Operation and maintenance simulation of generic crew transfer vessels for an offshore wind farm

Jarmo Ling
lingjarmo@gmail.com
Instituto Superior Técnico, Universidade de Lisboa, Portugal

October 2019

Abstract. The economics of an offshore wind farm is proven to be sensitive to the maintenance fleet. Depending on the size of the farm, distance from the shore, and weather conditions the importance of having an optimum fleet can vary. One of the best parameters to decide the fleet's performance on is yield-based availability because having different weather responses for each of the vessels under consideration results in different wind farm uptime. Crew transfer vessels (CTVs) can handle most of the service tasks and are used most often. There are three main types of builds monohull, catamaran and Small Waterplane Area Twin Hull (SWATH). Monohull has usually the lowest performance, while SWATH has the highest.

Taking into account the characteristics of CTVs already during the wind farm planning phase can increase the availability. The direction from where waves and winds are reaching the vessel during the crew's transfer to the turbine can have very significant effects on the stability of the vessel. Using catamaran's hydrodynamics to design the boat landing has the biggest potential compared to other vessels.

In this exemplary offshore wind farm of Borssele 1 and 2 a one percent improvement in yield-based availability is worth around 3.5 million euros a year, which gives a rule-of-thumb that if any next investment increases availability by 1 % and the marginal cost is less than 3.5 million, it is worth it and overall economics is moving closer to the theoretical least-cost point.

Key words: O&M simulation, crew transfer vessel, availability, energy loss, maintenance strategy

1 Nomenclature

AEP	Annual Energy Production
BLO	Boat Landing Orientation
CTV	Crew Transfer Vessel
KPI	Key Performance Indicator
LCOE	Levelized Cost Of Energy
MCR	Maximum Continuous Rating
MSI	Motion Sickness Incidence
NPV	Net Present Value
O&M	Operation And Maintenance
OWF	Offshore Wind Farm
RMS	Root Mean Square
SOV	Service Operation Vessel
SWATH	Small Waterplane Area Twin Hull
WACC	Weighted Average Cost of Capital
WT	Wind Turbine

2 Introduction

Operation and maintenance costs make up around 20-30 % of the LCOE for offshore wind energy, that of which around 73 % is made up of vessel-related costs and potential revenue losses (Dalgic et al., 2014). Thus to increase the profitability of an offshore wind project, one of the most effective ways is to optimize the costs and revenue losses related to vessels.

Around 75 % of malfunctions in an offshore wind farm are minor failures and can be addressed with a crew transfer vessels (Dalgic et al., 2014). There are three main types of CTVs used in the offshore wind industry: monohull, catamaran, and SWATH, whilst catamaran being the most popular option. Each type responds differently to the environmental conditions and their performance is largely a function of size, design, and engine power. SWATH has the most complex design, is most expensive, but if well designed also most comfortable, while monohull is at the other end of the spectrum.

As the performance of each of the transfer vessels is unique, so is the subsequent cost curve. At some point increasing the number of vessels and technicians does not yield much difference in the availability, as all of them still have the same limitations, however, it would exponentially increase the costs related to the maintenance and diminish the profit.

According to LAZARD, the latest LCOE for unsubsidized offshore wind energy ranges from 56-110 EUR MWh^{-1} (Lazard, 2018), with the lowest recorded value of 44 EUR MWh^{-1} in Denmark (Carr and Hodges, 2019). Innovations in the field are driving the costs down even further. The purpose of this research is to simulate and optimize the configuration of CTVs and maintenance strategy by considering the hydrodynamics of the most common vessels. The selection of the best scenario is made after energy cost which is most affected by yield-based availability (DNV GL, 2017).

3 Method

In order to find the difference in vessels' performance in various environmental conditions, a simulation tool was built. It is using the MatLab software to run simulations, the database files are Excel files. The script is made up of 11 smaller modules, which give intermediate results for better transparency of the end results. The model can be split into 5 parts depending on the inputs and purpose:

1. Databases;
2. Assumptions;
3. Maintenance strategy;
4. Simulations;
5. Calculations.

3.1 Databases

Several types of databases are used as inputs. Combinations of different databases creates operation criteria, indicating which interim results need to be considered as downtime. Downtime can occur due to exceeding certain thresholds or by having a certain sequence of values which is considered as downtime because of the maintenance strategy.

3.1.1 Weather

The weather datab used was collected from the North Sea from the 1st of January 1990 until the 31st of December 1999 with an hourly time resolution. The database is made up of 10 different parameters that are describing the wind, wave, swell, and current situation. The most dominant wave, wind, swell, and current directions are illustrated in Fig. 2. The average wind speed at wind turbine hub height is 7.2 m s^{-1}, making it a relatively good area for wind energy production. Significant wave height of 1.54 m, which is on the border for many CTV types as their maximum wave height threshold (Dai et al., 2015).

3.1.2 Hydrodynamics

MARIN has developed a hydrodynamic database to describe the response of three most common vessel types: monohull, catamaran, and SWATH, each of which is 20 m in length. This is specifically made for weather conditions that match the situation in the North Sea. There are two sets of databases, one for transit phase and one for zero speed transfer phase. These describe the motion responses for environmental conditions while in transit or transfer. The databases have three levels of performance depending on the vessel power, for transit the MCR is either 50 %, 75 %, or 100 %, which affects the vessel performance. For transfer database, it is bollard push levels, ID 1, ID 2, and ID 3, representing bollard push of 6.25, 12.5, and 15.6 tonnes of thrust. ID 1 is the most realistic to the vessels with such size and engine power.

3.1.3 Daylight hours

Daylight hours for a location near the Borssele wind farm were collected and made into a database showing the average amount of sunlight per day every month, this will be important to determine when servicing is available in the wind farm.

3.1.4 Wind turbine characteristics

In the wind farm Borssele 1 and 2, there will be 94 Siemens-Gamesa SG 8.0-167 DD turbines, which have rated capacity of 8 MW making the overall capacity of the wind farm 752 MW. The power curve of such turbines has the cut-in wind speed at 3 m s^{-1}, it will achieve its rated power output of 8 MW at 12 m s^{-1} and reaches cut-off at a wind speed of 25 m s^{-1}. Turbine height is considered to be 110 m above sea level.

3.2 Assumptions

Assumptions compile different relevant parameters from the literature review which were used as limitations to determine downtime, simulate failures, determine costs and create a realistic situation, which could describe Borssele wind farm.

3.2.1 Failure rates, repair times and crew size

Wind turbines are experiencing failures, which can be categorized by severity as a major replacement, minor replacement, and minor repair, each of which needs on average different amount of technicians and times to resolve. Offshore wind turbine failure rate and downtime are in Table 1.

Table 1. Failure characteristics (Carroll et al., 2016)

Category	Failure rate [per turbine per year]	Duration of repair [h]	Size of crew [-]	Failures [per year]
Major replacement	0.265	116.19	9.14	$94 \times 0.265 = 25$
Major repair	1.062	17	3.44	$94 \times 1.062 = 100$
Minor repair	6.178	6.67	2.61	$94 \times 6.178 = 581$

3.2.2 Cost

The literature review identified many cost-related parameters that are relevant to this research. A database with the costs used in earlier research papers and relevant websites was created. It includes charter costs of vessels, mobilization costs, expenses on the technicians, preventive maintenance cost, fuel and energy prices. Combining these with the revenue losses will give the vessel-related costs, which is different to each of the types and by comparing them will identify the optimum case. See Table A1 for most important assumptions made in the modeling part.

3.3 Maintenance strategy

In other word operation logic determines the windows of time when a certain operation will be available. The simulation creates results of binary databases of ones and zeros (uptime and downtime respectively) for different operations, however, this is *raw* data and needs to be processed to better reflect the reality of the situation.

3.3.1 Vessel availability window

A vessel is considered to be available in a window where there is a possibility to transit to the wind farm, and after which it is possible to climb on board the turbine and there is a possibility to transfer back to the vessel and transit back to the base at some point during 10 hours (assuming the shift length is 12 hours and total transit and transfer time is 2 hours). During this 12 hour shift, the motions in transit or transfer are allowed to exceed the limits, if they are not relevant to the current phase of the operation. For example, exceeding the transit limit during the day when the crew is already working on the turbine is not considered unavailability.

3.3.2 Operation window

This describes when is it necessary and possible to access the turbines. Several databases are matched by time and all of these need to have an uptime to find an operation window: it needs to be daytime and working day and the vessel needs to have an availability window at the same time. The maintenance strategy is illustrated as a flowchart Fig. A1.

3.3.3 Repair time

After an occurrence of failure, the downtime of the turbine starts counting until there has been a window of X amount of hours where the crew can access and address the problem. In case the crew needs to return to the base (bad weather conditions, sunset), the sum of several operation windows will have to add up to the necessary amount of working hours on the turbine. The number of hours needed for a failure is described in Table 1.

3.4 Simulations

Simulations were done in several steps: vessel availability simulations, which are divided into transit and transfer phase, each have their limitations or combinations of limitations; and turbine downtime simulation due to turbine failures.

3.4.1 Transit simulation

Transit from the maintenance base to the wind farm was simulated by matching the extensive weather database with the motion responses from the vessels' hydrodynamic databases. By defining the coordinates between the base and wind farm a predominant vessel traveling direction was found and subsequent motion responses if the vessel travels in given weather conditions for the extent of the database. Crew comfort was set as a limiting factor. Whenever MSI value exceeds 25 %, meaning if more than one-fourth of the technicians start vomiting due to motion sickness the operation would be aborted. The rule of thumb is that if any of the crew members start vomiting the operation is aborted, most of the transit is due to minor repairs or replacements as these make up around 96 % of the failures thus the crew is not more than 4 technicians (see Table 1). Using the MSI approach is more refined and has some benefits over the more common, more general, *significant wave height method* (Bos et al., 2018).

3.4.2 Transfer simulation

Transfer from the CTV to the turbine was simulated similarly to the transit phase. Most important parameters are the BLO and the heave motion at the bow of the vessel with respect to the boat landing on the OWT. Limitation for the heave movement was chosen to be 0.3 m, which would occur if the vessel moves one boat landing ladder rung spacing up or down due to sea conditions (Carbon Trust, 2017).

3.4.3 Downtime simulation

Using the values from Table 1 Monte Carlo approach was used to generate randomly occurring failures with various levels of severity (Andrawus et al., 2007). For example, a wind farm of 94 turbines is expected to experience 25 major replacement type failures (see Table 1). This simulation is run 100 times to find the normal distribution of energy loss.

3.5 Calculations

The previous simulations are giving results in the time-domain, so to get more insight how the vessels differ, the results need to be transformed to energy domain and costs, illustration is found in the appendix Fig. A1. Most interesting results are listed in Table 4 as KPIs.

4 Results

All of the simulations were run with limitation values listed in Table A1. If the motion exceeded these thresholds then it was considered unavailability.

4.1 Boat landing orientation

The first step in finding the optimums is going to the design phase of the wind farm, an important variable which plays a big role in transfer availability is the orientation at which the boat landing is put. There are several approaches to calculating the optimum BLO: using the *loading on the boat landing due to the environmental conditions* approach and calculating the most suitable direction (El-Reedy, 2015), or optimizing it according to the vessel's hydrodynamics; this research uses the latter.

Monohull and catamaran proved to be more sensitive to the orientation of boat landing, while SWATH remained almost the same for each of the angles. Figure 1 shows that the best overall results for monohull and catamaran are found while the orientation is either at 135° or 315° and as the result are not conclusive a qualitative estimation dictates that 135° is more suitable due to wind turbine shield the boat landing more from the wind and sea waves. The SWATH has the best performance on the 45° and 225° line, which is parallel to the main wind direction and current direction and with similar assessment, it can be concluded that optimum is the 45° orientation for it shields the transfer operation from main wind and wave loading. Changing the BLO parameter only changed the transfer availability so all of the other changes are originating from there.

4.1.1 Importance of an optimum BLO

Determining the direction of BLO can be considered as an investment decision. The orientation affects greatly the transfer workability of a vessel and thus influences revenue losses. NPV is a financial function which helps to evaluate the profitability of the investment and by calculating NPV of each of the landing angles by taking the revenue loss each year during the lifetime of the project as negative cash flow, it could be estimated how much a poor decision would affect the operating profitability. Assumptions for NPV calculations are listed in Table A1, while the definition of the approach and the formula can be found at Investopedia (Kenton, 2019).

Table 2. NPV difference

		Δ, [MEUR]
Monohull	ID 1	18.9
	ID 2	22.6
	ID 3	8.6
Catamaran	ID 1	24.6
	ID 2	17.2
	ID 3	7.8
SWATH	ID 1	11.3
	ID 2	1.1
	ID 3	0.4

The most insightful values in the NPV calculation are the minimum and maximum values and their difference. The difference, Δ in Table 2 is an expense that can be eliminated during the lifetime of the farm just by finding the optimal BLO during the design phase. Modeling the BLO after catamaran seems most reasonable for that vessel is more sensitive to it with high potential to have good performance, while SWATH is relatively stable at any BLO and monohull is under-performing compared to any of the alternatives.

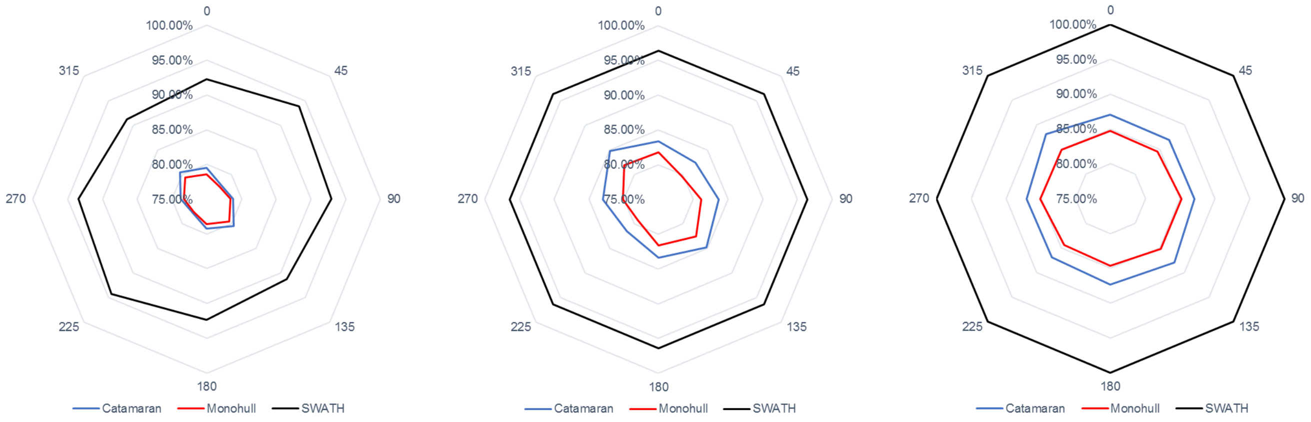
4.2 Engine power rating

The second stage of finding the optimum configuration is to determine whether it is better to use the full power of the vessel and maximize the performance of the vessel or is it possible to save of costs on fuel while still having a similar outcome.

Table 3. Engine power influence on transit availability and energy cost

	MCR, [%]	A_{transit}, [%]	Energy cost, [EUR MWh^{-1}]
Monohull	50	87.37	11.3
	75	89.55	10.2
	100	84.27	10.6
Catamaran	50	81.69	10.1
	75	96.29	9.8
	100	98.94	9.5
SWATH	50	69.26	10.4
	75	84.84	8.2
	100	86.53	7.9

Intuitively by increasing the engine power the traveling speed increases and the transit workability increases also, this trend can be seen in Table 3. As motion sickness incidence is a factor of time as it accumulates over time due to motion, so, on one hand, spending less time in transit decreases chances of developing motion sickness, but on the



(a) ID 1 (b) ID 2 (c) ID 3

Figure 1. Boat landing orientation sensitivity to bollard push

other hand vessel motions also change, which means the resulting comfort could go either way depending on specific conditions. An example of the latter happening can be seen from monohull as the availability increases until 75 % power but at 100 %, the increased speed comes from the expense of the comfort and has more downtime than before. The other interesting insight is how in the case of SWATH and catamaran increasing the power from 50 % to 75 % increases availability by around 15 %, indicating that if the vessel moves faster and cuts through the waves it also increases the comfort of the crew. These vessels need a certain speed to benefit from their unique hull design.

4.3 Optimum case

The optimum case was decided after *energy cost* parameter, the smaller it is the higher the projects profit margin can be. One has to keep in mind that this is only vessel-related energy cost and cannot be compared to LCOE as it is only a small part of it. Based on previous results it can be said there is no single "best" configuration. For monohull, catamaran, and SWATH the best BLO is respectively 135 °, 135 °, and 45 °. For MCR respectively 75 %, 100 %, and 100 %. Most realistic ID level for all was 1, translating to 6.25 tons of bollard push. The resulting energy cost for vessels was 10.3 EUR MWh^{-1}, 9.5 EUR MWh^{-1}, and 7.9 EUR MWh^{-1} respectively. The simulation results for the optimal cases are in Table 4

Interesting insight from Table 4 is that monohull and catamaran are more sensitive to the engine power and are consuming significantly more fuel. The increased fuel consumption due to different engine for monohull and catamaran does not play a big role in the project economics, but has a significant impact from the environmental standpoint, as it emits one-third more CO_2.

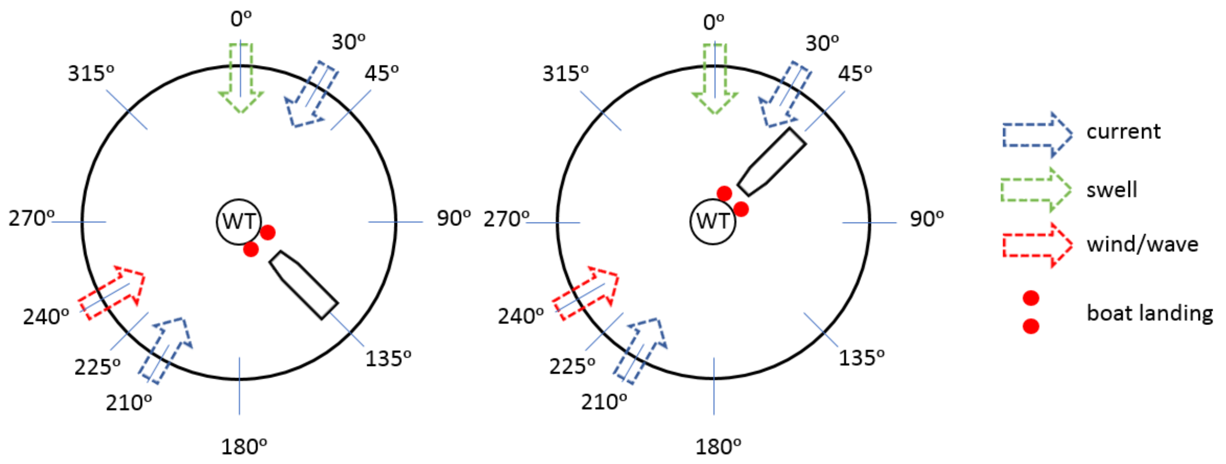
Table 4. Optimum configurations results

	Unit	Monohull	Catamaran	SWATH
A_{yield}	%	94.99	95.40	96.39
A_{time}	%	95.95	96.20	96.73
A_{vessel}	%	77.13	82.57	88.79
A_{transit}	%	89.55	98.94	86.53
A_{transfer}	%	79.57	80.43	93.84
Revenue loss	MEUR	17.3	15.9	12.5
SOV cost	MEUR	4.6	4.5	4.6
Charter cost	MEUR	3.4	3.1	2.7
Staff cost	MEUR	1.0	1.0	0.9
Planned maintenance	MEUR	0.4	0.4	0.4
Fuel cost	MEUR	0.2	0.2	0.1
CO_2 cost	MEUR	0.1	0.1	0.1
Total cost	MEUR	27.1	25.2	21.2
Emissions	t	2855	3379	2151
Travel time	min	47	47	37
Technicians	-	12.4	11.6	10.3
CTVs	-	3.3	3.0	2.5

Considering a wind farm with a large capacity of 752 MW, and AEP of 2788 GWh, every small change in the availability becomes very important because of the amount of energy it represents. Even though using the monohull vessel yields only around 1.4 % of less energy, the revenue lost is close to 5 million euros a year, which should give enough incentive to optimize the vessel selection and consider its hydrodynamical performance during the design phase of the wind farm.

4.3.1 Cost breakdown

From Table 4 the different costs types can be illustrated by compiling direct vessel-related costs like charter, fuel and



(a) Monohull and catamaran

(b) SWATH

Figure 2. Optimum boat landing orientations with environmental influence

corresponding externality costs into CTV costs and from Fig. 3 it can be seen that revenue costs are still by far the most important source of cost.

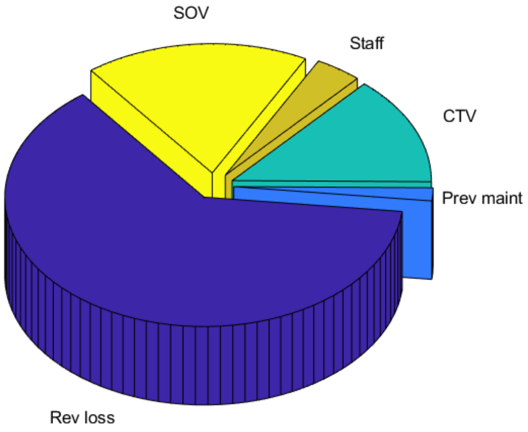


Figure 3. Cost breakdown of catamaran optimum configuration

Revenue loss makes up more than 60 % of the total costs related to O&M. Regardless of the type, maximizing the vessel workability will result in the highest yield availability and the best economics. Also regardless of the differences in total cost the breakdown of it stays relatively similar for all vessels as seen from Fig.3.

5 Conclusions

The maximum availability achievable with a maintenance strategy described by used inputs and assumptions is 96.39 % with SWATH vessel. To optimize the costs it can be seen from Fig. 3 that revenue loss is the most dominant cost in the O&M part related to vessels so best approach to lower the costs would be to use a CTV that has the highest availability which in this case would be the SWATH type vessel. Monohull vessel is under-performing in every aspect compared to catamaran and SWATH, so using only monohull vessels would not be justified unless the charter costs prove to be significantly lower than the alternatives.

When designing the BLO the best decision would be to go after the catamaran optimum case, because SWATH is not as sensitive to the angle whereas catamaran could yield some large losses when orientated incorrectly. Using this method results two equally good choices to put it at an angle of 135°, or 315°, but by considering wave loading the optimal would be at 135°. This would put the vessels almost perpendicular to the current direction and main wind direction (see Fig.2).

Ultimately, there is no "one size fits all" solution, and a lot depends on the choice of the vessel. In the current case the optimal configurations are in Table 5.

Table 5. Configuration summary

Vessel	BLO	MCR	ID	YBA [%]
Monohull	135	75	1	94.99
Catamaran	135	100	1	95.40
SWATH	45	100	1	96.39

Overall using yield availability and chosen input values and approaches to optimize the vessel selection gives a clear indication that SWATH type with performance parameters listed in Table 5 would be the best choice. The price of 1 % increased availability is close to 3.5 million euros, so as a rule of thumb if achieving the next percent of availability comes at a lower cost than that, the investment would be worth it and the economics of the project would be moving closer to the theoretical point of least cost. From an environmental standpoint finding a balance between the maintenance vessel emissions and produced energy should also be a criterion to consider.

Previous conclusions were made for specific vessels that were modeled by MARIN and simulated using specific input data, this does not mean that SWATH is always a better vessel of choice or with higher workability than monohull and catamaran.

Appendix A: Assumptions

Table A1. Main assumptions

Parameter	Value	Unit	Comment
Motion Sickness Incidence	25	%	(MARIN, 2018)
Roll RMS	6	°	(MARIN, 2018)
Pitch RMS	5	°	(MARIN, 2018)
Heave at bow	0.3	m	(Carbon Trust, 2017)
Rolls RMS	3	°	(MARIN, 2018)
Number of turbines	94	-	SG 8,0 MW-167 DD (RVO, 2017)
CTV contract	313	days per yr	Sunday is day off
Shift length	12	h	-
Electricity price	0.124	EUR kWh^{-1}	Tender price cap for Borssele site (RVO, 2016)
Fuel price	1.5	EUR l^{-1}	-
CO_2 price	28.5	EUR t^{-1}	CO_2 European emission Allowances (Business Insider, 2019)
Average technicians cost	82886	EUR per yr	(Smart et al., 2016), (Maples et al., 2013), (Owlguru.com, 2019) (HAYS, 2016), (Myhr et al., 2014)
Average CTV charter cost	3340	EUR per day	(Smart et al., 2016), (Maples et al., 2013), (Dalgic et al., 2014)
SOV cost	32900	EUR per day	(Ashish and Asgarpour, 2016)
Preventive maintenance cost	4385	EUR per turbine per yr	(Smart et al., 2016)
Project lifetime	25	yrs	(Hundleby, 2017)
WACC	10	%	(Hundleby, 2017)

Appendix B: Maintenance strategy

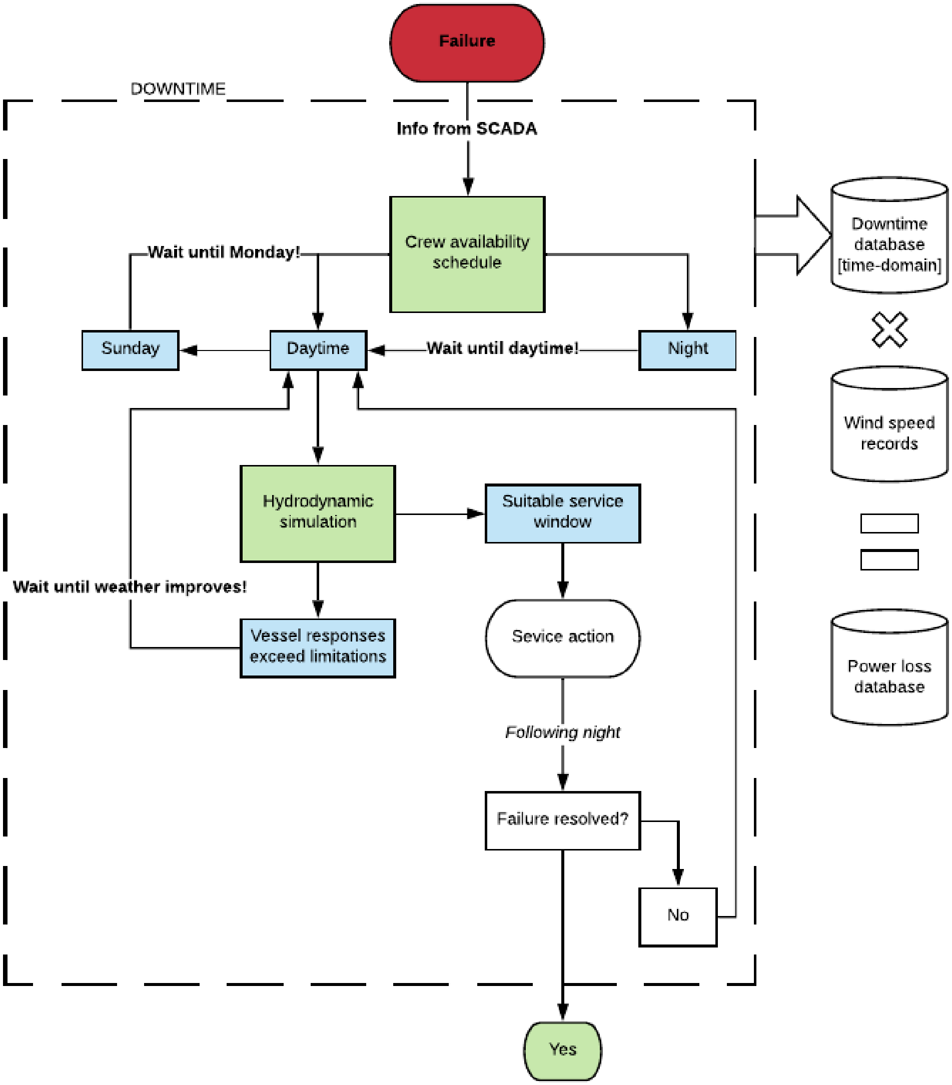


Figure A1. Flowchart

References

Andrawus, J. A., Watson, J., and Kishk, M.: Wind Turbine Maintenance Optimisation: Principles of Quantitative Maintenance Optimisation, Wind Engineering, 31, 101–110, https://doi.org/10.1260/030952407781494467, 2007.

Ashish, D. and Asgarpour, M.: Reference O&M Concepts for Near and Far Offshore Wind Farms, Ecn-E–16-055, p. 49, 2016.

Bos, J., Houben, I. M., Drongelen, A. V., Valk, P., and van den Broek, J.: Offshore Maintenance Seasickness Model, 2018.

Business Insider: CO2 European Emission Allowances History | Markets Insider, https://markets.businessinsider.com/commodities/historical-prices/co2-european-emission-allowances/euro, 2019.

Carbon Trust: Crew Transfer Vessel (CTV) Performance Plot (P-Plot) Development, pp. 1–18, 2017.

Carr, M. and Hodges, J.: U.K. Renewable Energy Auction Could Spell the End of Subsidies, https://www.bloomberg.com/news/articles/2019-07-04/u-k-renewable-energy-auction-could-spell-the-end-of-subsidies, 2019.

Carroll, J., McDonald, A., and McMillan, D.: Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines, Wind Energy, 19, 1107–1119, https://doi.org/10.1002/we.1887, 2016.

Dai, L., Stålhane, M., and Utne, I. B.: Routing and Scheduling of Maintenance Fleet for Offshore Wind Farms, Wind Engineering, 39, 15–30, https://doi.org/10.1260/0309-524x.39.1.15, 2015.

Dalgic, Y., Dinwoodie, I., Lazakis, I., McMillan, D., and Revie, M.: Optimum CTV fleet selection for offshore wind farm O&M activities, Safety and Reliability: Methodology and Applications, pp. 1177–1185, https://doi.org/10.1201/b17399-164, 2014.

DNV GL: Definitions of Availability Terms for the Wind Industry, Dnv Gl White Paper, 2017.

El-Reedy, M. A.: Helidecks and boat landing design, Marine Structural Design Calculations, pp. 189–216, https://doi.org/10.1016/b978-0-08-099987-6.00005-2, 2015.

HAYS: Oil & gas global salary guide: The 2016 Compensation, Recruitment and Retention Guide for the Oil and Gas Industry, 2016.

Hundleby, G.: LCOE and WACC (weighted average cost of capital), https://bvgassociates.com/lcoe-weighted-average-cost-capital-wacc/, 2017.

Kenton, W.: Net Present Value (NPV), https://www.investopedia.com/terms/n/npv.asp, 2019.

Lazard: Lazard's Annual Levelized Cost of Energy Analysis (LCOE 12.0), pp. 0–19, www.lazard.com, 2018.

Maples, B., Saur, G., Hand, M., van Pietermen, R., and Obdam, T.: Installation, Operation, and Maintenance Strategies to Reduce the Cost of Offshore Wind Energy, Technical Report Nrel/Tp-5000-57403, pp. 1–106, http://www.nrel.gov/docs/fy13osti/57403.pdf, 2013.

MARIN: Hydrodynamic Numerical Analysis for Wind Turbine Support Vessels, I, 2018.

Myhr, A., Bjerkseter, C., Ågotnes, A., and Nygaard, T. A.: Levelised cost of energy for offshore floating wind turbines in a life cycle perspective, p. 15, 2014.

Owlguru.com: How Much Successful Wind Turbine Technicians Make In 2017, https://www.owlguru.com/career/wind-turbine-service-technicians/salary, 2019.

RVO: Borssele Wind Farm Zone Wind Farm Sites I and II Project and Site Description, p. 69, https://offshorewind.rvo.nl/file/download/43061512, 2016.

RVO: Borssele Wind Farm Sites I II, https://english.rvo.nl/subsidies-programmes/offshore-wind-energy/borssele-wind-farm-sites-i-ii, 2017.

Smart, G., Smith, A., Warner, E., Sperstad, I. B., Prinsen, B., and Lacal-Arantegui, R.: IEA Wind Task 26 Offshore Wind Farm Baseline Documentation, National Renewable Energy Laboratory, https://doi.org/NREL/TP-6A20-66262, www.nrel.gov/docs/fy16osti/66262.pdf, 2016.