to increase the value of OWF with a technology assessment (TA) approach. The initial findings of this study suggest that combining different multi-use functions within an OWF seem the best choice to increase the spatial value. The diversity of functions can increase the social acceptance of different stakeholders and increase the chance of joint financing and use of environmental resources that support each other's exploitation. As a result, upscaling may be possible. However, current research shows there are many exploitation risks, uncertainties, and dilemmas of stakeholders, that resembles the implementation of different multi-use functions within an OWF. Therefore, this scientific paper aims to introduce an alternative and realistic pathway to multi-use exploitation. Lessons learned from the Building with Nature (BwN) process, which had similar dilemmas ten years ago, are used to reach this objective. The results of this research suggest that involving a gradual process of change and development for multi-use exploitation is desirable because it will reduce the size of the knowledge gaps at each step. This evolutionary approach should integrate functions one by one, rather than waiting for a revolutionary multi-use 'big bang' consisting of the best multi-use combination. This incremental approach should consist of smaller pilot projects of multi-use and constructive cooperation between the stakeholders, that will eventually lead to large scale multi-use exploitation.

Keywords: Multi-use, Offshore Wind Farms, Building with Nature, Development Approaches, Stepping Stones

1 INTRODUCTION

The first paragraph describes the spatial challenges for multifunctional use of the North Sea. The second paragraph introduces the principle of multi-use by outlining the necessity, potential impact and opportunities. Next, the current approach of the Dutch government to multi-use is explained in paragraph three, and the current developments are described in paragraph four. The last paragraph explains the context and essence of this research.

1.1 Marine spatial planning

The North Sea is one of the busiest seas in the world (Nilsson et al., 2018). The Dutch North Sea contains established markets such as shipping, oil, gas, dredging, military, nature reserves and fisheries. Besides, new markets emerge, for instance, offshore wind, that according to the Dutch Government could require up to 24% of the Dutch North Sea area (Matthijsen et al., 2018). The growth of the Dutch offshore wind industry started in 2008 and influenced the spatial planning of the North Sea. For instance, shipping routes were redirected (Mehdi, 2017), ships over 24 meters are prohibited in wind farms (MIeM, 2015), and some OWF areas are planned in ecologically valuable areas. The growth of the offshore wind industry is putting pressure on the environment and established stakeholders. Therefore, a new North Sea layout is desired by the current stakeholders (OFL, 2018).

The marine spatial planning of the North Sea is currently fragmented through single-use planning that is not sustainable with the rise of new OWF. New concessions are needed to share the spatial area of the

North Sea. Therefore, several scientists concluded that multifunctional use of the wind farm area, also called multi-use or co-use, is essential for solving the marine spatial challenges within the North Sea (Lacroix and Pioch, 2011; Lagerveld et al., 2014; Kannen, 2012).

1.2 Multi-use Principle

Multi-use has the aim to combine multiple purposes in one zone, which means that North Sea stakeholders have to share the area for multiple businesses as visualized in Figure 1. The first multi-use research applicable towards offshore wind originated in 2001 when Buck investigated the combination of aquaculture with offshore installations (Buck, 2001). Since then, many researchers examined potential multi-use projects, for instance, passive fishery (Verhaeghe et al., 2011), tidal energy (Lamy and Azevedo, 2018) and marine aquaculture and fisheries (Schupp and Buck, 2017).

Fig. 1. Multi-use within an offshore wind farm (TKI, 2019)

The area between the wind turbines could potentially be used for the development of other businesses. For example, Deltares studied the available area for multi-use in OWF Hollandse Kust Zuid (HKZ) in Table 1 (Bolman et al., 2019). This table shows three scenarios with respectively the potential area for multi-use with a maintenance zone of 50, 100 and 250 meters at each side of the infield cables.

Table 1. Potential multi-use area in HKZ. Based on (Bolman et al., 2019)

	Total surface area HKZ	Available area for multi-use activities	Percentage available area for multi-use activities
Scenario 1	214 km^2	190 km^2	88.79 %
Scenario 2	214 km^2	171 km^2	79.91 %
Scenario 3	214 km^2	116 km^2	54.21 %

The current research towards multi-use is exclusively focussed on the area within the OWF because they are a new market in the North Sea and have high multi-use potential (Bolman et al., 2019). The OWF's use large areas of the sea, while most of their structures are underground and above the water surface.

Although researchers warned for the spatial pressure of OWF's at the North Sea, Table 1. shows that there is a massive area available for multi-use projects. Besides, specific multi-use projects in OWF's could benefit from the shipping restrictions and visual border of the OWF (MIeM, 2015). The opportunities are the trigger for many organisations to develop multi-use strategies. In response to these new opportunities, the Dutch government is creating a North Sea strategy for marine spatial planning.

1.3 North Sea Strategy

The potentially available area may be the solution to the spatial planning problems. Therefore, the Dutch government is developing the 2030 North Sea strategy, that will discuss potential combinations and cooperation within the North Sea to solve the marine spatial planning challenges (IDON, 2017). The project has three main goals on the agenda that are visualized in Figure 2. (North Sea Strategy) and listed below.

- Robust Nature
- Energy Transition
- Future Proof Food Supply

The government has a challenge to enhance robust nature development, energy transition and future proof food supply with the existing stakeholders of the North Sea. The role of multi-use within this strategy is still uncertain because there are many knowledge gaps and risks regarding multi-use implementation. Therefore, the Dutch government has established the Community of Practice multi-use Noordzee2030 (CoP). This community consists of stakeholders in the North Sea, that organize workshops and informative lectures intending to share knowledge, find solutions and final implementation of multi-use projects.

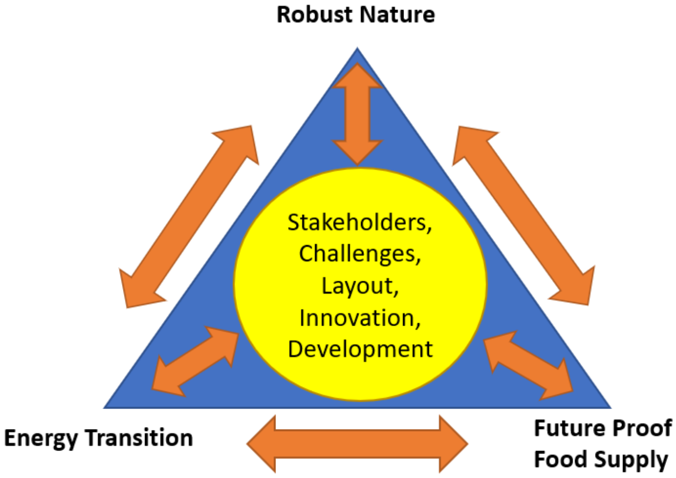

Fig. 2. North Sea Strategy (Noordzeeloket, 2018)

The current approach of the Dutch Government is aiming to bring all knowledge together and find 'perfect' solutions to achieve their goals of Figure 2. They push for integral multi-use projects that satisfies several companies and the goals of the North Sea Strategy.

1.4 Multi-use development

Due to (a) the economic growth, (b) the crowded area, and (c) the energy transition, multifunctional use of the North Sea is a likely scenario. The development of multi-use is diverse and is emerging over the last decade (Wever et al., 2015). Numerous companies understand the potential and need for multi-use and are, therefore developing their multi-use projects (Bolman et al., 2019; Lacroix and Pioch, 2011). The wide variety and amount of separated multi-use start-ups are difficult to determine because some of the projects are developed in classified circumstances. In addition to the start-up's, consortia are formed between committed parties. Many of these initiators are seeking for the ground-breaking multi-use business plan, that satisfies the political ambition.

1.5 Research Context

Previous research has observed that in the current approach governmental knowledge gaps, economic risks and exploitation uncertainties are the biggest challenges for the implementation of multi-use (Buck et al., 2018; Groenendijk, 2018; Krause et al., 2011; Kannen, 2012; Wever et al., 2014). As a result, multi-use is not exploited yet in OWF on a large scale. This research aims to find the knowledge gaps, risks and uncertainties of multi-use projects by highlighting the difficulties in current approaches. Besides, this research tries to explore an alternative approach towards multi-use application. The technology assessment (TA) method was adopted to assess the multi-use projects and approach. The TA will assess current multi-use projects on their uncertainties, risks and knowledge gaps in offshore wind farms. The results of the TA are used to discuss the knowledge gaps and dilemmas that impede large-scale multi-use of OWF's. After that, this research used lessons learned from the Building with Nature (BwN) approach, that had similar challenges in the past. The TA and comparison with BwN are conducted to explore a workable alternative pathway towards the implementation of multi-use in OWF's at the Dutch North Sea.

1.6 Resume

Due to the development of OWF's in the North Sea, marine spatial planning is under pressure. Therefore, several activities should be combined in the same area (multi-use) to overcome the spatial problem. OWF's seem applicable and full of opportunities for multi-use. Therefore, the Dutch government is searching for pathways towards multi-use exploitation. In the current setting, stakeholders of the North Sea are developing multi-use projects and approaches separated from each other. Exploitation is not yet in sight because of specific knowledge gaps, mismatches between stakeholder views and related uncertainties. This research aims to clarify the importance of these via application of a TA. Furthermore, this research explores new pathways towards multi-use exploitation in an OWF.

2 METHODOLOGY

Chapter one implicates that multi-use uncertainties are the reason that multi-use is not developed yet. Therefore, this research will use TA methods to increase the understanding of technologies and the view of stakeholders. The first paragraph introduces the general TA method in this research, while the second paragraph explains the applied TA design to assess current multi-use projects. The TA aims to reveal uncertainties and blocking points in the current multi-use approach. In addition, a comparison with the Building with Nature approach is conducted to learn how approaches with similarities overcame the development uncertainties.

2.1 Technology Assessment Methodology

The TA is a research framework aiming to advise decision-makers (TAMI, 2004). The method claims to generate practical information about new technologies and their consequences, not only for engineering but also for society. This method is particularly useful to assess new technologies and to determine strategies for the implementation of technology (Fleischer and Grunwald, 2008). The TA has a wide variety of tools available, that could be used for the assessment of diverse technologies (in this case, multi-use technologies within OWF). This variety allows the researcher to draft a TA towards different fields of technology (Schot and Rip, 1997). Nevertheless, the TA follows a structured design visualised in Figure 3. Starting with a situation analysis and a realistic goal setting performed in chapter one. This goal shall be examined with a customized project design (chapter two) and execution (chapter three). The outcomes are described in the result chapter and describe the impact of multi-use and the attached uncertainties.

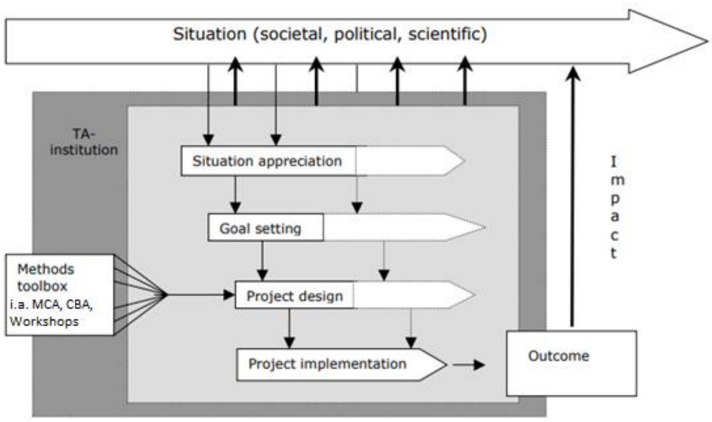

Fig. 3. Technology Assessment Framework (TAMI,2004)

2.2 Technology Assessment Project Design

The TA project design is built up from different tools/ methods to assess multi-use projects described in this paragraph. The MCA will increase the understanding of stakeholders. The valuation approach will improve the understanding of economic values. Moreover, the expert panel should give a better understanding of the exploitation uncertainties.

Multi-Criteria Analysis: The primary tool used to understand the stakeholder views of multi-use projects is a multi-criteria analysis (MCA). The goal of the MCA is to create a clear overview of the current multi-use projects and their applicability within future projects.

Literature study and unstructured interviews were conducted to discuss useful criteria and related weights for the MCA. The interviews give the respondent the option to explain their view and allows the researcher to probe for a deeper understanding of their view. Each interviewee was chosen based on their unique expertise and position in decision-making processes. The functions of the interviewees were: 1) stakeholder manager, 2) environmental specialist, 3) R&D specialist, 4) senior advisor marine and coastal management, 5) leading professional water management, 6) resource economist. These experts are familiar with MCA techniques and the North Sea stakeholders. The information obtained from the interviews is used in successive interviews for verification of the criteria and weights.

The scoring of the MCA is performed on four main criteria with an ordinal scoring system: legal applicability, scalability, technology readiness level (TRL), social acceptance and two sub-criteria: option for transit and financial self-sufficiency. The scoring is based on literature and stakeholders' views. For this research, about 25 stakeholders are contacted at stakeholder conferences, the Community of Practice or with individual interviews. Contacted stakeholders are OWF developers, Fishermen, NGO's, consultancies, research institutes, governmental organisations, and multi-use initiators.

Multi-use Economic Valuation Approaches: The second method is performed to understand the economic uncertainties. As described in chapter 1, specific multi-use projects have (environmental) benefits. Some of the benefits are difficult to quantify or monetize. Therefore, the actual value of multi-use projects is uncertain.

For this reason, semi-structured interviews were conducted with three environmental economics to examine a suitable valuation approach that could reveal the environmental value of multi-use projects.

Expert Panel: The results of the MCA and economic valuation approaches are presented to an expert panel of the marine contractor Van Oord. This panel consists of 6 experts with unique expertise. It represents several groups within Van Oord which are: Research and Development (R&D), Communication & Markets, Environmental Engineering, Tender Engineering, Project Engineering and Finance. This expert panel session aims to examine the exploitation uncertainties and execution challenges while discussing potential follow up steps in the development of multi-use projects.

2.3 Building with Nature Comparison

The blocking points, uncertainties and difficulties in the current multi-use approach could be compared with the BwN approach that served similar challenges. This approach succeeded with several large scale pilot projects. Therefore, this research will compare the BwN approach with the current multi-use approach to find potential improvements. This comparison is conducted in chapter five because first, the current multi-use approach is assessed in chapter three and four.

2.4 Resume

To get a better understanding of the stakeholder's views towards multi-use, an MCA is developed. Next to that, valuation approaches are assessed to clarify economic uncertainties. The exploitation risks will be clarified by using an expert panel of a maritime contractor, and the multi-use approach will be compared with the BwN approach that faced similar challenges. The next chapter will present the results of the described TA methods.

3 RESULTS: TECHNOLOGY ASSESSMENT

Paragraph one to four describes the results of the TA. The fifth paragraph will reflect on the TA results and will present the follow-up steps to find the reason why multi-use is not exploited yet.

3.1 Multi-Criteria Analysis

This study found several potential multi-use initiatives that fall inside the scope of this research. About 50% of these multi-use projects were found in scientific journals, while others were found at (governmental) research programs and institutes such as Topsector Kennis & Innovatie (TKI) and the Netherlands Enterprise Agency (RVO).

The twenty-six projects found could be divided into four primary purposes: Fishery, Nature/Environment, Energy and Nutrition. Most of these projects aim to develop one function, while six projects focus on multiple purposes in one project. These integrated projects score significantly higher in the MCA than single-purpose projects because:

1. Integrated projects score higher on social acceptance because they serve more stakeholders than singular projects.
2. Integrated projects score higher on scalability because they use mixed resources and have widespread financing possibilities.

The most significant disadvantage of integrated multi-use projects is that the OWF will have more shareholders with more equipment and labour, which increases the risks and uncertainties. Figure 1. visualises an OWF with multiple multi-use projects. Combining the area could result in additional risks, such as the transit of recreation through the seaweed area, or oyster bed development that could be demolished by fishing.

Currently, nature/environment projects scored well because their risks are well controllable, and they are often easy to combine with other functions.

It is apparent from the MCA that more significant floating constructions such as floating tidal or solar energy score lower because of their risks. Several stakeholders are against large floating structures in the North Sea because of collision risks.

The results give a general idea about promising multi-use projects. However, the North Sea future is difficult to determine because the legislation of multi-use is still uncertain. Currently, fishery-related multi-use projects score relatively low. However, when the Dutch government decides to support the fishery industry over their environmental objectives, then, these projects will be more promising in the future. The view of the government, wind farm developer and other stakeholders could vary over time (Schupp et al., 2019). Therefore, the MCA is an indicative tool that creates more certainty about the potential multi-use projects. However, it is not prescriptive because the legislation toward multi-use can be adjusted in the following years.

3.2 Valuation Approach Assessment

Environmental economists and literature studies claim that environmental benefits could be monetized and used for multi-use development (Growbrowski, 2012). Currently, several multi-use projects struggle with their financial feasibility (Van den Burg, 2016). Earlier researches advised investigating the environmental benefits which are created by the activities (Van den Burg, 2016; Kannen, 2012).

The research found that environmental value could be determined with specific valuation methods. However, these methods are often based on quantitative data. Therefore, projects should be implemented to measure the m³ water filtered, the flat oysters born, or the increase in cod. Currently, there is no multi-use project implemented and monitored in OWF. For this reason, there are no measures of multi-use, the value cannot be monetized, and therefore no complete business case can be developed. This process is a vicious circle of uncertainties, that should be breached for further multi-use development.

3.3 Development Uncertainties

This research tries to explore the most promising multi-use project. However, this research encounters multiple uncertainties in the technology development of multi-use, that are described in Table 2.

Table 2. Multi-use Development Uncertainties

Strategic Uncertainty	Vague goals of the Dutch government; Unclear future tender changes; Unclear multi-use permit legislation;
Outcome Uncertainty	Multi-use profitability; The environmental value of multi-use; Technical, environmental and social impact; Unintended consequences;
Communication Uncertainty	Cooperation risks; Separated multi-use approach; Integral risks communication; Diversity of interests among stakeholders;
Success Uncertainty	Target market; Overexploitation; Subsidies; Insurance claims;
Commitment Uncertainty	Innovation threatens other organization's norms; Role OWF Developer; Stakeholders commitment; Law obligations;

At the current approach, multi-use initiators and decision-makers struggle with the uncertainties. As a result, it is very challenging to continue developing a multi-use project, and the current pathway to multi-use exploitation has reached an impasse.

3.4 Expert Panel Conclusions

The panel mentioned that currently, many stakeholders have specialised knowledge, that could be combined to reduce the uncertainties of multi-use implementation, for example, the oyster recovery projects consisting of Van Oord (contractor), Stichting de Noordzee (NGO), Eneco (OWF developer), Bureau Waardenburg (consultancy firm) and Wageningen Marine Research (research institute). Such consortia can bundle their knowledge to overcome uncertainties and knowledge gaps.

Besides, the panel advised looking into the BwN projects and how these projects did succeed while not having a closing business case.

The panel thinks that multi-use can be implemented, but first, small pilots should be implemented to reduce the uncertainties for other stakeholders. The panel mentioned that construction, transportation and installation is not the impasse that keeps multi-use from further development.

3.5 Technology Assessment Findings

The government, OWF developers and other stakeholders are aware of the pressure and potential benefits for multi-use functions. The MCA results and the governmental target indicate that combining multi-use for a 'perfect' project is desirable for all parties. However, currently, stakeholder's view, economic value and development uncertainties block the 'perfect' multi-use projects from further development. The step from the idea phase to exploitation is too big while the expert panel of Van Oord concluded that construction and installation of the projects is not the bottleneck.

During the TA this research examined that the uncertainties were driven by underlying dilemmas. These underlying dilemmas are the blocking points that impede further development of multi-use projects and are the cause of several uncertainties. These underlying blocking points that create the uncertainties are discussed in chapter 4, while the comparison with the BwN approach is conducted in chapter 5.

3.6 Resume

The TA indicated that there are promising integrated multi-use options. However, economic, governmental and exploitation uncertainties impede further development of the current multi-use development approach. This research found underlying dilemmas that caused the uncertainties and the next chapter will elaborate on these dilemmas.

4 REFLECTIVE RESULTS: UNDERLYING CHALLENGES IN CURRENT MULTI-USE DEVELOPMENT APPROACH

Paragraph one to four will describe the difficulties in the current multi-use approach. The fifth paragraph displays an overview of the current approach and the dilemmas. Besides this paragraph will make a connection to the BwN approach, that has similar difficulties over the past.

4.1 Competitiveness

The North Sea CoP members are aware of multi-use importance and are therefore sharing knowledge to a certain extent. However, the stakeholders have their agenda or stake that they would prefer over others. Besides, multi-use projects could grow to bigger businesses. Therefore, some stakeholders are not willing to share their technology in this potentially competitive field. The Dutch government is developing a North Sea agreement that will outline strategies and agreements of North Sea stakeholders for the long-term development of the North Sea (Noordzeeloket, 2019). They created the CoP consisting of North Sea stakeholders with the aim of knowledge sharing to stimulate multi-use (RVO, 2019). A CoP has a high potential for the exchange of knowledge between the concerned parties (Ruikar et al., 2009). However, CoP's are not functional in competitive fields, where there is hesitation to share competitive knowledge (Kimble and Hildreth, 2004). As long as multi-use stakeholders are not entirely transparent, multi-use will face problems in the development phase.

4.2 Fragmented knowledge of Multi-use Approach

At the moment, over 25 different multi-use projects are known. Each project has unique uncertainties and risks, which results in a complex matrix of interrelated risks between the multi-use initiators, OWF developers, governmental organisation and other stakeholders (Buchanan, 2018).

Traditional planning and policy instruments tend to look at single sectors and scales. Communication areas and guiding visions for defining priorities between conflicting interests, e.g., renewable energy development versus shipping versus nature protection, are missing (Kannen & Burkhard, 2009).

Multi-use is aiming to combine these so-called 'conflicting interests', and an integrated policy is needed to overcome the current fragmented approach. Many risks could be solved or mitigated by combining the knowledge and cooperation of multiple stakeholders. In this case, the interrelated uncertainties can be solved before the exploitation. However, currently, stakeholders cannot be forced to cooperate in multi-use projects. Besides, not all stakeholders are eager to cooperate because they do not want to be responsible for shared risks.

This fragmented approach to multi-use resembles a 'prisoner's dilemma' in which all actors develop the safest plan for themselves. However, integrating business cases and jointly developing an integrated exploitation and risk plan would be a better choice for all involved stakeholders. In this case, the risks are shared, and uncertainties can be more easily managed (Kannen & Burkhard, 2009; Forst, 2009).

4.3 Waiting game

A waiting game represents when multiple companies are competing with the same technology, and all wait for the other to introduce the innovation, that would present the first opportunity to learn about public acceptance and uncertainties of the innovation (Robinson et al., 2014).

Currently, the multi-use stakeholders and innovators are playing the waiting game in multi-use development, which creates an innovation impasse. This strategy is understandable because the followers could learn from the mistakes of the pioneer and could adapt their strategy on the results of the first initiator. Besides, the pioneer will face the risks and has to deal with the uncertainties.

4.4 The Innovation Valley of Death

New technology developers are often encouraged by research programs, institutes or R&D subsidy. The developers could get a research budget and support with their innovation (Upadhyayula et al., 2018). In an ideal scenario, companies from the commercial market invest in further development and exploitation. The gap between these 2 phases is called the valley of death, where innovations could get stuck for years. One multi-use example is tidal energy project if BlueTec. There is a prototype available, and the technology is in an advanced state. However, there are no companies that are willing to invest in further commercial development. As long as the market is not investing in the multi-use project, it will be difficult to escape the ‘valley of death’.

4.5 Current Multi-use Approach Dilemmas

It is a noble aim to create multi-use that could fulfil all stakes mentioned in Figure 2. The current road to multi-use is full of uncertainties and has reached blocking points described in this chapter. The current approach seems not sustainable for multi-use development. Figure 5. visualizes the current approach and the connective challenges, as described in this chapter.

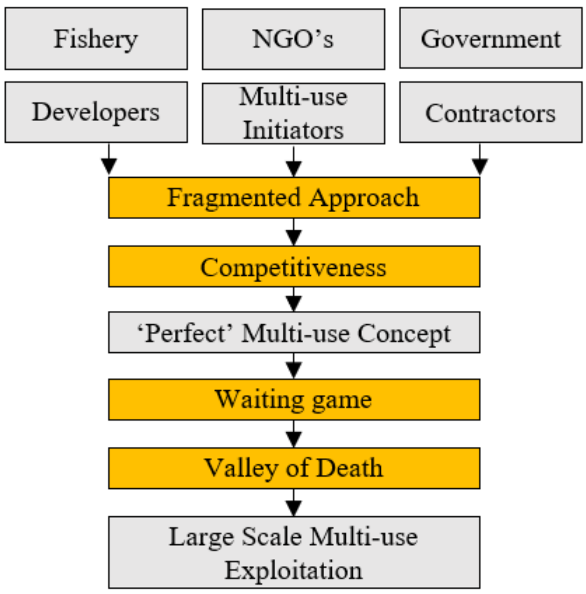

Fig. 5. Dilemmas in Current Multi-use Approach

The ‘prisoner’s dilemma’ and vicious circles described in this chapter are preventing multi-use exploitation. Therefore, alternative approaches should be considered to realise multi-use. The noble aim towards the 'perfect' integrated multi-use should be reconsidered by learning from other approaches that involve innovating, multifunctional and environmental challenges.

The BwN approach proposed in an article by de Vriend and van Koningsveld (2012) has certain similarities with the multi-use dilemmas. The BwN approach is a mindset change towards integral projects that integrate stakeholders and the environment for new project development. The BwN approach created a systematic approach with pilots projects, positive energy flow by small successes and knowledge improvements with adaptive management. This approach has proven to be successful in several projects, for instance, the Sand Engine and Houtribdijk (DeZandMotor, 2019; EcoShape et al., 2018). Therefore, this research will take lessons learned from building with nature and apply these on an alternative multi-use approach.

4.6 Resume

Fragmented multi-use approach, competitiveness, waiting game and the valley of death are the most prominent underlying dilemmas that currently keep multi-use from further development. In the process of exploring alternative approaches, lessons could be learned from the development of the BwN philosophy, which faces similar dilemmas in upscaling its application.

5 COMPARISON WITH BUILDING WITH NATURE

One of the BwN fundamentals is that the BwN approach requires a paradigm shift and requires thinking, acting and interacting differently (de Vriend and van Koningsveld, 2012). The first paragraph will elaborate on the comparison between multi-use and the BwN approach. The consecutive paragraphs will describe the critical success factors in implementing BwN: the learning by doing principle, the BwN design process and its robustness, the flexibility and adaptiveness in the BwN approach. The fifth paragraph clarifies what valuation issues BwN is facing while the sixth paragraph will summarize relevant lessons from the BwN approach.

5.1 Building with Nature Approach Similarities

Literature has shown the difficulties of multi-use acceptance of stakeholders (Schupp et al., 2019). The current stakeholders have to be convinced that multi-use is added-value for them to create exploitation opportunities (Krause et al., 2011). Besides, multi-use projects are challenging to predict and monetize because many of these projects are working with

living organisms.
These challenges could be compared with BwN projects, that faced similar challenges over the last few years (de Vriend et al., 2014). In 2018, the organisation of the BwN principle EcoShape published a building with nature business case guidance report which explained the need for BwN Business cases. '*'The BwN approach is often associated with uncertainties regarding (long term) performance. The evidence base of BwN is small compared to conventional approaches, and ecological solutions are sometimes less predictable than humanmade structures. Therefore, dealing with and reducing these (perceived) uncertainties is just as important as valuating the co-benefits to stimulate upscaling of BwN (EcoShape, 2018).''*
This quote applies to multi-use as well and, therefore, the lessons learned from BwN are used to discuss realistic approaches towards multi-use development.

5.2 Learning by Doing

Description: A research review of the BwN approach over the last ten years recommended that more large-scale pilot projects with the involvement of communities in planning and implementation phase are essential to scale up and sustain BwN solutions (Eekelen et al., 2019). Initiating pilot projects and using these results to overcome knowledge gaps and create a positive flow is used in the BwN approach and is called learning-by-doing (de Vriend, 2012). In BwN, the availability of full-scale pilot experiments forms the critical ingredients for driving successful projects (Aarninkhof et al., 2012). For instance, the Sand Motor pilot near the coast of The Hague is studied by several researchers in the last few years, and this data could be used for related sandy solution projects. There are various merits in this learning by doing approach: conducting pilot projects means that information and success can be obtained at limited risks and insights and data will feed the further development process. At the same time, the positivity around the application of innovative solutions will create a further breeding ground for spin-offs. For instance, the Sand Motor has inspired others to create a similar solution at the coast of England, that was finished in the summer of 2019 (Van Oord, 2019).

Applicability: The approach of learning by doing could be a valuable stepping stone towards large scale multi-use because it splits the exploitation phase into smaller comprehensible pilot projects. The pilot projects could reveal the effect of multi-use and could clarify the current uncertainties. A few multi-use initiators embrace this idea and are introducing pilot projects. For instance, Van Oord is active in the flat oyster pilot in OWF Luchterduinen. Until 2022, nature development within the wind farm will be investigated by research institutes. The aim is to determine whether the oysters grow and reproduce sufficiently and whether their larvae establish themselves in the vicinity and form a reef (Van Oord, 2018). This small pilot could solve these questions and will contribute to the larger goal to enable nature to thrive within OWF.

5.3 Robust Design

Description: New techniques come with knowledge gaps and uncertainties in pilots and projects. Safeguarding these gaps is essential to introduce a new technique. Therefore, BwN projects have often a robust design, that will result in fewer uncertainties (EcoShape, 2018).
Robust design is often costlier than the initial design. However, it acts as a stepping stone towards larger-scale implementation. When a robust project succeeds, this will result in a more positive mindset and coherence towards further optimisations rounds. This cycle of improvement (Figure 7.) could eventually lead to an optimized design of multi-use. After each phase, they have the opportunity to adapt and resolve the uncertainties before moving to the next phase.

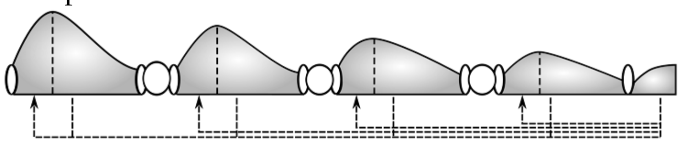

Fig. 7. Project realisation phases of BwN (https://publicwiki.deltares.nl/display/BTG/Steps+and+phases)

Applicability: Multi-use studies have faced robust design requirements already. For instance, the Edulis project in Belgium had to increase the anchor weights to safeguard the risk of mussel lines going adrift. These requirements created the possibility to start a potentially over-dimensioned pilot project. In the following researches this designed could be optimized with help of the pilot measurements. Multi-use projects could use robust design approach in small pilot projects to safeguard the knowledge gaps while optimizing the design for future large scale projects.

5.4 Flexible and Adaptive Approach

Description: The continuous improvement of pilot projects requires a flexible and adaptive approach. New techniques need to be flexible with uncertainties and hazards. Flexible goals could create margins for new development. These margins should be used for constant learning by adaptive management (Figure 6.). This approach could fill the knowledge gaps over time and create the trust of the stakeholders.

Fig. 6. Adaptive Management (CEDA,2015)

Applicability: A flexible and adaptive approach is essential to introduce new techniques. For instance, the first test results of the flat oyster projects from Van Oord had disappointing results. They need to adapt the oyster cage structures to improve the stability and hopefully the results. Multi-use projects should have an open mindset for changes in their project to adapt to the environment and legislation.

5.5 *Create Awareness of Added Value*

Description: Valuing co-benefits of the BwN using ecosystem services approaches is critical in demonstrating the added value of BwN over conventional approaches (EcoShape, 2018). Such natural benefits that may be provided as goods (e.g. fish) or services (e.g. clean water provision), are collectively known as ecosystem services. Ecosystem services are defined as 'the benefits people derive from ecosystems' (MEA, 2003). Linking co-benefits to stakeholders can be a valuable input in the process of finding (co)finance sources.

The interviewed BwN specialist explains that these services have a specific economic value. Valuation methods try to get a clearer understanding of the value of ecosystems by monetizing the effects. The economics of ecosystems and biodiversity (TEEB) database contains valuations of the ecosystem services. Such key-figures could be used to determine the economic value for BwN projects and multi-use projects.

Applicability: Multi-use projects could increase the value of the OWF by creating co-benefits. Van den Burg et al. (2016) claim that seaweed is not economically feasible yet. However, the societal benefits as water filtration can add to the total value of seaweed. This research raised the question of how such benefits can be converted into financial benefits to make seaweed economically feasible. The co-benefits of multi-use could be linked to stakeholders, and this could increase the willingness to invest and cooperate in multi-use projects.

5.6 *Resume*

From the development process and project implementation of BwN, it can be learned that in order to get (pilot) application starting, it is vital to demonstrate technical feasibility (show that it works). Learning by doing (piloting) is vital not only to learn about (better) ways to apply the necessary technological innovations but also allow the development of the necessary mindset of continuous learning and adaptive management at various stakeholders. Finally, executing BwN pilots and projects has assured that relevant stakeholder perspectives are made more explicit. Taking these lessons into account, an alternative approach towards multi-use development could be explored.

6 DEVELOPMENT OF A REALISTIC CONCEPT APPROACH

Chapter three explained the TA approach toward multi-use. This pathway to the perfect business case has reached an impasse because of the uncertainties and risks, that are too severe for developing business cases. Chapter four explained some underlying processes and dilemmas that are challenging in the current approach. In chapter five, the research explained the lessons from the BwN approach that could be used for multi-use development. This chapter will use the lessons from BwN and the results of this research to discuss an alternative concept approach. The first paragraph will introduce the different approaches, and the second paragraph will introduce the new stepping stone approach.

6.1 *Evolutionary or a Revolutionary Approach*

The TA results reveals the uncertainties and lack of cooperation in the development phase and the underlying dilemmas that impede further development.

At the current approach, everything is focussed to the creation of one big multi-use solution, and therefore the challenges seem unbridgeable.

Lessons from BwN taught us that pilot projects are vital for implementing alternative construction projects (Aarninkhof, 2012; Eekelen et al., 2019). Multi-use needs a stepwise integration of risks, functions and knowledge. This ‘evolutionary’ approach is more realistic for multi-use exploitation than the current ‘revolutionary’ approach. BwN has already shown the potential of such an incremental approach. BwN has already executed over 20 different projects, with total revenue of almost 50 million euros (Eekelen et al., 2019).

6.2 Stepping Stones Approach

Uncertainties and knowledge gaps should be reduced and gapped for implementing multi-use. Therefore, smaller stepping stones are advised for future development.

Figure 8. shows that the current straightforward strategy is not working. An alternative approach with stepping stones and continuous improvement is, therefore, a more desirable pathway.

At each stepping stone, the consortia should evaluate, plan, design and potentially adapt their strategy to overcome the challenges as shown in Figure 6.

The stepping stones are aimed to form close partnerships with small consortia and small pilots in the first phase. At each stage, new measurements are used to improve the project and reduce the knowledge gaps. Besides, these smaller trusty partnerships will be the basis to overcome mistrust, competitiveness and insurance claims.

While the process is proceeding, more additional partners could be asked for further cooperation. Besides, the pilot projects could be scaled up if the first projects were successful. If these projects were not successful, then the group should adapt their strategy and try again.

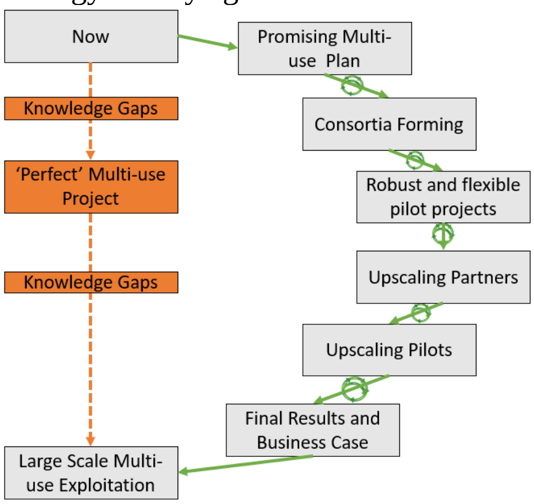

Fig. 8. Alternative Approach to Multi-use Development

This pilot-based approach will have enough room for stakeholders to become aware of the added-value for them and their partners/clients. When there is money/value to be made, then stakeholders are more interested in cooperating. In that case, the subsequent step could be reached.

6.3 Resume

Bridging the gaps between stakeholders and allowing for appropriate development and implementation of innovative technologies, a new 'evolutionary' approach is more realistic for multi-use exploitation than the current 'revolutionary' approach. BwN showed the potential of their approach. This research recommends to further explore such an alternative approach with stepping stones and continuous improvement.

7 DISCUSSION

Due to the nature of this research (assessing the viability of multi-use), there is quite some subjectivity regarding the outcomes. It must be noted that this research is performed for the University of Twente with the cooperation of Van Oord and that the aim of the research was not to find the 'best' multi-use for Van Oord (or another stakeholder) but rather to investigate the suitability of multi-use for the OWF in general. As the invitations, contacts and many experts that this research has used were connected to Van Oord, this might have led to a bias in the information that has been studied and the perspective of both the involved stakeholders (as they were talking to some-one related to Van Oord) and the researchers. This issue of contact and knowledge sharing within and between stakeholders is one of the findings. It has been articulated during the research to all involved, so it is perceived that this influence is acceptably low.

Both the assessment and the judgements on the feasibility of the current 'revolutionary' approach should also be seen in the light of subjectivity. The business case for multi-use in OWF is improving as the topic is further studied, and efforts to integrate the system by different groups of stakeholders are undertaken. However, following the practical approach of the TA in this research, the remaining risks at the OWF developer are considerable and difficult to insure, making it very difficult in the current setting that the multi-use revenue will exceed (the costs of) these risk.

However, in theory, prominent players of the North Sea could set themselves up as the system integrator who takes care of the risks. Nonetheless, this role is unlikely because of the massive potential insurance claims by the OWF developers. In this case, only the OWF developer could be the system integrator. However, this will probably not happen until the multi-use revenue exceeds the risks.

It must be noted that several consortia already apply the presented 'evolutionary' approach. Partly, this confirms the viability of such 'stepping stone' strategy, but also it indicates that in practice, the approaches are more blurred than presented in this memo. Within this paper, the differences between the two approaches have been highlighted because it was observed that many stakeholders are firmly focussed on an approach towards their 'perfect' business case, which in light of evolutionary approach is counter-productive.

More productive is the tendency towards various small pilots that are conducted at the moment providing valuable learnings for the techniques that are tested, but also for multi-use in general.

One of the setbacks of the 'evolutionary' approach is that it does not affect dealings with government legislation uncertainties. The road towards multi-use exploitation still depends on governmental permits, and it is not given that the government will authorise the multi-use pilots of the 'evolutionary' approach. Therefore, it is not guaranteed that the 'evolutionary' approach is feasible in each case. According to this research, smaller steps are more feasible, and uncertainties will be mitigated. These findings suggest that smaller pilots will, therefore, be authorised more easily than the 'revolutionary' projects.

8 CONCLUSIONS

This article described the background and the current approach of multi-use development. The reflective results of the TA conclude that the government and several multi-use initiators are currently aiming for a ‘perfect’ multi-use business. This ‘revolutionary’ approach has reached an impasse. This research found that there are blocking points in the current approach towards ‘perfect’ multi-use projects:

- Competitiveness
- Separated approach
- Valley of Death
- Waiting game

The difficulties mentioned above have shared triggers, namely exploitation uncertainties, economic risks and governmental knowledge gaps. These are the leading causes that impede further multi-use development.

This research explored how alternative pathways could reach multi-use exploitation. Therefore, this research compared the multi-use challenges with the BwN development approach. This approach has proved its effectiveness in several integrated civil engineering projects over the last decade. The BwN philosophy is facing similar difficulties and therefore inspires the current multi-use case. Continuous improvement and the ‘’learning by doing’’ approach could be a workable alternative for multi-use exploitation. Therefore the following lessons learned from the BwN are useful to create a mindset for an alternative approach:

- By executing pilot projects, the exploitation uncertainties will be better observable and manageable.
- Frequent monitoring and adaptive management will create transparency and new knowledge under the stakeholders, which could increase the positive mindset towards the new technology.
- Robust design to safeguard knowledge gaps is useful to reassure that other stakeholder will cooperate in the development.
- Valuation of co-benefits and linking those co-benefits to stakeholders could increase the stakeholder's willingness to invest in multi-use projects.

The lessons learned, combined with the reflective results of the TA, are used to explore an alternative approach to reach multi-use development. The BwN approach proved that an incremental approach with continuous improvement and a positive mindset could work in integrated projects. Besides, the TA found that the current dilemmas are blocking further development of multi-use. Therefore, an alternative approach is needed for further development of multi-use projects. BwN taught us that an ‘evolutionary’ approach is more realistic for project development than the current ‘revolutionary’ approach.

The ‘evolutionary’ stepping stone approach proposed in this research suggest that a multi-use project should follow an incremental approach to overcome the uncertainties and dilemmas of multi-use development. Consortia should be formed, and small pilots should be implemented to reduce exploitation uncertainties. Valuating the positive effects and linking these stakeholders could help the projects to scale up. With small successful pilot projects, the general mindset will increase positively, and more significant pilots could be implemented. Measurements and adaptive management towards the pilot projects will safeguard the risks and could lead to new technologies. This continuous cycle of implementing, adapting and improving could lead to massive scale multi-use exploitation in offshore wind farms.

RECOMMENDATIONS

Further research is recommended towards the position of companies within the multi-use consortia. Additional research is needed to determine the value of multi-use because it can motivate the stakeholders to choose for cooperation.
Potential subsidies and pull factors of the government should be examined to tackle the valley of death.
Multi-use is not necessarily bound to OWF. It could be used for other parts of the North Sea. Besides, this research is focussed on the Dutch North Sea while other pressurised seas could also benefit from multi-use functions. Further research is recommended to

multi-use in other areas.

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