Risk Management in Offshore Wind Farm Development

Master's Thesis in the Master's program Design & Construction Project Management

ERIK AHLGREN
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Department of Architecture and Civil Engineering
Division of Construction Management Click here to enter text.
CHALMERS UNIVERSITY OF TECHNOLOGY
Master's Thesis BOMX02-17-61
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Cover:
Picture of jack-up vessel erecting a turbine tower. Source: Offshorebiz, 2016.
Department of Architecture and Civil Engineering
Göteborg Sweden, 2017

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ABSTRACT

In addition to wind energy being a carbon dioxide and fossil free energy production, the main benefit with offshore construction as opposed to onshore is more frequent and stronger winds, which of course means a higher energy production. There are however also some disadvantages, building offshore is complex, cost intensive and is associated with more risks than onshore construction.

The purpose of this thesis was to identify the major risks in offshore wind farm development and to unravel how those risks are controlled. Furthermore, the thesis aimed to investigate how the offshore wind farm industry is working with risk management and to provide suggestions for improvements by researching existing theories on risk management. Lastly, the Swedish offshore wind farm development as well as the potential risk reduction of building offshore wind farms in the Baltic Sea will be analyzed. To achieve the purpose, a case study on the offshore wind farm, Rødsand 2, was conducted where several of the actors involved in the project were interviewed regarding which risks they were exposed to and how those risks were controlled. The risk management plan used by E.ON for this particular project was analyzed and compared with existing theories on risk management.

The results from the study shows that the major risks with offshore wind farm development is connected to weather and seabed condition. Furthermore, it is concluded that risk management is an area in offshore wind farm development which is taken very seriously and given a good amount of resources. The risk management plan as well as the risk management process used in Rødsand 2 follows a general approach to risk management and relevant tools and methods were used. There are however a few aspects which could be improved. The emphasization on positive risks needs to be given more resources, risk response plan should be considered in an earlier stage of the risk management process and the risk management plan should be more tailored to the industry it's used in. Lastly, it's concluded the building wind farms in the Baltic Sea is associated with less risk than building in, for example, the North Sea.

Further research should focus on investigating the advantages and disadvantages of using a partnering contractual approach with cost-plus contracts between developers and subcontractors. This would mean a significant increase of the developer's risk, but could have positive effects by lowering risk premiums, increasing quality and improving the transparency between client - contractors which could be beneficial in for example the risk identification phase.

Key words: Risk management, offshore wind farm, Rødsand 2, Baltic Sea, offshore construction

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Contents

Preface

This thesis has been conducted at the Department of Architecture and Civil Engineering, Chalmers University of Technology, during the spring term of 2017. Several persons have help with the progress and should therefore be acknowledged.

First, we would like to thank our supervisors Christian Koch & Alexandre Mathern for the great support during the time it has taken for us to write this thesis. You have provided us with great feedback and insights which has strengthen this thesis and developed our critical thinking.

Second, we would also like to give a big thanks to all of our interviewees who generously spend their own valuable time to participate and contribute to this thesis. Thank you for the interesting conversations and discussions.

And finally, since this thesis is our last effort of our Civil Engineering education, we would like to thank Chalmers University of Technology and all the teacher we have had during our years as students. Thanks for providing us with a high-quality education and for being a big part of our lives.

Gothenburg, June 2017

Erik Ahlgren & Edis Grudic

Figures

Tables

1 Introduction

1.1 Background

In addition to wind energy being a carbon dioxide free and fossil free energy production, the main benefits with offshore construction as opposed to onshore is more frequent and stronger winds, which of course means a higher energy production (Ng & Ran, 2016). Building offshore also allows for installation of bigger turbines since the size of onshore turbines is limited to what is possible of transportation on the roads. Furthermore, offshore wind farms do not affect the aesthetics of the landscape, or bother the public with noise pollution or cast shadows to the same extent as onshore turbines. And lastly, a large proportion of a country's population tends to live close to the coastal line, which means that their energy demand can be produced locally (Haluzan, 2011).

There are however also some disadvantages, building offshore requires several custom built offshore construction vessels, huge foundations that should be attached to the seabed and the constant risk of being delayed due to harsh weather condition. When the turbines are operational there is also a need for continuous service and maintenance which itself is expensive due to it takes place offshore (Ng & Ran, 2016). The aforementioned factors make the offshore construction, not only more complex and cost intensive, but also riskier than onshore construction.

Sweden is behind some of its neighboring countries when it comes to energy production from offshore wind. The reason for that is mainly because the subsidies for renewable energy production in Sweden is the same for all renewable sources, regardless if it is solar power, hydropower or onshore wind. And as mentioned before, building offshore is more expensive than onshore, and it is difficult to get the investment profitable. Another reason stems from the fact that Sweden already gets around 50 % of its energy from hydropower and biomass (Energimyndigheten, 2016). This means that Sweden has already met the EU 2020 goal of 20 % renewable energy and on top of that, Sweden is a net exporter of energy (Dolff et al, 2014). However, the Swedish government has set a goal of 100 % renewable energy by 2040 (Regeringen, 2016) and the aforementioned arguments do not consider long term energy balance. If Sweden is to be able to reach the goal of 100 % renewable energy and be able to cope with both aging nuclear plants and an increased energy consumption from, for example, electric cars, offshore wind has to be a part of the solution (Dolff et al, 2014).

There are some aspects that indicate that a development in the Baltic Sea on the Swedish east coast could be associated with reduced risks, as opposed to other seas such as the North Sea, as opposed to other seas such as the North Sea (Malmberg, 2012). The Baltic Sea is a regarded as an inland sea, which means that weather condition in regard of waves and storms are reduced. The reduced saltwater level of the Baltic Sea also decreases the wear on components which increases the lifespan of wind turbines or reduces the construction costs.

1.2 Purpose

This thesis aims to identify the major risks in offshore wind farm development and unravel how those risks are controlled. Furthermore, the thesis aims to investigate how the offshore industry is working with risk management and to provide suggestions for improvements by researching existing theories on risk management. Lastly, the Swedish offshore wind farm development as well as the potential risk reduction of building offshore wind farms in the Baltic Sea will be analyzed.

1.2.1 Scope

This thesis focuses on financial risks. The thesis will not address the part of risk management concerned with health, safety and environment, though it might be discussed to some extent since the two areas are overlapping.

Furthermore, the thesis will focus on the risks associated with the offshore construction work. Including preparation of seabed, installation of foundations, installations of cables, and transportation and erection of wind turbines and their support structure.

1.3 Method

1.3.1 Research approach

Since the problems with risk management in the offshore wind farm industry were unknown when the research began, this thesis used an abductive research approach. An abductive research method allows theory and empirical research to develop simultaneously (Dubios & Gadde, 2002), which means that the theoretical framework was developed and changed to complement the empirical findings.

To reach the aim/objective, this research began with a literature review on risk management. The literature research focused on general risk management, risk management in the construction industry, offshore industry and wind industry. The research was conducted on Google Scholar and Chalmers library using keywords such as; risk management, construction industry, offshore, offshore wind farms, offshore construction, risk management in the offshore oil & gas industry. A thorough research was made on the risk management process (RMP) found in the Project Management Book of Knowledge (PMI, 2013). That RMP was chosen due to it being a general and widely acknowledged risk management plan.

The theoretical research served, both as a background to the interviews, and as a comparison to the empirical findings. The theory was continuously updated and developed as the empirical results asked for more background.

The empirical research was based on interviews with professionals from different actors involved in the construction of the offshore wind farm Rødsand 2 in Denmark. As stated in the scope, focus was on the offshore construction work, which is why three actors performing work offshore in Rødsand 2 were interviewed. An additional three interviews were held with professionals not involved in Rødsand 2, who after both theoretical and empirical research, were deemed necessary to be able to give a valid view of how the industry is working with risk management.

As a complement to the empirical research conducted in this thesis, already existing empirical research was analyzed. On recommendation from thesis supervisor, the work of (Gerdes, 2010) and (Thomsen, 2014) were reviewed.

1.3.2 Empirical study

1.3.2.1 Selection of case study project

To get an overview of which potential case-studies existed, *table 1,* was created. *Table 1* consist of all offshore wind farm projects in Germany, United Kingdom, Denmark and Sweden commissioned within the last 10 years and with a total capacity over 200 MW. One exception on the list is Lillgrund which has a capacity of 110,4 MW, but since it is Sweden's largest wind farm an exception was made, more as an interesting comparison rather than a potential case study.

Table 1: Offshore wind farms in Europe. (Scource: 4C Offshore, 2017-03-03)

Name	Sea	Commission year	Number of turbines	Capacity (MW)	Foundation	Distance to shore
Germany						
Amrumbank West	North Sea	2015	80	302	monopile	40 km
Bard offshore 1	North Sea	2013	80	400	tripile	101 km
Borkum Riffgrund	North Sea	2015	78	312	monopile	54 km
Butendiek	North Sea	2015	80	288	monopile	32 km
Dantysk	North Sea	2014	80	288	monopile	70 km
EnBW/Kriegsflak	Baltic Sea	2015	80	288	monopile/jacket	32 km
Global Tech 1	North Sea	2015	80	400	Tripod	115 km
Meerwind syd/ost	North Sea	2014	80	288	monopile	53 km
Nordsee ost	North Sea	2015	48	295,2	jacket	57 km
Sandbank	North Sea	2017	72	288	monopile	90 km
Trianel Windpark Borkum	North Sea	2015	40	200	tripod	45 km
Veja Mate	North Sea	Construction	67	402	monopile	95 km
Wikinger Offshore	Baltic Sea	Under construction	70	350	Jacket	35 km
Denmark						
Anholt	Kattegatt	2013	111	399,6	monopile	15 km
Horns rev 2	North Sea	2010	91	209,3	monopile	31,7 km
Rødsand 2	Baltic Sea	2010	90	207	gravity base	8,8 km
Horns rev 3	North Sea	Pre construction	49	406,7	monopile	29 km
Sweden						
Lillgrund	Oresund	2007	48	110,4	gravity base	11,3 km
United Kingdom						
Greater Gabbard	North Sea	2013	140	504	monopile	36 km

Gunfleet Sands	North Sea	2010	48	172,8	monopile	7 km
Gwynt y mor	Irish Sea	2015	160	576	monopile	16 km
Humber Gateway	North Sea	2015	73	219	monopile	10 km
Lincs	North Sea	2013	75	270	monopile	8 km
London Array	North Sea	2013	175	630	monopile	20 km
Ormonde	Irish Sea	2012	30	150	jacket	9,5 km
Rodin Rigg	Irish Sea	2010	58	174	monopile	11 km
Sheringham Shoal	North Sea	2013	88	316,8	monopile	23 km
Thanet	North Sea	2010	100	300	monopile	12 km
Walney phase 1	Irish Sea	2011	51	183,6	monopile	14 km
Walney phase 2	Irish Sea	2012	51	183,6	monopile	14 km
West Duddon sands	Irish Sea	2014	108	389	monopile	15 km
Westermost Rough	North Sea	2015	35	210	monopile	8 km
Burbo Bank Extension	Irish Sea	Under construction	32	254,2	monopile	6 km

As apparent from the table above there are three projects highlighted. The common thread between the three is the following; Commissioned within the last 10 years, total capacity over 200 MW and lastly, built in the Baltic Sea. As stated in our objective the results from this thesis should be able to benefit the Swedish development of offshore wind farms, which is why the Baltic Sea was chosen as a criterion. The reason for the 200 MW criterion derives from the fact that a larger project comes with higher risk which makes such project more likely to have a proper risk management plan. The reason for choosing three instead of one is simply because of the risk of not being able to establish contact with the project developer. Of the three highlighted projects, E.ON agreed to participate in this thesis, thus Rødsand 2 was chosen as case study.

1.3.2.2 Interview Process

In this thesis we conducted several interviews, both with professionals involved in the development of our case study project and professionals connected to either risk management, offshore wind farm industry, or both. The objective of our interviews was to gather specific information about the offshore wind farm industry regarding risk management and the industry in general. During our interviews, we also wanted to be open to potential issues the interviewees had experienced when working with the topics. To obtain both information about specific topics and issues that the interviewees had experienced, we prepared structured, predefined questions and at the same time tried to be open minded and follow up on side tracks. To achieve this, we used a semi-structured interview technique which combines a structured and unstructured format. One of the difficulties with the unstructured part of interviews is the risk of influencing the participants' answers with our own preconceptions (Wilson 2014). To work around this dilemma, we tried to avoid asking specific questions about known problems with risk management, but instead tried to direct the interview so that the problems were brought to the surface naturally.

1.3.2.3 Interviewees involved in Rødsand 2

E.ON

Original owner, developer and operator of Rødsand 2.

Representatives:
Anders Ljungman - Project Manager, Rødsand 2(2017-04-03)
Staffan Sjölander - Risk Manager, Rødsand 2(2017-03-03)

A2SEA

Responsible for the transportation of the turbines from the Nyborg harbor to the offshore site.

Representatives:
Niklas Peter Karlsson - Director, Head of Marine Standards & Operations.
Tony Millward - Vice President, Head of Tenders & Contracts.

Peter Madsen Rederi

Responsible for trench digging and backfilling of the offshore grid cables and the export cables, installation of scour protection.

Representative:
Henrik Sandberg - Marine superintendent.

Aarsleff & Bilfinger Berger

Responsible for design, production and installation of gravity based foundations.

Representative:
Florian Koch - Quality assurance, health, safety and environment engineer.

1.3.2.4 Interviewees not involved in Rødsand 2

DNV- GL

DNV- GL, Renewable Certification was interviewed because they provide project certification services to offshore wind farms as an independent and accredited third-party unit. This service is common, which gives investors, project owners and other stakeholders in such projects, a form of security. DNV- GL was not a part of Rødsand 2. They also provide marine warranty survey services.

Representative:
Fabio Pollicino - Global Service Line Leader for Project Certification.

Vattenfall - Taggen wind farm

We conducted an interview with Vattenfall to get a better understanding of why the development of offshore wind farms in Sweden is staggering and what should be done for it to start.

Representative:
Göran Loman - Project manager at Taggen offshore.

NCC Heavy industries

NCC provided insight of how risk management is conducted in onshore wind farms as well as for other energy producing utilities, such as combined heat and power plants.

Representative:
Ola Daleke - Manager Heavy Industry, NCC Infrastructure.

1.3.3 Analysis/Conclusions

In the analysis, the empirical findings were compared to the theoretical research. Risks that were identified during the interviews and, especially, the actions and decisions made as a response to those risks were compared theory on the matter. This was done to investigate how the risk response and certain decisions affected the overall risk in the project and if anything could be improved by learning from theory on the subject. Furthermore, a comparison between the RMP used in Rødsand 2 and the RMP provided by the PMI was conducted. This was done to investigate how the risk management process, used in Rødsand 2, stood against an acknowledged RMP and if it could be improved by learning from theory. The analysis resulted in a few suggestions of improvement, which are presented in the conclusion part.

2 Offshore wind farms

This chapter is more of a general, technical chapter to provide the reader with appropriate information about wind turbines, offshore wind parks, foundation types but also about the installation process, substations, cables, vessels and show how it is all connected. The point is to present the whole process so one can be familiar and further understand the complete installation, and what problems that can arise when building offshore wind farms.

2.1 Wind turbine

A turbine is a device with blades that can transform kinetic energy from wind to electrical energy. A wind turbine consists of a Nacelle, tower, substructure and a foundation, see figure 1. The nacelle is what covers the turbine and all its components, and is seated on top of the tower. The tower's function is basically to add height so the turbine, where the wind generally is stronger. The substructure connects the tower to the foundation and supports the tower. The foundation is the load bearer and stabilizer of the wind turbine (Kaiser & Snyder, 2012).

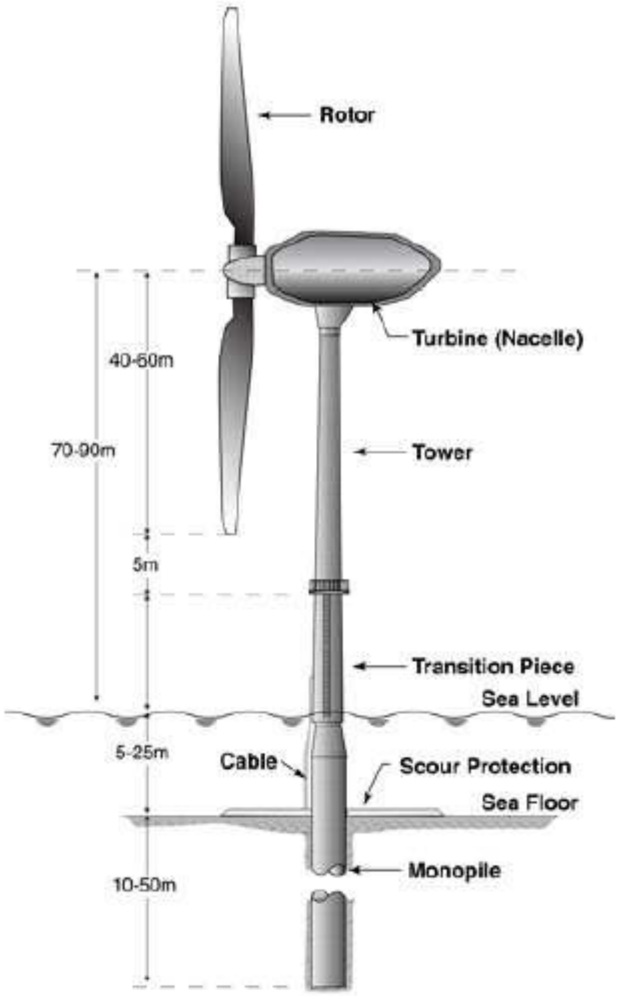


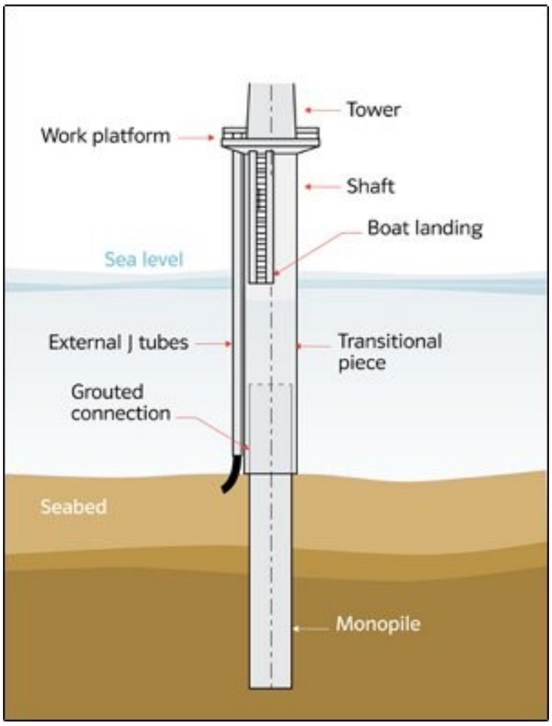
Figure 1: Wind turbine components (Source: Malhotra, 2011)

2.1.1 Foundations

Foundations exist in many shapes and sizes. The four most common foundation types are monopiles, jacket, tripod and gravity foundations (Thomsen, 2014). Which type of foundation and which size that is suitable depends on external factors such as maximum wind speed, water depth, height of waves, and seabed properties (Kaiser & Snyder, 2012).

The most used foundation for offshore wind farm installations are monopiles and they account for almost 75 % of all wind farm foundations (Sovacool et al, 2016). The monopile has a simple design and is made of a cylindrical steel tube, see figure 2 (4coffshore 2013). A monopile should be driven into the seabed with a hydraulic hammer or installed through drilling. How far the pile is driven into the seabed depends on the environmental conditions, but mostly the hardness of the seabed. A too rough seabed can cause deformations on the steel piles during installation. The monopiles are mostly suited for water depths up to 25 meters (Zhang, 2016).

The Jacket foundation is a three or four-legged structure mostly used for oil platforms and the second most used offshore foundation (Zhang, 2016). There are piles in each corner of the structure, connecting the foundation to the seabed, see figure 2. The loads are transmitted in axial direction through the components, which makes the structure stiff and more durable to tidal waves and loads compared to monopile foundations. The foundation is relatively light but can still cover deep waters up to 50 meters. A downside is that the manufacturing price is high and construction requires more manual work. One of the benefits with a jacket foundation is that the load from waves is low because the area that the waves can hit on is limited. Also, since many oil and gas platforms use jacket structures, this kind of fabrication is available in most places (4coffshore, 2013). The disadvantage is that it is more expensive to construct and maintain than monopiles. This foundation type is suited for water depths of 30 to 80 meters (Zhang, 2016).



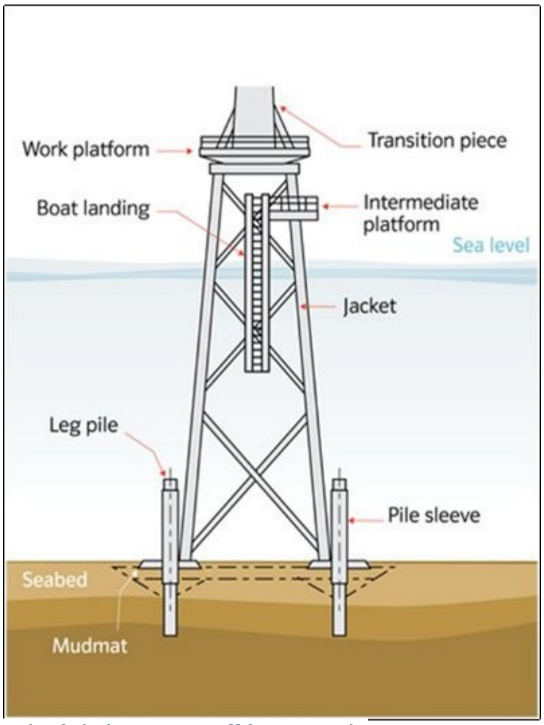
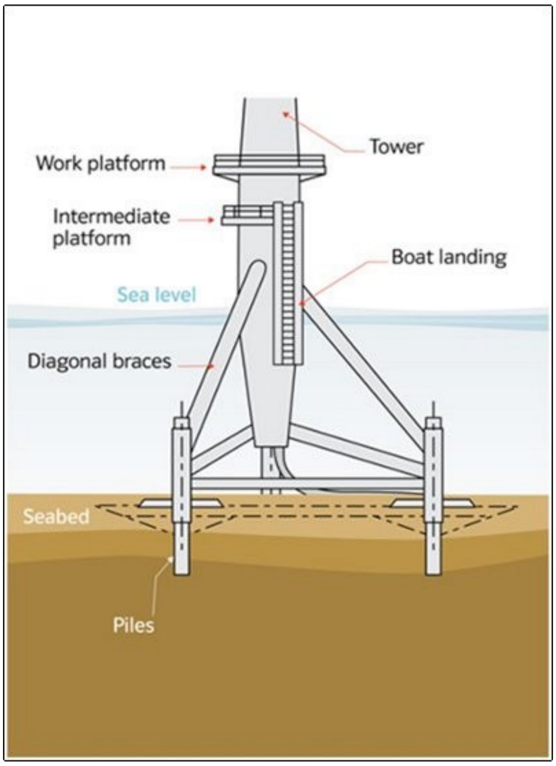


Figure 2: Monopile foundation (left) and Jacket foundation (right), (Source: 4coffshore 2013).

A tripod is a foundation type consisting of three legs and like a jacket foundation because it also has piles that are connected at every leg position and driven into the seabed with a submersible hammer, see *figure 3* (4coffshore 2013). The tripod foundation is more resistant to waves and loads than the monopile foundation. The support structure itself is pre-assembled onshore before it is placed on a vessel, fit to carry it, transported to the location of use and slowly lifted off the vessel and lowered into place (4coffshore 2013). A tripod has good stability, decent stiffness, and is suitable for depths between 25 and 50 meters. These foundations are very expensive because they are difficult to transport, takes much longer to install and construct, compared to monopiles (Zhang, 2016).

A gravity foundation, concrete or steel, is filled with ballast (sand, ore, iron or rock etc.) into the base of the foundation. This makes it relatively heavy, which is good to resist overturning and to support the structure, since it will lay up straight onto the seabed, see figure 3. Gravity base foundations are appropriate for water depths up to 25 meters and when the seabed is stiff. Material is cheap but installation process is expensive and time consuming (Zhang, 2016).



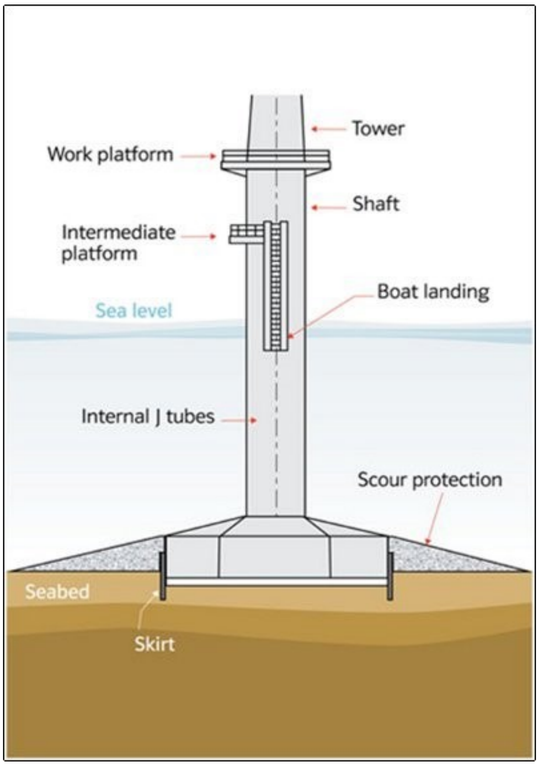


Figure 3: Tripod foundation (left) and Gravity foundation (right) (Source: 4coffshore 2013)

There are more foundation types, but the four mentioned above are the most common ones according to Thomsen (2014).

2.2 Installation

Foundations for offshore wind parks should be transported from harbor to the offshore site (4COffshore, 2013). As explained above, foundations are different in terms of size and weight, and thus the convenient transportation method might vary. If the foundation is heavy, it might be floated into position, like for some gravity based types, or it can be transported with a barge. In some cases, the foundations are lifted from harbor, and placed onto Vessels, big ships, and transported out to site, where cranes can lift them off the vessels (4COffshore, 2013).

At the offshore location, the actual installation method also differs from project to project. Monopiles are driven into the seabed with a hydraulic hammer. Here, the foundation is driven into the seabed and stays in place by cohesive forces, see figure 2, above. Jacket and tripod foundations have a similar installation process, because they both have piles in the corners that are driven into the seabed, and connect the foundation to the seabed, see figure 3 (4COffshore, 2013).

To install gravity based foundations, the seabed should be dredged and backfilled, so that the topography is horizontal during installation, and afterwards the foundation is placed on top of the seabed and filled with ballast, making it heavy and non-movable. The backfilling is put around the base of the support structure to mitigate instability by keeping the waves from eroding the seabed, see figure 3 (Kaiser & Snyder, 2012).

Vessels themselves can have cranes pre-installed, but since it must be able to keep balance while lifting foundations at sea, these are heavily restricted in terms of lifting capacity (Ng & Ran, 2016). Considering how turbines get bigger and bigger, larger cranes will ultimately be needed. The most common used vessel for installations today are Jack-ups, which is a vessel that has movable legs and that can lift the hull above sea level. This gives the vessel a stable ground to stand on, and makes it less affected by weather, such as high waves and strong winds, see figure 4.

Figure 4: Jack-up rig/Jack-up vessel (Source: Offshorebiz 2016)

2.3 Wind farm Layout

A wind farm, or wind park, is turbines grouped up in an area. An offshore wind farm is usually placed close to coastlines, because of easier access and installation, but also in locations where the wind speed benefits the park.

Foundations are installed at first, before the tower and turbines can be put in place. Afterwards, dredging or excavation vessels are used to dig lines underground for where the cables are to be laid. After cable installation, the excavations are backfilled with soil to ensure that the cables will not be open to external damage, such as anchors from vessels. The cables at one end are connected to the generator where electricity is created. On the other end, cables are connected to an offshore substation, where electricity is converted from direct current to alternating current. From the offshore substation, the electrical energy is transferred to an onshore substation via additional cables, before it is directed to the main network and finally distributed to homes, see figure 5. The cables are normally buried 1 to 2 meters below seabed, and depending on the project size and distance to shore, the total length of cables can vary up to hundreds of kilometers (Ng & Ran, 2016).

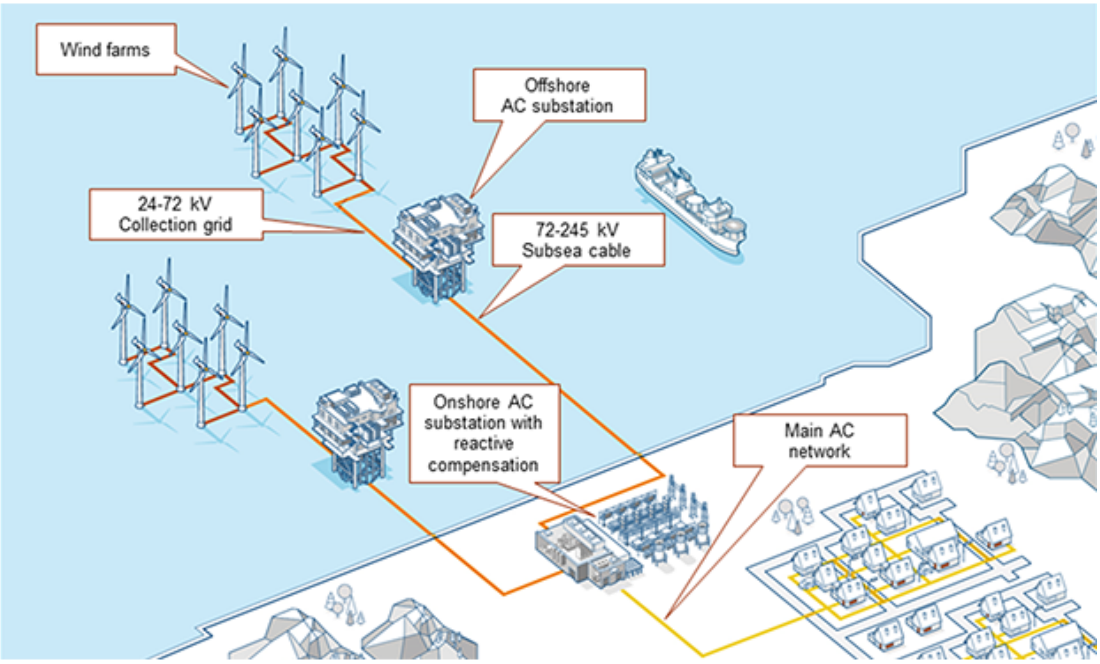


Figure 5: Offshore wind farm layout (Source: ABB)

2.4 Development process

According to Gerdes et al (2010), the offshore wind farm industry operates under seven main steps that should be performed and followed during the planning and realization of a wind farm, for the projects to be successful. The steps are:

Pre-project planning
Detailed project planning
Production of wind turbines and foundations, and procurement
Engineering, testing, installation and commissioning
Full operation

Repowering
Dismantling

The following sub-chapters will represent a short description of the general views of Gerdes et al. (2010), and their thoughts on the development process for offshore wind farms.

2.4.1 Pre-planning and detailed planning

The first phase consists of early project planning and analysis of wind farm locations (Gerdes et al., 2010). The point is to find suitable locations, where extensive conflicts that would affect projects, can be avoided. In most cases, not only one suitable location is found but many, so the data is valuable for future projects as well, giving the government a chance to plan further. The desirable site should have the absolute minimum impact on nature and environment, and provide the developing company with a high degree of planning safely. Involving stakeholders and media here is a great way of dealing with conflicts early instead of later, especially in case resistance occurs towards the project. Also, quality test controls would be beneficial, in this case testing of a wind turbine, the service and maintenance of all wind turbine components included, as well as make sure that the site is reachable. Work packages are to be figured out and tried before the production and erection of the wind turbines would be started, to ensure that the project is feasible.

2.4.2 Procurement and contracts

The common contracting principles in the offshore industry, is either a multi contractual approach or an EPC (engineering, procurement, construction) contract (Gerdes et al., 2010). An EPC contractor must deliver the project in time and budget, and bears all risks and warranties. The contractor can then place orders with other subcontractors, as well as try to transfer risks and responsibilities on others. In a multi contractual approach, the developer divides the scope into packages which are outsourced to contractors and suppliers.

EPC contracts are therefore more trivial and safer for the developer, which could be beneficial if the internal experience is low. EPC contract providers are required to take on all installation risks as well as risks related to uncertainty, such as bad weather, i.e. a turnkey contract. This contract reduces the project risk for the developer significantly, but of course adds a huge risk premium to the project cost. There are few contractors who would accept the risk of being responsible for a whole offshore wind farm so there is a risk that competition would be lower which also adds to the project cost. A multi-contractual approach means that the developer takes a bigger risk and is responsible for several procurement processes. The upside is that although the risk for individual contractors will be lower, the competition for the different packages will be higher, which will reduce the project cost (Gerdes et al, 2010).

2.4.3 Quality control and grid connection

Early maintenance, repairs and improvements that must be done on installed turbines, are five times as expensive offshore compared to onshore (Gerdes et al., 2010). This creates a bigger pressure on early quality control, to mitigate the risk of having to deal with these problems since the process can be more cost effective. The more tests manufacturers can perform that could be evident to minimize problems, the better predictions and improvements can be made, and thus cost savings. As mentioned before, turbines and towers are getting larger by the year. This is becoming problematic since quality controls become harder to perform in labs for instance when the blades are getting bigger. In addition, one time consuming task in the offshore industry is the laying of cables for the grid connection. The process is massively restricted to powerful tidal currents. The planning of cable laying should be performed long ahead of schedule, and must take the risk of bad weather into account. The industry is in a great need of experienced project managers, that can foresee the typical weather risks, and plan appropriately. A common mistake is to think of only tidal waves as the unwanted factor, but wind is also a problem. Wind turbines are designed to catch wind, but the only time this is not wanted is during installation (Gerdes et al., 2010).

2.4.4 Economy

The distance from an offshore wind farm to land is the most vital part for determining the cost benefits of a project (Gerdes et al., 2010). As previously explained, the distance can vary a lot. Considering that laying of cables is a time-consuming task, and that weather uncertainty can have great impact on the overall financial situation. In some projects, the connection grid could be paid for by an investor or the government, but if this is not the case then extreme caution is advised in determining whether an offshore site is suitable or not.

3 Theoretical framework

In the following chapter a literature review of risk management is conducted. The aim is to give the reader a fundamental understanding of what risk management is, and how it is conducted. The chapter ends with an extensive presentation of the RMP found in the Project Management Book of Knowledge.

3.1 Risk management

Risk management is a widely researched area within project management, and several research institutes, such as the project management institute and international organization for standardization have their own model of how to manage risks on a project level. The project management body of knowledge (PMBOK) defines the objective of risk management as ".... "....to increase the probability and impact of positive events and decrease the probability of negative events in the project." PMI (2014, 309).

As apparent from quotations, risks can be both positive and negative. Smith et al, (2004) explains that implementation of risk management to avoid downside risks is a good approach to reach project objectives. It should, however, also be recognized as a method to exploit opportunities (Chapman & Ward, 2006). Evaluating risks and determining their probability makes it safer to challenge them and exploit possible positive outcomes (Smith et al., 2014).

In the offshore industry, a positive event could for example be if the weather condition turns out to be better than expected, and the offshore installation process can proceed faster than the initial plan. If this is not recognized in an early stage, the suppliers might not have a sufficient buffer to take advantage of the good weather and the opportunity of jumping ahead of planned schedule is lost (Chapman & Ward, 2006).

Furthermore, Smith et al. (2004) mentions that risk management is not about predicting the future, it is about getting to know your project better and making better decisions. Decisions are a huge part of every construction project, for an offshore wind farm project it can be decisions regarding which foundation type should be used or which capacity the turbine should have. Which alternative one chooses is based on the information available, the problem is that the information available rarely leads to one alternative being 100 percent certain. For example, one can have decades of weather data for a location, but the world is in a constant change so the underlying conditions for that data set is always changing (Winch, 2010 & Smith et al., 2014). Therefor it will always be an element of uncertainty involved in using that data, which imposes a risk for the project.

3.1.1 Risk and uncertainty

Two frequently used terms that recurs in risk management literature is risk and uncertainty and there are quite a few different definitions that explain the same thing. Smith et al 2014 define risk as; "risk exists when a decision is expressed in terms of a range of possible outcomes and when known probabilities can be attached to the outcomes" (Smith et al 2014, 4). They also explain uncertainty as; "uncertainty exists when there is more than one possible outcome of a course of action but the probability of each outcome is not known (frequently termed estimating uncertainty)" (Smith et al 2014, 4).

Cleden (2009) defines risk as "Risk is the statement of what may arise from that [referring to the "don not know" from uncertainty] lack of knowledge" (Cleden 2009, 5). And uncertainty as: "Uncertainty is the intangible measure of what we do not know." (Cleden 2009, 5)

Furthermore, Winch (2017) defines risk as "...where a probability distribution can be assigned to the occurrence of a risk event" (Winch 2017, 348) and uncertainty as "the condition where no such probability distribution can be assigned" (Winch 2017, 348).

PMBOK defines risks as "Project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality. A risk may have one or more causes and, if it occurs, it may have one or more impacts." (PMI 2013, 310)

The common thread between the four definitions of risk and uncertainty mentioned above is that a risk is something known, an event that can be foreseen and the probability of the outcome can either be estimated or not. While uncertainty is an event that we do not know and thus cannot measure. Every risk event is either certain, impossible or somewhere between. Furthermore, there is no risk without uncertainty.

In addition, (Winch, 2017 & Smith et al, 2004) explains that risks can be categorized into four different groups; Known-knowns, known-unknowns, unknown-knowns and unknown-unknowns. Where known-knowns are risks that are identified and a probability of occurrence can be assigned. An example of a known-known is weather data, you know that the weather can cause for example a delay, and in a lot of places in the world, weather data has been recorded for decades, so in most cases a probability of occurrence can be assigned. Known-unknowns is an identified risk to which a probability of occurrence cannot be assigned. Unknown-knowns is when somebody is aware of a risk and the probability of occurrence but keeps that secret. The last one, unknown-unknowns, also known as force majeure, is a risk event which is not identified and thus cannot be assigned a probability of occurrence. Figure 6 shows how risk increases from the decision maker's perspective when events go from certainty to impossibility (Winch, 2017 & Smith et al 2004).

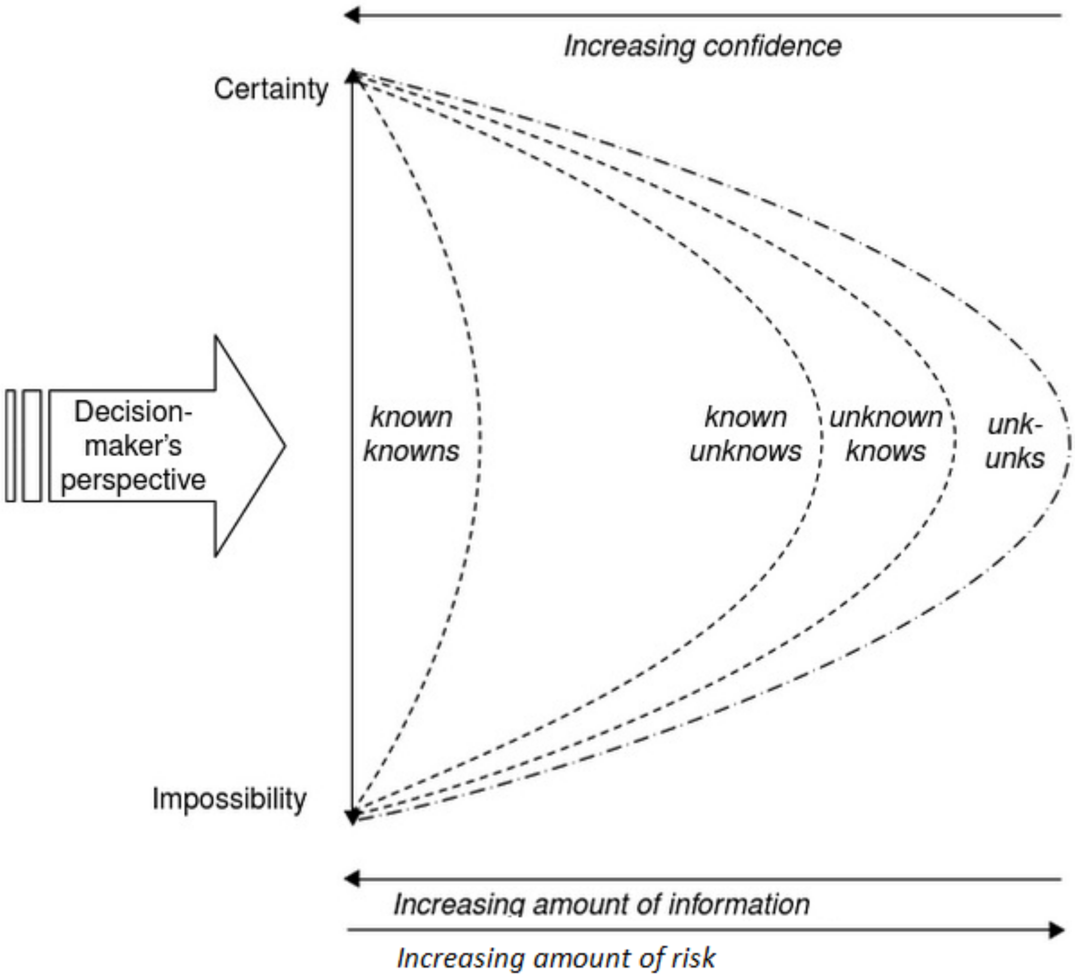


Figure 6: Decision-maker's perspective. (Source: Winch, 2010. Edited by authors)

3.2 Risk management process

The RMP looks different depending on author, but the basic principle for several of the authors researched for this thesis is, however, the same. Winch (2010), Smith et al (2014) & PMI (2013) all have the following steps in their RMP: Identification, analyze/assess, response & control, see figure 7.

Identification - This stage is obviously pivotal for the whole process, if there are no risks there will not be any risk management. The objective is to identify all knowns and put them in a risk register (Winch 2010). This is usually done by relying on experience from staff and stakeholders, through risk management workshops, brainstorming sessions or such. It is important that the group consists of a variety of professionals with expertise from different areas (Smith et al 2014).

Analyze/assess - The purpose of this stage is to analyze the known risks to be able to categorize them. In this stage, a probability of occurrence and impact on project is assessed by using either a qualitative our quantitative assessment.
Response - When the risks are assessed and there is knowledge about the consequences, be it positive or negative, a response to the risk can be planned.

Control - Making sure that the risks are monitored and controlled, keeping track of potential updates relevant to every risk.

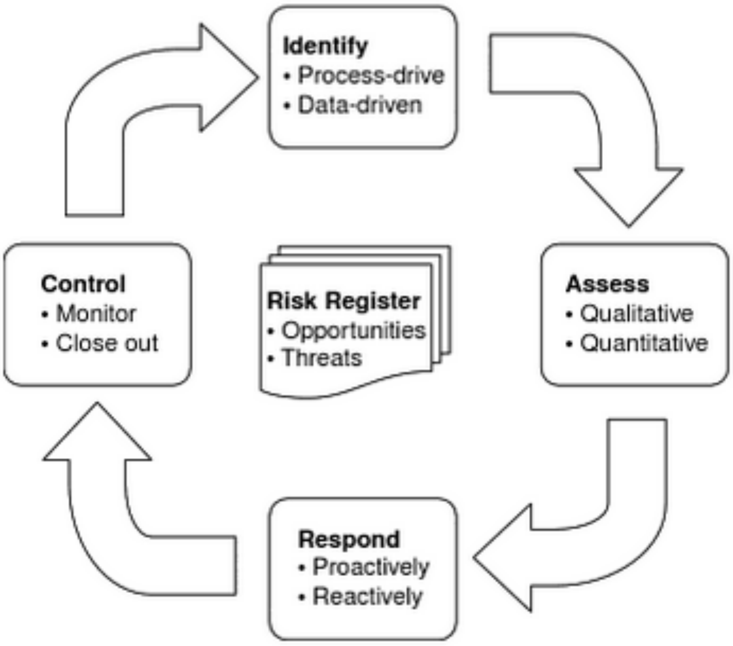


Figure 7: RMP model (Source: Winch, 2010)

Chapman & Ward (2006) say the following about the idea of a formal RMP: "Formality is desirable because it provides structure and discipline, which facilitates efficient and effective risk management" (Chapman, C & Ward, S 2006, 55). They also say that "formality... is about providing a framework that guides and encourages the development of best practice" (Chapman, C & Ward, S 2006, 55). Furthermore, the authors explain that it is important that all organizations that intend to use an existing RMP as a part of every project need to adapt it to suit their industry.

Chapman & Ward (2006) compare different RMPs, such as PRAM, PMBOK and RAMP, and argue that these processes have an important role to play in achieving best practice of work. A good approach for considering the RMPs in any industry, is to start with a general approach to risk management. In addition, they state that "Giving people the comfort that all the key questions have been asked and addressed is the basic rationale of a formal RMP. How they are addressed is orders of magnitude less important" (Chapman 2006, 55).

3.2.1 PMBOK risk management process

The RMPs described in Project Management Book of Knowledge (PMI, 2013) is a five phase plan managing risks in a project, these are: Plan risk management, identify risks, risk analysis, plan risk responses and control risks.

3.2.1.1 Phase 1 - Plan risk management

The first phase includes planning of activities, how they will be structured and performed to oversee risks in the whole life cycle of the project (PMI, 2013). In general, this phase deals with the balance between risks and project importance. The plan is important regarding communication, agreement and support from all stakeholders to ensure that risk management is supported and performed productively over the whole lifetime of the project. The planning phase is also essential to assure that resources are always available, as well as occasions for special activities of risk management. The risk management plan should be rational and conducted in accordance with the supplementary management plans. The more the subsidiary management plans are considered early, the less inconvenience is generated afterwards. Feedback should also be considered, from senior managers, project stakeholders and managers previously involved in similar projects as well as consultants, professionals and technical associations, ensuring a stable foundation for the risk management plan.

A risk management plan according to PMBOK needs to address approaches, tools and data gathering, but also roles and responsibilities in the project, which is needed to implement risk management (PMI, 2013). In addition, the budget is made as an estimation of capital demand, based on needed resources for the project. When and how often RMPs will be executed is predefined into the schedule, and the risks are sorted accordingly to fit certain categories for how risks should be organized. This can be done with a Risk breakdown structure (RBS) and helps the team to consider various sources from where risks may originate. RBS looks different depending on project, but basically the tool consists of a processed list where all risks are designated into categories, see figure 8.

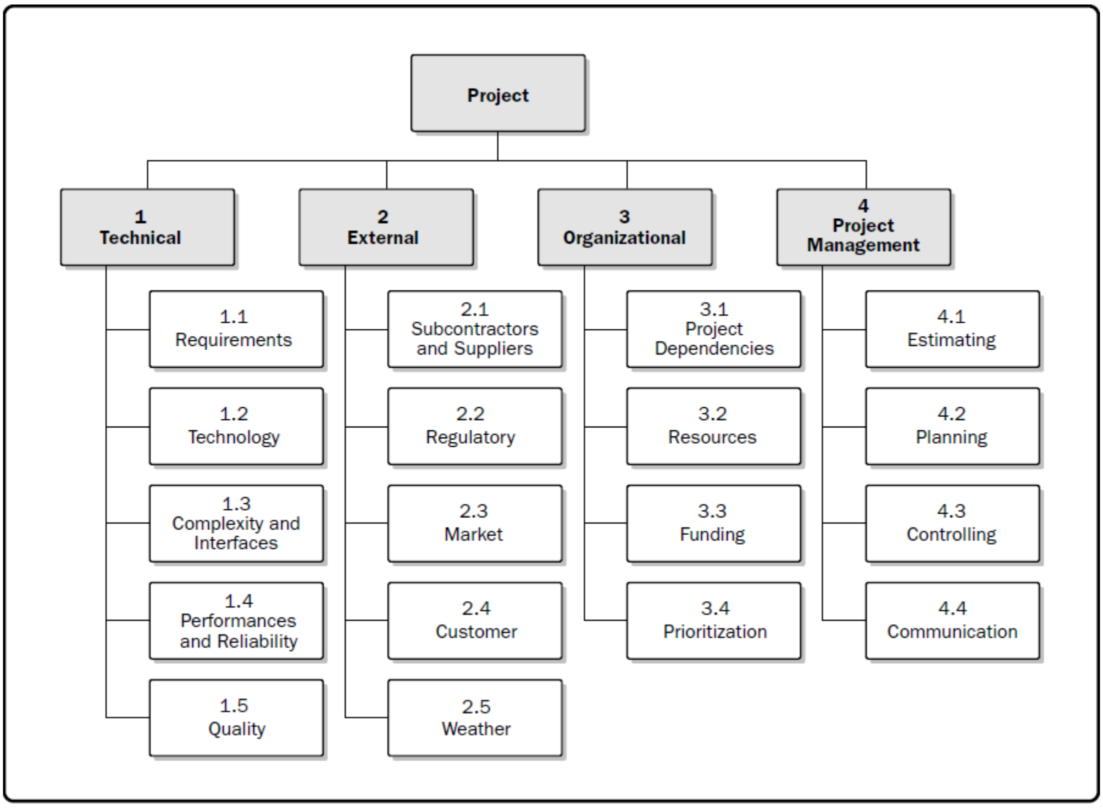


Figure 8: Risk categories (Source: PMI 2013)

For each event, be it negative or positive, there is a certain impact and probability for that event. In the risk analysis, a probability and impact matrix is formed in a grid, where the potential risks are weighted to the effect they could cause on project objectives (PMI, 2013). Organizations usually have a risk threshold, that is, how much risk they can tolerate and how willing they are to accept risks. If a risk exceeds the pre-ordinated acceptance, there is a higher chance that it will impact the project. The tolerance threshold does not only apply to the organization, but the stakeholders as well. The plan needs to include how risks, roles and responsibilities and arrangements of risk management activities between stakeholders, will be shared. The risk breakdown structure is a perfect tool to show how responsibilities will be shared. How each risk is reported is defined in the risk plan, as well as how the content will be documented and analyzed.

3.2.1.2 Phase 2 -Identify Risks

The purpose of the "Identify risks" phase is to find potential risks that might disturb the project and noting the specific attributes these risks have so that they can be anticipated in the future (PMI, 2013). A list of potential risks can be seen in figure 9.

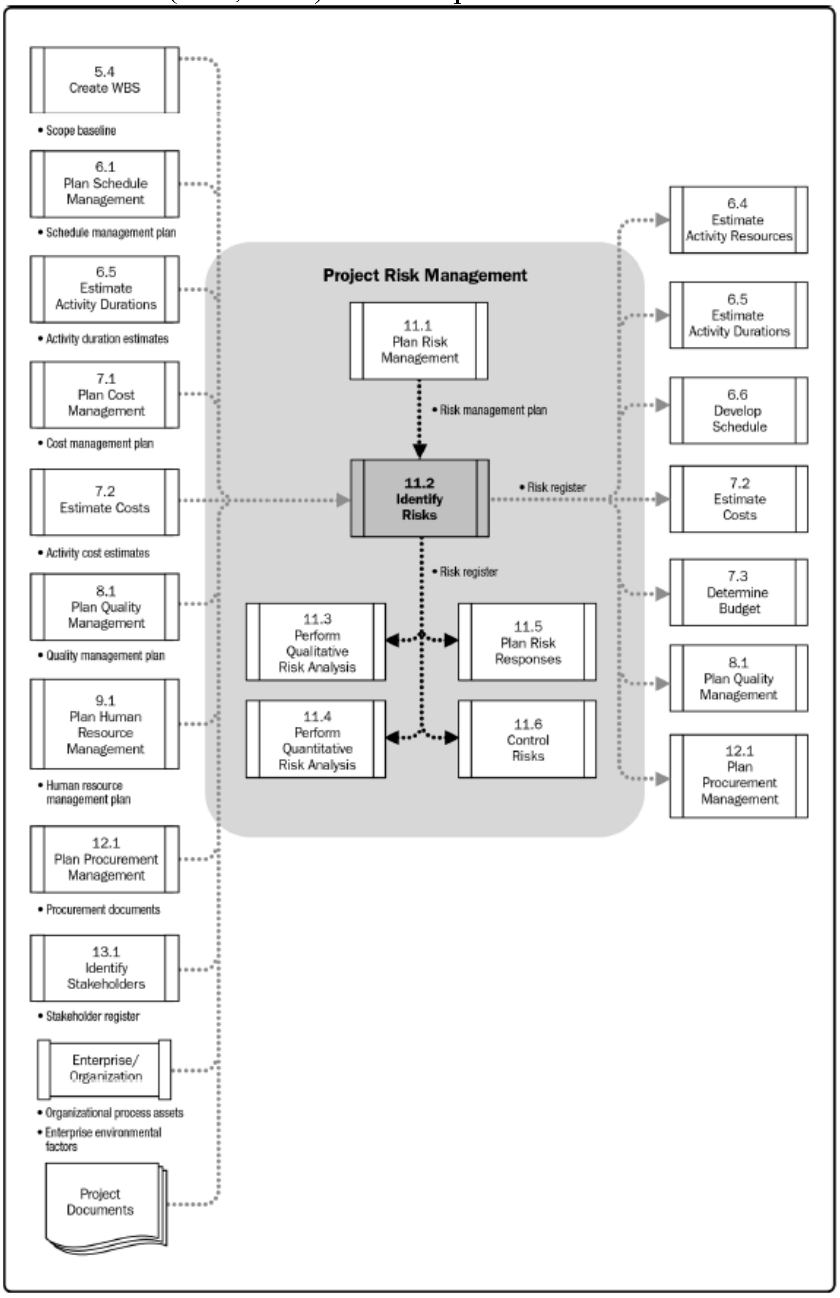


Figure 9: Risk identification (Source: PMI 2013)

Although the list is straight forward, identification of risks is a constant process since uncertainties can turn up at any time during the project. The composition of risks should be ongoing to make sure that all risks are clear and to ensure efficient and consistent response (PMI, 2013). The risks would in this phase be presented with alternatives, making it easy to compare different solutions, impacts and effects against each other. Further development of a project would thereafter be directed according to a company's values and risk threshold.

The cost management plan, which is part of the identify risks phase, consists of measures and actions that can be used to identify risks (PMI, 2013). The schedule management plan is a help for keeping track of time, objectives and possible outcomes of the project. The human resource management plan defines how humans should be managed and put to work, as well as individual responsibilities. The cost estimation and duration of activities is calculated to give a prospect of how much it will cost to complete phases in the project.

3.2.1.3 Phase 3 -Risk analysis

The risk analysis can be explained in two steps, a qualitative risk analysis and a quantitative (PMI, 2013). In the qualitative step, managers can sort out risks that are likely to occur, and thus reduce uncertainty in the project. This is done by prioritizing the risks in relevance to probability of occurrence and impact. The input here comes from chapter 3.2.1.1 and 3.2.1.2, as well as a with a work breakdown structure. Combining these elements would result in the proper project documents that would be used further, see figure 10. The quantitative risk analysis is a more analytical way of working with risks by numerically analyzing consequences with every project objective. The input is similar as with the qualitative risk analysis but with the added exception of a planned cost management.

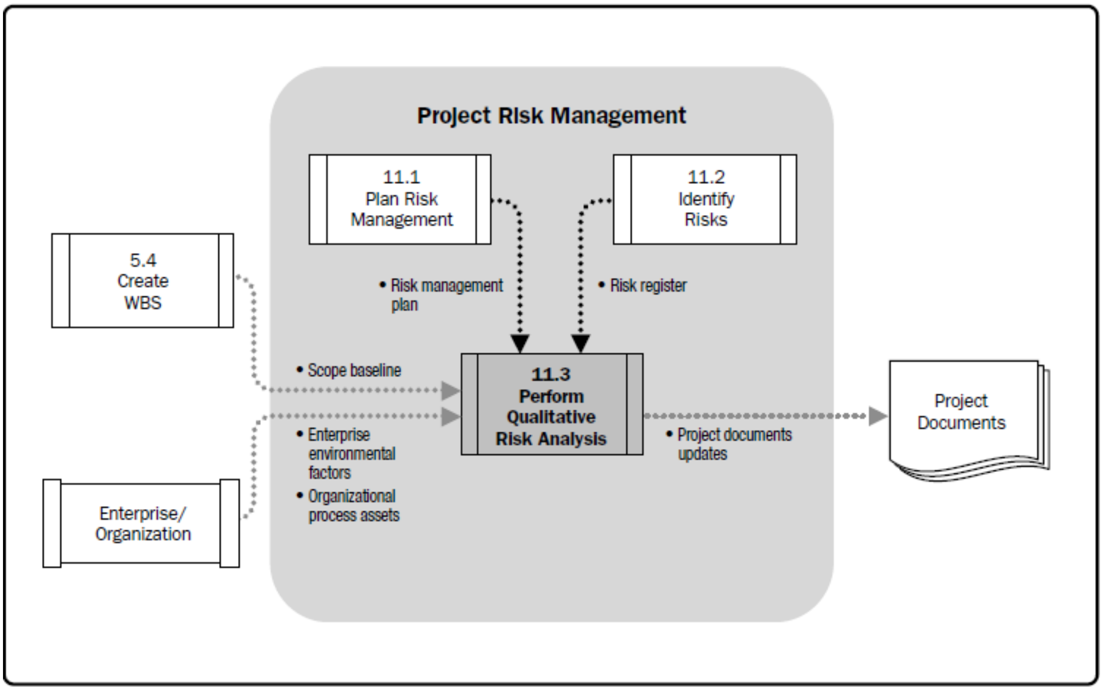


Figure 10: Qualitative risk analysis (Source: PMI 2013)

As explained in chapter 4.2.2.1, an organization's risk threshold and preparedness also plays a huge role for how uncertainties are managed, but also other factors such as scope, schedule, cost and quality (PMI, 2013). If a project is relatively common they tend to have less uncertainty as the risk types have previously been handled, while the newer types of projects, more complex ones, clearly require newer types of analysis performed and thus include greater uncertainty. In general, similar projects tend to be easier to execute since information from older projects can be valid in the future.

Risks are rated in accordance with the description given in the risk management plan, see phase 1, where risks with small importance will be put aside on a “watch list”, or a risk register where it is monitored, while the risks with bigger probability and impact may offer greater benefits and thus should be taken care of first (PMI, 2013). With a probability and impact matrix, and a company’s given ruleset for different risks, the outcome is presented as a number where the higher number means bigger chance, see figure 11. The ruleset here can be seen at the bottom of the matrix, where the span goes from “very low” to “very high”, or with the numerical values of 0,05 to 0,8. The matrix can be used for both negative and positive outcomes. The threshold in this case goes by dark gray for very high probability (N>0.2), light gray for medium probability (0.5<N<0.2) and medium gray for low probability(N<0.5). Information regarding impact and probability are gathered mostly from interviews or experts with previous experience from similar projects. The acceptable level for an organization is reflected on the potential cost estimates, schedule and listed completion dates in coherence with the probability rates.

Probability and Impact Matrix

Probability	Threats					Opportunities				
0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	0.05/ Very Low	0.10/ Low	0.20/ Moderate	0.40/ High	0.80/ Very High	0.80/ Very High	0.40/ High	0.20/ Moderate	0.10/ Low	0.05/ Very Low

Impact (numerical scale) on an objective (e.g., cost, time, scope or quality)

Each risk is rated on its probability of occurring and impact on an objective if it does occur. The organization's thresholds for low, moderate or high risks are shown in the matrix and determine whether the risk is scored as high, moderate or low for that objective.

Figure 11: Probability and impact matrix (Source: PMI 2013)

The data used to examine risks also needs to be evaluated, to see to what extent this data is useful in form of accuracy and reliability (PMI, 2013). The sources for the risks are categorized, as described above from the risk breakdown structure, which helps develop effective ways of dealing with risks. The RBS is a good tool to deal with uncertainty.

The risk register should be kept up to date every time new information is represented, but also assumptions in certain risks might get changed when other data becomes available (PMI, 2013). A quantitative risk analysis can be repeated here to see if the overall project risks have decreased to a more adequate level.

Other form of tools can be the data gathering for cost estimates, which are represented in a range of project cost estimates, to show how much the project can differ in price for the best and the worst-case scenario, for an example see figure 12. Data is mostly gathered through interviews (PMI, 2013).

WBS Element	Low	Most Likely	High
Design	$4M	$6M	$10M
Build	$16M	$20M	$35M
Test	$11M	$15M	$23M
Total Project	$31M	$41M	$68M

Figure 12: Cost estimates (Source: PMI 2013)

A sensitive analysis is used to correlate potential negative and positive impacts to one another. It is useful for comparing variations between risks for the uncertainties in the project objectives (PMI, 2013). One way the sensitivity analysis can be displayed is with the tornado diagram, see figure 13. The diagram is favorable when wanting to compare importance and possible effects from variables that are very unclear.

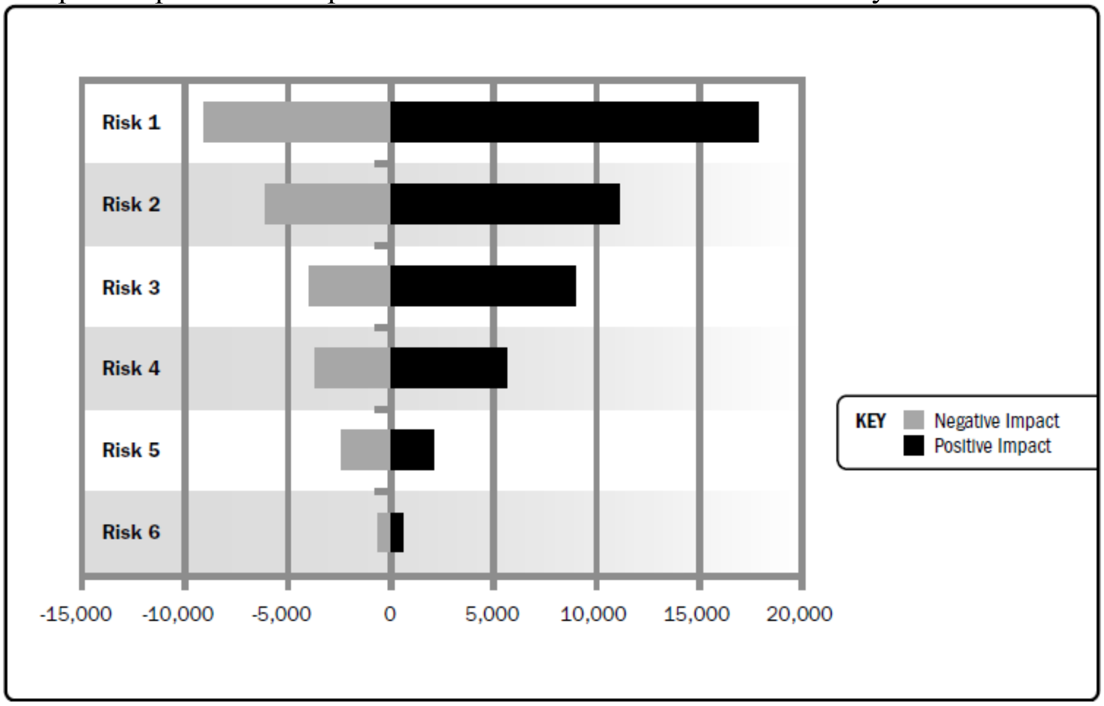


Figure 13: Tornado diagram (Source: PMI 2013)

3.2.1.4 Phase 4 - Plan risk responses

To enhance opportunities and to reduce risks, that is what the plan risk responses is about. In this phase, the appropriate actions are developed, where the schedule, budget and management is adjusted correspondingly, and resources and activities are managed in a way that the organization chooses to address each risk (PMI, 2013). The inputs come from the plan risk management phase, see chapter 3.2.1.1, and the Identify risks phase, see chapter 3.2.1.2, and the risk response is planned to take these inputs into consideration. Subsequently, if the risk analysis process is used it also affects each risk response since the risks must be understood and identified by the person responsible.

The risk register, or watch list as referred to before, comes to use more in this phase where low-prioritized risks become more and more relevant as time passes (PMI, 2013). When these risks become more relevant, they become easier to understand and the effect and response can easier be highlighted.

Many risk responses are available for dealing with risks, where the response which most likely will be effective, is selected for dealing with that risk. A decision tree analysis is a tool that helps sort out the responses, but also in choosing the most fitting response (PMI, 2013). Obviously, the more information that is presented, or the more experience a company has, the less complicated the choosing is between appropriate responses. In addition, a fallback plan is what is referred to as a backup response in case the first response was not fully effective or if one risk that the company chooses to accept, does affect the project.

There are four ways of dealing with negative risks; avoid, transfer, mitigate or accept (PMI, 2013). Avoiding a risk is a strategy in which the company tries to avoid the risk by either eradicating it or protecting the project from the possible impact. It can also include to make changes in the project plan. Another way to deal with risks is to transfer them to another team, including the response the risks bring with themselves. The third option is to mitigate, by which the team tries to lessen occurrence or possible impact the risk can have on a project, so that the company's risk threshold is not breached. The last and by far least favorable strategy is to accept the risk, passively or actively. A passive approach indicates that nothing will be done except that the risk will be documented and followed to secure that it does not get out of control. The team will have to deal with the risk once it occurs. An active approach means that additional time, resources or money will be accounted for to deal with the risk after it occurs.

In the plan risk responses phase the outcome are updated documents showing when appropriate risk responses are appointed and admitted, but also included in the so-called risk register (PMI, 2013). In this register, it is important that the information provided corresponds to the level of detail that coincides with the preference ranking.

There are also four ways of dealing with possible positive risks, namely exploit, enhance, share or accept (PMI, 2013). The Exploit strategy is essential for where the organization wants get rid of uncertainty, and thus ensuring opportunity. This can for instance be done by reducing time for completion with the use of resources of high quality, or with the use of new and upgraded technology to decrease costs. Enhance is used to increase the chance or positive outcomes of opportunities. To identify and boost the most vital parts for success, can increase the chance of a more positive outcome. An example would be to increase the amount of resources for the activity so that the task can be finished sooner. The share strategy is basically to share risk with another party, which is specialized in apprehending positive opportunities, so that all parties gain from their actions. To accept is a strategy that indicates that an organization is enthusiastic to accept opportunities if they arise, but not to seek actively for them.

3.2.1.5 Phase 5 - Control risks

The process of controlling risks is the last step in PMBOK and is the process of actual work being carried out to prevent risks from arising (PMI, 2013). This phase comprises implementation of planned responses to risks, tracking and monitoring continuing risks and checking up on effectiveness of risk processes. Thus, the planned risk responses are carried out but the risk register is still monitored and updated to keep track of new and old risks, but also to get rid of outdated ones.
From this phase, it is evident that risks that a company has been exposed to now can be added to their risk template for future prosperity. But at the same time the effectiveness of previous, actual risk responses, should be noted and compared to planned results. To keep track of time and resource contingencies is also included in the analysis. It is of great importance that risk management is a part of held meetings, because the more often risk is mentioned, the better one becomes at identifying and dealing with them.

As a product of control risk process, the risk register should be updated with new risks, recalculation of probabilities and possible impacts, risk priorities and response plans, as well as risk responsibility, revised control of low-priority risks, time and resource available in case of risk occurrence (PMI, 2013). Any outcomes of risks and planned responses can be evaluated at a project's end, and used to improve upon the risk breakdown structure, the risk management plan template and risk register.

3.2.2 Advantages and disadvantages

PMBOK provides a general description of a RMP, and as said before, can be applied to any industry. In PMBOK, every phase is divided into inputs, tools & techniques and outputs. The input is data that is put into the system and that will be used with the tools & techniques that are explained in each phase. After data has been used and analyzed correctly, the outcome of the process becomes the output, like for instance the "risk management plan" in phase 1 (PMI, 2013). This systematic approach makes it easy to understand the general working ways of PMBOK, because the purpose and structure of each phase becomes very clear (Chapman & Ward, 2006).

The risk management approach by PMBOK is detailed and covers a lot of different topics that should be taken into consideration. The problem, however, is that the authors do not mention repetition of steps except the identification phase, and therefore additional problems that arise would perhaps not be analyzed clearly in other phases (Chapman & Ward, 2006). It is difficult to know how much information that would be applied in different phases. Another example is the emphasis on upside risks, or commonly known as opportunities. There is no precise explanation for how one would emphasize upside risks, or what consequences this could have on the project. Chapman & Ward (2006) further argue that the fourth step, "plan risk response" comes relatively late since PMBOK is presented as a linear process. Therefore, there is no need to separate the identification of risks from response planning, because it becomes ineffective to operate under this paradigm. If the process is linear, it would mean that time would be wasted on issues that might turn out to be less important, and important issues might be left out because they were not foreseen at the beginning. To solve this, an iterative approach would be recommended, where phases are repeated and risks continually updated, developed or reconsidered (Chapman & Ward, 2006).

Another remark can be done on importance of ownership descriptions in a RMP, how the responsibilities are divided between risk managers, risk owners, action owners or project managers (Chapman, 1997). In PMBOK there is no description to who should do what, or any explicit ways of how the risks are distributed in each phase (Chapman & Ward, 2006).

It is further argued that risk efficiency is essential, because a RMP also uses up resources, which can be a risk (Chapman & Ward, 2006). The amount of investments made on risk management, should be explained in form of expected benefit for a project, so that the RMP can be improved as well. In addition, the RMP needs to address risk response planning in PMBOK early, together with the identifying risk phase to increase risk efficiency. Some risks can be filtered and do not have to go through the whole process if it is generally known how that risk can and will be handled. Since we argue for a more formal RMP directed to the industry, the notion of an early risk response planning could save both time and resources. Another process that Chapman & Ward (2006) argue for is a stage called “harness”. The stage refers to the importance of translating strategic risk response plans into tactical response plans which can be implemented in practice.

4 Empirical findings

This chapter will start by reviewing two existing empirical studies on offshore wind farm development to investigate to what extent risks and risk management is discussed by authors with experience from the industry. The chapter will continue with a case study of the offshore wind farm Rødsand 2, and highlight the major risks, and analyze the risk management plan used by the developer E.ON in the project. Finally, two additional interviews, not connected to Rødsand 2, as well as topics discussed during interviews not directly associated with Rødsand 2 will be presented.

4.1 Existing empirical research on the offshore wind farm industry

In the following section, we will review existing empirical research on the offshore wind farm industry to investigate to what extent risk management is discussed.

4.1.1 European Offshore wind farms - A Survey for the analysis of the experiences and lessons learnt by developer of offshore wind farms

In 2010, Gerhard Gerdes et al, published a report called "European Offshore wind farms - A Survey for the analysis of the experiences and lessons learnt by developers of offshore wind farms" where the authors conducted case studies on eight offshore wind farms, both fully commissioned and under construction. As the title disclose the purpose of the report was to evaluate experiences and lessons learnt from offshore wind farm projects in northern Europe with the directive to increase the knowledge for future wind farm projects. There is no mention of risk management in the detailed description of the different stages or the flowchart model. He does however identify that several projects have a collision risk plan, which is referring to the potential risk that a ferry or service boat encounters problems and drifts off course into either a tower or a rotor blade. At another point of his study he mentions risk plan for service technicians when they move from a service boat onto the wind turbine platform. But overall the absence of risk management is imminent.

In the report, Gerdes (2010) mentions that the most common contract form, at the time the report is written, in offshore wind farm development is multi-contractual, which basically means that one entrepreneur is hired for every major part of the development, as opposed to one contractor having a turn-key contract responsible for the whole project. Multi-contractual contracts intend to make every contractor responsible for their own risk, since they know their line of business best they will have less uncertainty than if a contractor from another branch would be responsible. The reduction of uncertainty means a lower overall risk premium for the whole project. Gerdes mentions that the total project sum has been lowered with around 20 per cent for projects using the multi contractual form. This can be pivotal for a project to be realized or not considering that the margin on offshore wind farms is tight.

To sum it up, Gerdes does not talk about risk management plans or methods similar to the one found in general risk management methods such as the PMBOK. He does however acknowledge that managing risk in an early stage is very important for the projects finance and that the choice of contract form can have a big impact on a project's total cost.

4.1.2 Offshore wind - A comprehensive guide to a successful offshore wind farm installation

In 2012 the first edition of Kurt E. Thomsen's book "Offshore wind - a comprehensive guide to a successful offshore wind farm installation" was released. As the title gives away it is a guide for building wind farms offshore based on Kurt's experience gained from 14 years in the offshore business and as one of the co-founders of the Danish offshore installation company A2SEA. The book targets everyone involved in offshore wind farm development, from technician to investor.

In the book, Thomsen (2014) does not discuss any typical methodology to follow when working with risk management, but he does however mention the importance of keeping risks and uncertainty to an absolute minimum, as offshore wind farm projects are very costly endeavors and few companies can finance with own capital. Therefore, most projects are dependent on external investors such as pension funds and banks. What is common for the two last mentioned institutions is that they require a yield with a relatively low risk. Thomsen (2014, 38) writes: "to get a nonrecourse financing portfolio, the project owner must remove the risk from the entire process to as close to the absolute freezing point as possible". With that said, it is obvious that such project needs to take risk management seriously. Later in the text he also mentioned that to get permission to start, insurance companies involved in the project require that uncertainties in the production/transport/erection phase need to be addressed. For example, before any offshore installation can start, a seabed scan should be carried out over the area affected by the installation.

In the text Thomsen (2004) mentions a few risk and uncertainties that can lead to considerable cost-overruns if they occur;

Ground conditions
A problem with the foundation of offshore wind farms is that the sea bed conditions can differ a lot over areas. This means that each turbine foundation should be calculated separately. Sometimes, as in the Baltic 2 project, there is a need for two completely different foundations.
Weather conditions
The common weather disturbances such as wind and waves. Too high waves would require bigger vessels, or create weather downtime. Wind is problematic during the installation of wind turbines, since the rotor blades are designed to catch wind.
Insufficient bearing capacity of sea bed
The seabed has not been analyzed properly and the result being that one or more of the legs of the jack-up rig punch through the soil. This is very serious for the offshore contractor and can be avoided by a core drilling test at every jack-up location, i.e. at every foundation.
Debris on the seabed
Can cause damage to either a jack-up rig or cable plow. Debris can for example be an old wreckage, war mine. Can be solved by a seabed scan.
Material delay
If a supplier does not deliver a critical component on time, it can affect the project in form of delays.
Insufficient area in port
The worst thing that can happen in an offshore wind farm project is waiting for material. The weather is a given obstacle that must be handled, but waiting for materials when

the weather allows for offshore construction is unnecessary, for instance during sunny and calm days. It does not only cost money, but the good weather window might disappear.

4.2 Case study - Rødsand 2

Rødsand 2 is a Danish 207 MW offshore wind farm with a yearly expected production of 800 million kWh per year (Ohlander, 2009). The wind farm is developed and originally owned by E.ON, today 80 per cent of the wind farm is owned by the Danish energy company SEAS-NVE. E.ON won the tender 2008 for the power purchase agreement of 0.629 DKK/kWh. The construction started spring 2009 and the wind farm was fully commissioned the autumn 2010. The construction offshore was delayed due to bad weather during the winter of 2009/2010 but still managed to be finished three months ahead of schedule and 15 per cent below budget (Koch, 2014). E.ON used a multi contractual approach for this project, which meant that the scope of the project was divided into different packages. Some of the packages which were included in the project were:

- Offshore transportation and erection of wind turbines
- Manufacturing and delivery of wind turbines to harbor
- Manufacturing and installation of substation
- Manufacturing and installation of export cables

Figure 14: Rødsand 2 wind turbines (Source: E.ON, 2015).

4.2.1 E.ONs risk management process in Rødsand 2

According to E.ON's risk management plan, the very reason to why they use it, is to "continuously identify, evaluate and prioritize risks in order to be able to avoid, or mitigate the consequences of all major risks". Furthermore, "a realistic examination of the project's conditions - goals, time- and cost frames etc., is received".

The RMP that E.ON uses consists of five phases, namely: Risk management planning, risk identification, risk assessment, risk response planning, risk control and risk monitoring.

The second, third and fourth step in the process, which is risk identification, risk assessment and risk response planning, are repeated continuously throughout the project.

4.2.1.1 Risk management planning

The process is commenced with a planning of the risk management, in relevance to the project. Points that need to be agreed upon are the scope, restrictions, roles, responsibilities, a consequences scale for assessing risks, but also time planning regarding risk management actions for mitigation of risks. Risk in a general sense refers to a potential negative effect on a project goal, and it is therefore important to clarify the project goals, which can be seen in chapter 4.2.2.1. To reach these goals, several sub goals are presented.

In Rødsand 2, some goals are created to form the scope of the project risk management. The general goals are meant to assist the project goals, and to inform and boost risk awareness for the project members. Some goals, for instance, were to keep the *risk register* and *action plan* updated, assign risk and action owners to all *significant* and *unacceptable* risks, to mitigate *unacceptable* risks to *significant* level or below and to have a planned response for all risks assumed to be *significant*. The risks categorized as *acceptable* are not treated.

4.2.1.2 Risk identification

In this part, workshops are held where a qualified group of people try to identify and determine weaknesses, uncertainties, but also risks that could be potential problems for the project. The risks are related to generic and project execution risks and all come internally from E.ON. It would therefore be exceptional to include the risk investigation from other contractors and external allies as well, so that this information is also taken into consideration. E.ON think that contractors ought to be obliged to deliver their risk management plan.

To make sure that all risks are handled and that the risk identification work is maneuvered in the right direction, a RBS is used. The RBS describes where risks originate from and how it can affect the project, the owner of the risk and the responsibility. Observations on each risk, which occur daily, are to be reported to risk managers, who documents the risk in a risk register, which is then handed over to the project manager.

4.2.1.3 Risk assessment

In the risk assessment, the group that identified risks in the previous step is inquired to evaluate the probability and effect for each described scenario. The contractor's assessed risks should be investigated as well, and compared to the overall project risks. If there are uncertainties it should be discussed and evaluated further, until a bilateral understanding has been grasped between the parties involved.

The level of a risk is determined by calculating the risk product, that is probability multiplied with the consequence, and the result is a demonstrated measure of the risk levels categorized *acceptable*, *significant* and *unacceptable*. Both probability and consequence for a certain risk, is scaled between 1 and 4, where 1 stands for the best-case scenario and 4 for the worst case.

With the given products of probability and consequence, together with the risk categorization scale, risks can be sorted into a risk matrix. The project coordinator decided on the values for consequence and probability for each risk.

The consequence is indicated by the impact it could have on the main, project goals and would therefore be related to:

- **Time** - Activities that are postponed or will result in delays for the project schedule.
- **Cost** - Increased costs that could cause the project to go over budget.
- **Working environment** - Injuries to people involved in the project.
- **Third party, injury** - Injury to people who are not involved in the project.
- **Environment -** Ecosystem damages.
- **Property -** Damages to property for any party involved in the project.
- **Third party, property** - Damages to property for parties not involved in the project.
- **Media** - Circumstances that could lead to bad publicity for the project.

4.2.1.4 Risk response planning

The last step in the workshops includes choosing the risk and action owners and come up with appropriate measures that can be taken to mitigate risks. There are four preferred strategies of dealing with risks:

- Eliminating risk by changing the project plan
- Reducing probability or consequence of the risk
- Transferring the risk to third party
- Accepting the risk and do nothing

To reach one of the four strategies, E.ON has three possible responses they work with:

- Preventive measures
- Insurance solutions
- Preparedness plans

The most major risks, are risks that need to be solved to reach the project goals. If a risk falls within this zone, the work should not be started or continued until the risk has been reduced. For the risks that less major, the work can continue, but the risk should be monitored and a response towards the risk should be implemented. Also, the cost and benefit of the risk should be considered in decision making. The rest are risks which require no response if they do not get worse.

4.2.1.5 Risk control and risk monitoring

The last step of the RMP is the monitoring and controlling of risks, to see how the risks in the project are developing over time. To successfully manage risks, it is important that there are clear responsibilities, the risk register gets updated and that the steering committee or project coordinator get detailed reports. To achieve this, monitoring and controlling risks should always be a factor to the project's planning of time and resources. The point is that risks should be followed up and monitored continuously throughout the whole project. Risks, as well as opportunities, should be reported to the risk manager by all people. Quality control, time follow-ups, cost follow-ups, and safety, health and environment follow-ups should be operated synchronically.

A risk register is used where the risks are presented in the project and the responsive plans are described. The risk register needs to be updated regularly so that it is always ready to be used. This means that when a response is realized, it is updated, and when a response is executed, the risk register is updated again, and if a risk is eliminated then that risk scenario will get closed.

The people in charge of a risk need to give an update every second month to the risk manager, who would strengthen the risk register with the help of all the reports. The information is then sent to the project coordinator, who every third month, forwards the risk statuses in a report to the steering committee. Also, the coordinator also prepares a verbal explanation regarding the condition, but also planned responses and activities.

In addition, risk management plans from subcontractors and suppliers should be provided in the beginning of the project. Then, a report containing the following points should be handed in monthly:

- Risks and the planned action
- Risks that have been closed
- Risks that have appeared
- Risks associated with activities within six months
- Incidents and accidents

4.2.2 Risks in Rødsand 2

Based on our interviews, this section will focus on identifying the risks that our interviewees experienced during their work on Rødsand 2.

4.2.2.1 E.ON

In E.ON's risk management plan description, risks are to not reach project goals. In Rødsand 2, the goals were to:

- Develop and implement a health and safety plan that delivers leading safety performance in offshore wind
- The wind farm shall be constructed with a capacity of 207 MW forecast to produce 803 GW hours per year, with a design life of 25 years
- The wind farm will be delivered to time and cost
- In accordance with all permits and consents.
- Being a good neighbor through implementing a stakeholder management plan.
- The project team will work with and provide input to the future operation and maintenance regimes, budgets and contracts.
- All outstanding issues with suppliers at the time for take-over shall be clearly specified and accepted by the Steering Committee.

Some major risks that E.ON was exposed to were:

Weather - The weather can pose a risk if the weather turns out to be worse than expected, wind speed and waves can stall the offshore construction phase and will have a negative effect on project time and budget.
Seabed conditions - Seabed investigations are performed by E.ON, mapping of the seabed and samples are distributed to contractors performing work on site. Samples are cost expensive so it is not economically feasible to take samples for every location where work is planned to be executed. Therefore, one sample will have to represent a big area which generates uncertainty in the project.
Return on investment - There is a risk that the wind farm does not produce as much as was estimated. E.ON and potential stakeholders would get their return on investment paid out later than estimated since they are paid per produced MWh due to the power purchasing agreement.

4.2.2.2 A2SEA

Weather risk - There is a wind speed and wave height threshold for which it is not safe to leave the harbor, operate the crane or jack-up the vessel. This means that there is a risk of cease in the offshore production if the weather is bad.
Seabed condition - As mentioned before, E.ON was responsible to provide data on the seabed. The data is used to calculate the jack-up procedure and if the data turns out to be wrong, or is analyzed incorrectly, it could for example lead to the jack-up process taking longer time than expected. In the worst case, a punch through could occur, which means that a leg on the jack-up vessel punches through the soil and damages the vessel.
Technical failure - The client is paying for a fully operational vessel, and if for some reason A2SEA has a technical failure which incapacitates the vessel, and the maintenance allowance is exceeded, the vessel will be declared off hire. There is however usually a liability cap written in the agreement to compensate for these kinds of failures.
Unexploded ordnance - There is a risk of encountering unexploded ordnance, but normally surveys are carried out by the client prior to construction start.
Financial risks - With the turbines getting bigger and bigger, larger vessels are required to be able to perform the job. Last time the vessels were updated was in 2012-2014, and according to Tony, newer Vessels will be required by 2025. A2SEA must get return on investment in about 10 years which is a risk, because vessels are very expensive. The older vessels can however still be used for maintenance for the turbine sizes they were able to install, and are therefore turned into service vessels later.
Increased competition - As the production costs has come down, and more offshore wind farms are being built, there has been an increased competition on the market. There are some companies that are trying to increase market shares by accepting risks which they cannot possibly live up to. There is also an increase in competition since there are more vessels available on the market for this kind of work.

4.2.2.3 Peter Madsen Rederi

Weather risk - If the waves are too high they will not be able to operate their excavation vessel, which means downtime. This in turn means longer project time and more costs.
Seabed conditions - As mentioned before, the client supplies the technical data of the seabed. The data does however not cover every location that they are working on so

some assumptions have to be made regarding the seabed conditions. A risk could for example be if the seabed turns out to be harder than the data showed which was provided by the client. That would mean that the excavation would take longer time than expected.

Contractual risk - PMR works as per specification agreed. If conditions differ from agreed there will be a dispute that will end out in a financial claim from one part to the other. This being the seabed or other items. Therefore, the more detailed the contract is and previous data are, prior project start, the more claims you can avoid afterwards.

Technical failure - There is a risk that the excavation vessel breaks down. The vessels are however maintained and serviced while docked in the harbor. They also have service contracts with technicians and crane manufacturers in Denmark who would come to their aid.

4.2.2.4 Aarsleff & Bilfinger Berger

Weather risk - The excavation work for the foundations were performed by Peter Madsen Rederi. If the waves are too high they will not be able to operate their excavation vessel, which results in downtime. This means longer project time and more costs. The foundations were transported on barges from Poland to the offshore site which

Seabed condition - As mentioned before, the client supplies the technical data of the seabed. It does however not cover every location that they are working on so some assumptions must be made in the tendering process. When the actual foundation design starts, samples are taken from every location that a foundation is going to be installed.

Technical failure - Risk that their major equipment breaks down, which then must be repaired as soon as possible. Mitigation action to reduce this risk is to continuously check/repair/maintain acc. to specific procedures and plans.

4.2.3 Risk response in Rødsand 2

It is obvious that the actors who conduct the actual offshore work are in direct contact with the potential risks associated with offshore work. The consequences of, for example a delay, will however also affect E.ON, and even a probability of occurrence can be attached to the weather risk, and the economic consequences of a delay is too big for subcontractors or supplier to be solely responsible for. Therefore, the companies we interviewed always strived to share the risk with the client.

4.2.3.1 Weather risk

From our interview with E.ON, they are always, initially, in a contract negotiation trying to transfer as much of the weather risk as possible to the subcontractors performing the offshore work. That however, seldom turns out to be the case because that would mean that the subcontractors would ask for high risk premiums. Usually the weather risk is managed by dividing it between different actors.

A2SEAs operation offshore was very weather sensitive, especially the lifting part, since they were lifting equipment which is designed to catch the wind in an area specifically chosen for its stable and strong winds. So as A2SEA puts it, it would not be economically feasible for the client to make them own the weather risk because of the high-risk premium they would have to add. Usually the client is chartering their vessel for a certain amount of days with some options. If they have some weather downtime they get a lower day rate. A2SEA also mentioned that how much risks the client expects them to own has much to do with how the project is financed. If the project is financed by external investors, the client wants them to take a higher risk as opposed to if the project is financed without external investors.

Peter Madsen Rederi had a somewhat different approach than A2SEA, and are usually hired on a lump-sum contract with some options regarding weather. They calculated the weather risk and added time to their contract which was supposed to cover eventual weather down time. They were however a much smaller part of the project compared to A2SEA, and the increased cost of them being responsible for more weather risk than A2SEA is negligible for the project. Also, since their scope of work mainly contained offshore excavation, they were affected by the weather to the same extent as A2SEA, but their overall weather risk was smaller and easier to assess.

Aarsleff & Bilfinger Berger, responsible for designing, manufacturing and installation of the gravity base foundations, had, as Peter Madsen Rederi, a lump-sum contract with E.ON. They manufactured all gravity foundations in Poland and transported them directly to the offshore site. The transportation of the foundations with barges from Poland was the most weather sensitive part for them in the project. To compensate for that, they made sure they had a buffer of foundations in Denmark, so the installation could proceed even if the weather did not allow them to transport from Poland. Furthermore, the transport was designed to be able to be carried out in high waves to reduce the risk of down time of equipment in Denmark.

4.2.3.2 Seabed condition

For Rødsand 2, E.ON was responsible to provide data on the seabed needed for contractors and suppliers to conduct design of the foundations and calculate tenders. Some data could be obtained from the Danish government but it was not enough, and E.ON had to conduct some cone penetration tests, take bore samples and do a seabed survey. Since it is very expensive to take bore samples offshore they usually take a few strategically placed samples which will have to represent the whole wind farm area. The data substantiate the subcontractors and supplier's tenders, and if it turns out to be wrong, E.ON is responsible for the extra costs associated with that. To mitigate the risk of providing wrong data E.ON could take more samples.

A2SEA was affected by the seabed conditions when they were jacking up their vessels. According to A2SEA, E.ON were responsible for the seabed data, but A2SEA were responsible to analyze it correctly. If they did not analyze it correctly it could, for example, mean that the jack-up procedure takes longer time than expected and the responsibility would be shifted to A2SEA instead.

Since Peter Madsen Rederi were responsible for the trench digging and backfilling of the grid and export cables, they were highly affected by the seabed conditions. But as mentioned above, they calculated their tender based on the data provided by E.ON, and whenever they experienced that the soil differed from the data provided, they took a sample, analyzed it and asked for a compensation.

As mentioned before, Aarsleff & Bilfinger were responsible for the design of the foundations. They used the data provided by E.ON to calculate their tender. When they won the contract and started the design, additional five cone penetration tests were conducted at every foundation location to investigate the seabed condition further for the actual design of the foundations. If the soil did not have the bearing capacity required, they had to excavate downwards until they found the right soil conditions. Or in worst case, request that the client chooses a new location for this specific foundation.

4.2.3.3 Technical failure

A risk which was affecting all the contractors performing work offshore is the risk of technical failure. This was not a risk which E.ON was affected by directly, but could of course be affected by indirectly if it led to delays. A2SEA considered this as one of their biggest risks since the only income they get was from their day rate for which the vessels were operating. If their equipment broke down, they would not be able to charge E.ON and would have been exposed to the risk of paying liquidated damages. To handle this risk A2SEA had a liability cap in their contract and continuous service on their boat whenever they were docked in the harbor.

4.2.3.4 Contracts

To lower the risk among the different actors in Rødsand 2, E.ON used a multi contractual approach where the scope of the project was divided into different packages. This lowered the risk for the subcontractors and suppliers, and thus decreased the total cost, as opposed to if one contractor had been responsible for the whole project. This approach lowered the total cost for the project, but increased the risk for E.ON since they became responsible for several procurement processes instead of just one. They also became responsible to coordinate the different packages. In other words, the multi-contractual approach meant a bigger involvement in the project from E.ON's side, but also a bigger risk. This also meant less risk for the contractor who was responsible for a package and thus resulted in lower risk premiums. Furthermore, E.ON explained that they wanted to procure bigger packages, but had a difficulty in achieving offers that they considered reasonable, because of the extra risk premium added from contractors. For example, they had one package which originally contained being responsible for the grid and export cables, which would mean being responsible for; trench digging, cable manufacturing, cable laying and backfilling. The price they got for someone to be responsible for that whole package was however too high, and they solved that by dividing that package into two smaller packages, one containing trench digging and backfilling, and the other one containing cable manufacturing and cable laying. This resulted in a bigger risk for E.ON because they had to manage more contracts, but it also resulted in a lower cost for the project because of lower risk premiums.

E.ON also mentioned that the wind turbine package went through some changes. E.ON wanted the turbine manufacturer to be responsible for delivering the turbines to the offshore site, but they did not want to own the risk of the offshore transportation. In the end Siemens delivered the turbines to the harbor, and after an examination E.ON overtook the responsibility (risk) of the turbines. After that, E.ON transferred the risk of the turbines to A2SEA who transported the turbines to the offshore location. When the turbines were lifted into position, Siemens came back and bolted everything into place and managed the installation and commissioning of the turbines. E.ON probably could have been able to convince Siemens to be responsible for the turbines all the way to the offshore site, but they did not see it as economically feasible in this case.

A2SEA mentioned that they work best with multi-contractual approach where the scope is divided into different packages, and the transportation offshore is one of them. A2SEA prefers a direct contract with the project developer and thus being responsible for their own package.

4.3 DNV- GL – project certification

As mentioned in the theory part, an offshore wind farm is a very expensive undertaking with a lot of stakeholders, not least investors who almost always are a part of the financing. The stakeholders are aware of the risks which are associated with offshore development and should thus presumably put some pressure on the project owner to have an excellent plan of how the project should be executed. In this thesis, we interviewed DNV- GL, who does provide project certification services. DNV- GL, Renewable Certification is an ISO 17065 accredited certification body who is independent from all suppliers and developers. "The objective of project certification is to ensure that the wind power plant will operate safely and cost efficiently, risks are mitigated and all technical, design and construction requirements are met." (DNVGL-SE-0190, 10).

E.ON mentioned in another interview that it is common that the stakeholders require the project developer to hire a marine warranty surveyor. The marine warranty survey covers only the offshore operations associated with construction, transport and installation of the main assets of the wind farm. The requirement for marine warranty survey typically is coming from the insurance companies.

The certification process provided by DNV- GL is divided into 10 phases which all represent a crucial part of the project's lifecycle. Each phase can be certified independently but to get a project certification the five following steps need to at least be certified; Design basis, design, manufacturing, transport and installation and commissioning, operation and maintenance. This service lowers the risks and increases the safety for all actors involved in the project, including E.ON, insurance companies and possible investors. According to information obtained from the interview, another reason which makes a third-party certification especially important on the current market is the increasing competition and decreasing project cost, which can affect quality and safety.

Furthermore, DNV- GL mentioned that the developers are becoming more confident – especially as big power producers are increasing their renewable share - and are conducting more of the designing, execution and operations activities in-house. It is good that the developers are becoming more knowledgeable but there is also a potential danger because of the risk of overlooking things when not involving outside actors to the same extent as before. Furthermore, it was mentioned that to be able to control the costs of a project, it is better for the developer to own and mitigate the risks.

4.4 Vattenfall - Taggen offshore

Taggen is a 300 MW offshore wind farm planned to be built in Hanöbukten, Sweden, but is currently under investigation. The project is to 50 % owned by Vattenfall and to 50 % by Wallenstam. Taggen has all the necessary permits to start the development, and are collecting wind data and they have handed in an application to increase the height of the turbines from 170 to 220 m to be able to have 8 MW turbines. The problem with Taggen, as with all other offshore wind farms in Sweden, is the financing part. Göran says that the economical endorsement for building offshore wind farms is the same as for all other renewable energy sources in Sweden, which is a problem since it is more expensive to build offshore compared to good onshore sites.

Vattenfall does however think that the cost of building offshore wind farms in Sweden will be reduced to a point where it becomes a profitable investment in Sweden in the future. Turbines are getting bigger which means less turbines need to be built to reach the same total effect. The life span of a turbine is also getting longer, which means that the investment has a longer economical life time. But if we do want a faster development in Sweden, the government should go in and either have subsidy for offshore wind farms or use the same tendering process as in some of our neighboring countries, where the developer is promised a compensation per kWh for a certain time period.

Vattenfall also discussed some of the benefits with developing wind farms in the Baltic Sea.

- No tide - the tide can for example change the water surface several meters which makes boat landings more difficult when maintenance must be performed.
- Inland sea - Generally lower waves, wind speed and brackish water. This means less strain on the substructure, and thus cheaper construction.
- The Swedish coastal line along the Baltic Sea is very long and the distance to land is short.

5 Analysis

5.1 E.ONs risk management process

All in all, E.ON's RMP is good and they have got a great grasp on their risk process planning. E.ON is one of the biggest electrical utility companies in Europe, and has been part of huge and complex projects before. This means that they have many years of experience on their shoulders. Additionally, there are a lot of stakeholders involved in these types of projects, so having a good risk management plan is not only in E.ONs interest. For instance, investors and insurance companies, among others, all put pressure on E.ON, so it does not come as a surprise that they have a good RMP.

This thesis did, however, intend to investigate if there was room for improvement in the risk management conducted in the industry. So, to get an understanding of the quality of the RMP used in Rødsand 2, it was compared to the RMP provided by PMI. In *table 2*, the processes are compared to each other and they are very like one another. The fact that they are almost identical makes us draw the conclusion that any critique targeting the RMP provided by PMI, can also be directed towards E.ONs RMP.

Table 2: E.ON and PMBOK risk management plan

Phase	PMBOK	E.ON
1	Plan risk management	Risk management planning
2	Identify risks	Risk identification
3	Risk analysis	Risk assessment
4	Plan risk response	Risk response planning
5	Control risks	Risk control and monitoring

What was found was that the RMP provided by the PMI was criticized for not emphasizing positive risks (Chapman & Ward 2006). That turned out to be correct for EON's RMP as well. They both mention positive risks, but they do not give positive risks the attention they require. Taking advantage of opportunities that arises is very important, especially in the offshore business where for example taking advantage of an increased weather window can be pivotal for a project's success. Furthermore, Chapman & Ward (2006) argue that the risk response phase, found in phase 4 should be considered in an earlier stage. Some risks can be given a risk response plan without having to go through phase 3. It could, for example, be risks that E.ON know will be transferred to a subcontractor or risks that they know by experience will not be a problem. By considering the risk response phase directly after the identification phase can thus make the RMP more effective. Making the RMP more effective and easy to use is critical

Lastly, Chapman & Ward (2006), advocates that a risk management process should be tailored to the industry, or even the project it is used in. The RMP provided by the PMI is general and can be applied to a lot of different industries. This is also true for the RMP used in Rødsand 2, because it is written in a very general sense, it is hard to see the connection to the offshore industry.

5.2 Risks in Rødsand 2

Most of the risks identified in Rødsand 2 were related to either the weather or the seabed conditions. The offshore construction work is affected by the weather because there is a wave height and wind speed threshold to which the offshore vessels can operate in. The lifting procedure in the foundation installation and turbine erection is especially affected by the wind. The wind speed also affects the electrical output of the wind farm in the operation phase. All the situations can have negative financial consequences for the project. The uncertainty of the seabed risk is created because it is not economically feasible to take samples of every location where offshore work is conducted. The seabed condition affects the jack-up procedure of the jack-up vessels, the foundation installation, design and planning and the cable laying. There are of course several other big risks but the two risks that the interviewed actors were exposed to are weather and seabed condition. This did not come as a surprise, it is a trivial finding, but a necessity to understand which actors were affected by these risks and how it affects them. It also helped as a limitation for the research questions.

To reduce the uncertainty related to wind and waves, there are databases containing weather statistics which are used to calculate probability of occurrence of weather down time in a project. It is also common to put up a weather station in the offshore area to gather additional weather data. This data is however not going to be 100 % accurate. The world is in a constant change, and even though weather statistics provide a good basis for analyzing the risk, there will always be uncertainties connected to the weather. In the case of A2SEA, E.ON owns most of the weather risk, the reason for that is simply because the only income of A2SEA comes from the offshore transportation, which means that they are affected by the weather during their entire scope. So, if A2SEA were to take the complete weather risk, they would have to add a very big risk premium to the contract, which would be very expensive for E.ON. So instead E.ON operates under a charter contract with A2SEA where their vessels and crew are rented for a certain amount of days, and if there is downtime due to weather, the day-rate is lower.

Aarsleff & Bilfinger Berger on the other hand had a scope containing design, construction and installation of the gravity foundations, which means that the offshore transportation of the foundations was only a small part of the contract. This means that Aarsleff & Bilfinger Berger's part of Rødsand 2 was not as weather sensitive as that of A2SEA, and in their case, they used a lump-sum contract which means that Aarsleff & Bilfinger Berger owned the weather risk.

Peter Madsen Rederi had a scope consisting of excavating cable trenches, backfilling cable trenches, scour protection and boulder removal which means that they were affected by the weather. But they did not use a jack-up rig and they did not do any lifting like A2SEA and were thus not as weather sensitive as A2SEA. In other words, Peter Madsen Rederi had also a lump-sum contract and owned the weather risk themselves.

E.ON strives to push as much of the risks to the contractors as possible. That combined with the increased competition and cost reduction can in fact increase the risks in the industry. Ten years ago, the market looked completely different because there were only a few actors in the market which meant that E.ON could take height in their contract to compensate for risks and have a safe workplace with high quality. For example, E.ON was the only company leaving a tender for Rødsand 2. They did of course not know that at the time but it says a lot about the climate back then and the fact that they could afford to play safe.

The increasing construction of offshore wind farms has also attracted actors from other businesses, big actors from the oil and construction industry. These companies can afford to take risks, and according to some of our interviewees, they have taken huge risks to fight their way into the market. Also, since the competition also exists between the developers, there is a risk that they allow subcontractors/suppliers to accept risk which they cannot live up to. This development does speak for the importance of having an independent third-party surveyor looking at the project from a distance with unbiased glasses. It also puts a responsibility on the developer, they must set demands and think rationally when they are procuring so that there are no unserious actors accepting risks which they cannot live up to. After all, most projects are still financed by the help of governmental subsidies which means that it is the taxpayers' money they are using.

The cost reduction and the increasing competition is good for the industry, because it forces the industry to find new better and more effective solutions which are beneficial for everyone. There is however also a risk that the quality drops with the pushed prices.

5.3 Offshore wind farm development in Sweden

The offshore wind farm development in Sweden is limited now, with the logical explanation that it is not a profitable investment. To get the development started there should be either a governmental subsidy system adapted to offshore wind or the production cost must come down. Several authors, Dolff et al (2014), Malmberg (2012) as well as the interview with Vattenfall regarding Taggen Offshore indicated that a development in the Baltic Sea could mean less risk and reduced costs, as opposed to building in the North Sea.

From the interview with Vattenfall, it was mentioned that a development in the Baltic Sea means lower risks because of reduced wave height and less storms than for example the North Sea. The reduced saltwater level of the Baltic Sea also decreases the wear on components which increases the lifespan of wind turbines or reduces the construction costs. The aforementioned risk reductions are also supported by Dolff et al (2014) and Malmberg (2012). If the wind farm construction in the Baltic Sea begins, there could be a market for a new type of cheaper installation vessels adapted to the less harsh environment in the Baltic Sea. The reduced wave and the reduced level of salt in the water also means that cost reductions can be made to the turbine structure.

6 Conclusions

The purpose of this thesis was to identify the major risks in offshore wind farm development and to unravel how those risks are controlled. Furthermore, the thesis aimed to investigate how the offshore wind farm industry is working with risk management and to provide suggestions for improvements by researching existing theories on risk management. Lastly, the Swedish offshore wind farm development as well as the potential risk reduction of building offshore wind farms in the Baltic Sea will be analyzed. To achieve that, a case study on an offshore wind farm was conducted where the risk management plan of that project was analyzed and compared to theory on risk management.

It is concluded that most of the risks associated with offshore construction are related to the seabed condition and weather. The seabed risk is mostly owned by the developer while the weather risk, not seldom is shared between client and subcontractor. Furthermore, it is suggested that the involvement of independent certifiers continue, or is increased, to keep the building quality in the offshore wind farm industry high even though construction costs are being lowered.

Further on it is concluded that risk management is an area in offshore wind farm development which is taken very seriously and given a good amount of resources. The risk management plan in Rødsand 2 as well as the RMP used in the project follows a general risk management process and relevant tools and methods were used. There are however a few aspects which could be improved. The emphasizing on positive risks should be given more resources. It is also suggested that risk response plan phase is considered in an earlier stage of the process to make the risk management more efficient. Lastly, it is suggested that the risk management plan should be tailored to the industry it is used in.

For the offshore wind farm development to gain momentum in Sweden there must be a governmental subsidy system adapted to offshore wind, or the production cost should be lowered. Building wind farms in the Baltic Sea can influence the latter. It is concluded that the Baltic Sea provides an inland sea environment which lowers the risks in the production phase and decreases the wear on the turbine structure in the operational phase. This could mean lower production costs, and if the market becomes big enough, specialized vessels and structures adapted to the less demanding environment in the Baltic Sea can be developed.

6.1 Suggestion for further research

Further research in risk management in offshore wind farm development should focus on investigating the advantages and disadvantages of using partnering contractual approach with cost-plus contracts between developers and subcontractors. This would mean a significant increase of the developer's risk, but could have positive effects in form of higher quality and a bigger transparency between client - contractors which could be beneficial in for example the risk identification phase.

7 References

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