EBDIG - WFSV

European Boat Design and Innovation Group – Wind farm Support Vessel

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List of abbreviations

DP	Dynamic positioning
HF	Human Factors
HTA	Hierarchical task analysis
STCW	Standards of Training, Certification and Watchkeeping
WL	Workload
WFSV	Wind Farm Support Vessel
CTV	Crew Transfer Vessel
UCD	User Centred Design
HMI	Human Machine Interface

Notes

1 INTRODUCTION

Within offshore activities, there are a number of complex maritime operations going on. Most of these are related to the oil and gas industry offshore which is quite developed and mature, with regards to safety, environmental and quality issues. There is today an increased focus for offshore renewables as an alternative way to the oil and gas energy and much development has been seen within wind offshore.

The wind offshore industry is an expanding area due to its potentials in the North western European Area. The main development has been seen in Europe however there are other areas under development in countries like United States, Canada, South Korea, Taiwan and China (MacAskill & Mitchell, 2013).

By the end of 2006 there were 800 MW delivered by offshore wind farms in Europe, this has increased to 3,8 GW at the end of 2011, were 1136 turbines divided in 45 wind farms was active. The trends are that more offshore wind farms will be installed in the economic zone of UK, Germany, Denmark and the Netherlands (Besnard et al, 2013). The target of the European Wind Energy Association is to reach 230 GW of installed wind power by the end of 2020, and 40 GW of this should come from offshore wind (Besnard et al, 2013).

When the installation of an offshore wind farm is finished, the operations phase starts. The operation phase involves offshore maintenance, which often is carried out by special workboats CTV –(Crew Transfer Vessels) or WFSV (Wind Farm Support Vessels). These boats are usually built with a capacity of 12 passengers plus the crew. The passengers are technicians who are transported out to the wind farm where they board the turbine pylons and perform their duties.

The number of wind farm support vessels has grown and in this emerging fleet the concept of a safe transfer of personnel to the wind farm unit is the most important objective.

It must be done in a safe and efficient manner through certain access points; the key in these operations is the access system and the procedures around it.

Competence and experience is there for vital to secure these objectives but it’s also important to apply user centred design (UCD) principles to, given the opportunity for the crew to handle the vessel correctly and in a safe manner. (Offshore wind Journal, 2nd quarter, 2013)

Within this lies a technical challenge and adjust these to user needs that support safe and efficient operations. General practise within the industry has been to “butt” the CTV tightly against the friction bars on the wind turbine and hold it there with forward propulsion (Marsh, 2013)

This “bump to bump” solution works with smaller vessels with wave heights up to 1,5 metres significant (Hs). However, as the operations intend to move further out at sea with larger vessels, other solutions, principles and procedures are required in higher significant wave heights (Marsh, 2013). Gangway or access system is used but it’s not common among these vessels, however as the vessels motions involves six degree of freedom (Pitch, roll, heave, surge, sway and yaw) it’s difficult to compensate for all motions at the same time which makes these technical applications difficult to apply on these small vessels.

There is an interest within the industry to focus on higher wave heights than 1,5m Hs to increase the accessibility to wind turbines and this is mainly driven by economic reasons. Much technology and development of for example boat design have this driven by this interest, the SWAT (Small Water plane and Twin Hull) design for example could according to some vessel manufactures met this.

Another important aspect, that should go aligned with the technical development is the way how human can interact with this equipment and design, if this interactivity is achieved the operational capability will most likely increase as well as the safety level. This can be done by applying User Centred Design (UCD) principles in order to get an acceptable Human Machine Interface (HMI).

2 METHODS

The following chapters describe in short the method form that was employed to form the results of the deliverable. Main focus was put on the offshore wind farm support vessels and their duties.

2.1 Task analysis

In order to obtain a better understanding of what offshore operations consist of, and in particular wind farm service operations, a hierarchical task analysis was conducted on a vessel crew, participating in this type of operation, primarily transporting technicians and cargo to and from the wind farm .
A hierarchical task analysis was chosen since it was expected to give timely results, and would not interfere with the operation. There is an intrinsic limitation with this method: cognitive processes and the level of mental workload needed in each step of the process are not direct part of the analysis. Thus effort was put to record these in a different manner, but linked to the hierarchical task analysis. Thus there are some differences between the performed task analysis and a "traditional" HTA.
Hierarchical task analysis (HTA) is a method to describe tasks. The HTA identifies and characterizes the fundamental characteristics of a specific activity or a set of activities by observing what an operator or a group of operators needs to do to achieve a given goal (Hollnagel, 2006). The method is widely spread and used in several different domains such as air traffic control, product design and nuclear domains as a few examples. The HTA is the natural step after a collection of data and provides a step-by-step description of the activity under analysis. The analysis breaks down the task into a nested hierarchy of goals, operations and plans. The advantages with using the HTA are that is a quick method to implement and requires minimal training and equipment to get a description of a complete task. With a pen and paper one can easily perform an HTA. The HTA is also a very flexible and can be used in many different domains. Of course the method has some disadvantages, the person conducting the method has to know other methods used in the data collection such as interviews and observations. The method also mainly consists of only descriptive information rather than analytical information and some other method needs be conducted to get that kind of information (Stanton, Salmon, Walker, Baber, & Jenkins, 2006).

2.1.1 Procedures

The performing of a HTA is divided into six different steps that are described below.

1. The first step when performing a HTA is to define the task that is being analyzed. The purpose of the analysis should also be defined. In this report the HTA analyses Wind Farm Support vessel operation, all relevant tasks and subtasks performed by the crew, and as well to identify tasks with higher complexity.

2. In the second step the data are collected. The data can be collected in many ways. For the HTA in this report the data collections were conducted with on-board observation, interviews and Video/Audio recordings

3. The third step is to determine the overall goal of the task. This determination is the top

of the hierarchy in the analysis. In this report the overall goal of the task is to describe WFSV operation.

4. In the fourth step the overall goal is divided into task sub goals, the sub goals together should form the tasks required to reach the overall goal. Sub goals in the HTA in this report is for example planning of the operation and getting the right equipment out on deck.

5. In the fifth step the sub-goals is divided into sub-goals themselves. This is done until it cannot be done anymore and the bottom level of the HTA is reached and the operation is fully described.

6. The last and sixth step is the planning of the analysis and should describe how the goals are reached. A simple plan would say do 1, then 2, then 3 and when it is completed return to the super-ordinate level. Example: for planning the operation perform these operations and then return to the next step that comes after the planning the operation. (Stanton, et al., 2006)

The results are presented in chapter 3.1 on page 10.

3 RESULTS

3.1 Task Analysis of a Wind farm support Vessel operation

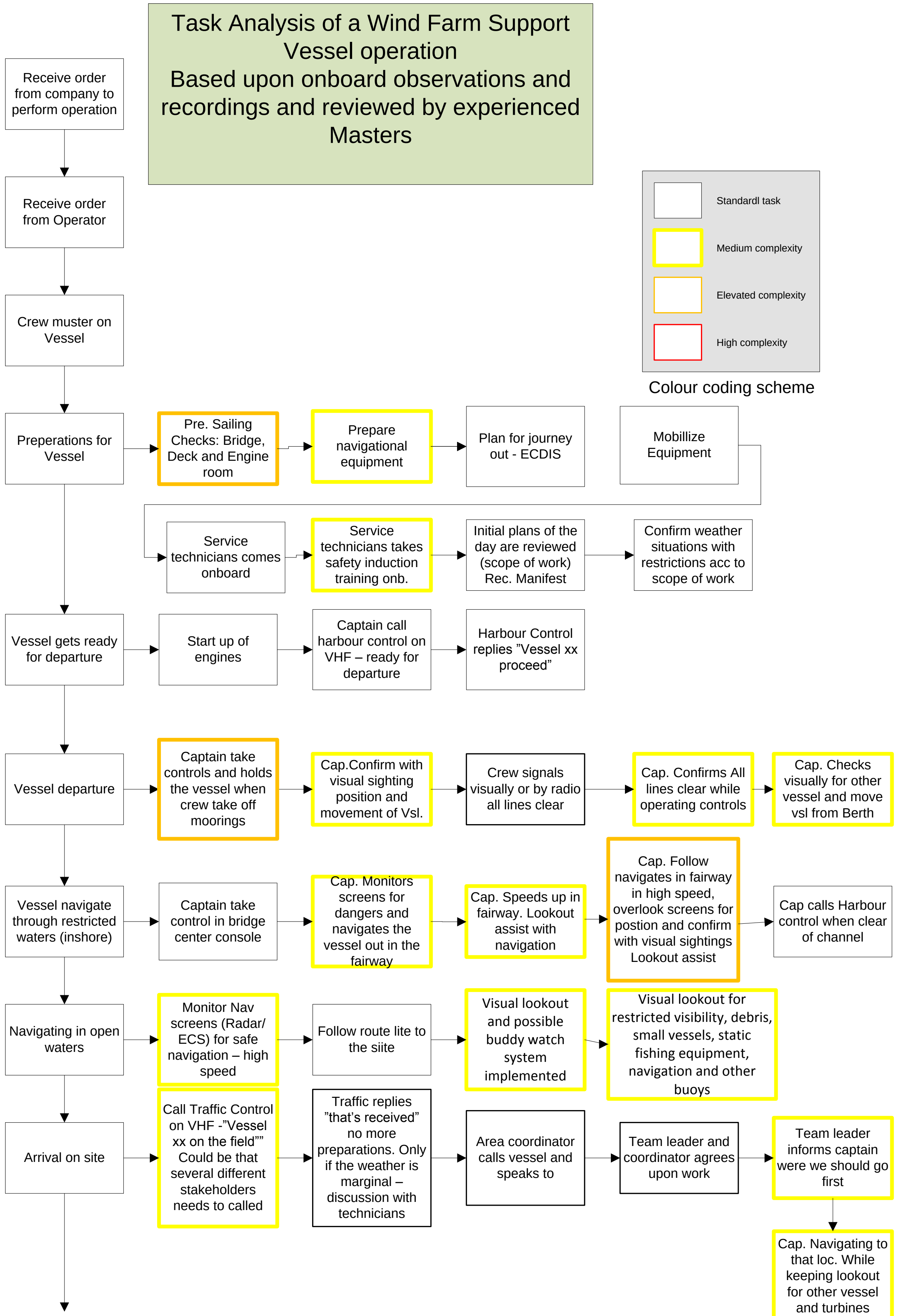
The on-board visit/observations took place on a CTV which was chartered for the wind farm operator Vattenfall; performing its duties on the DanTysk offshore wind farm west of Esbjerg (DK). There were three crew members who belonged to the vessel. On that day for the observation there were eleven technicians coming out for conducting work in the wind farm, which were fifty nautical miles off the coast. The crew was experienced regarding these operations and have been in the field for quite some time.
The conditions of the day were declining weather and sea, easterly winds around 20-25 knots. The wave height in the morning when arriving the field had a bit to the marginal with Hs 1,5-1,7 m and maximum wave height around 2-3 meters slowly reducing. However at one point when the vessel was pushing on the turbine wave heights of 4-5 m was observed causing the vessel move heavily on the friction bars on the turbine. These only occurred one time, but the fact remains that high waves can occur despite other reference values in for example weather forecasts which still makes sea conditions unpredictable. In interviews with captains, they often mention the current as the force that mostly affects the vessel ability to approach in an safe and efficient manner however on the DanTysk this was marginal.

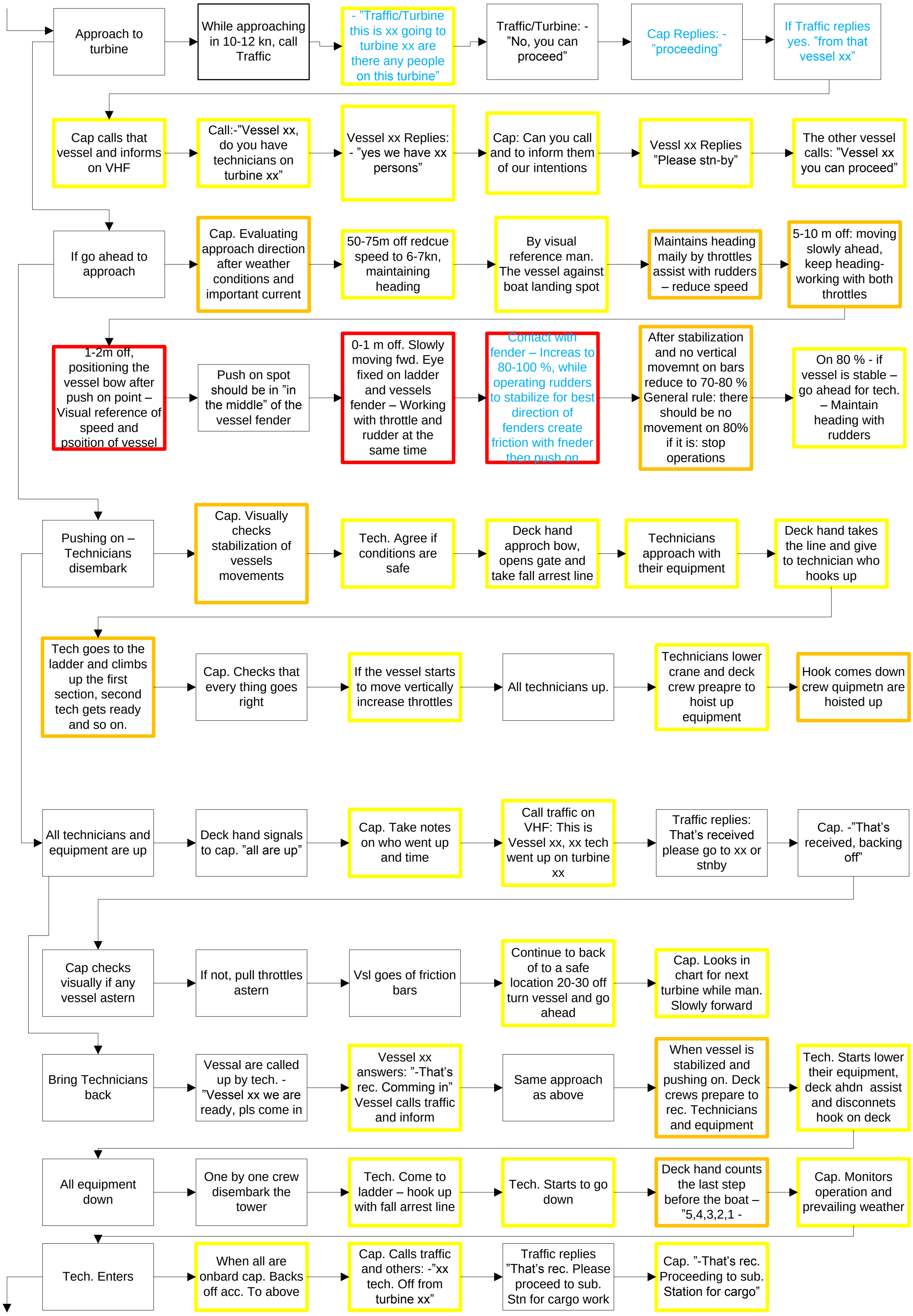
The hierarchical task analysis (HTA) in this report is a result of the observations, recordings and interviews during its operations in the Wind farm that day. Mainly the observation took place from the bridge of the concerned vessel, covering navigation to field, different approached to different turbines/floatels and substation, a cargo operation at a sub stations was also observed. The Analysis have been reviewed by two captains; the onboard captain and one from another similar company.

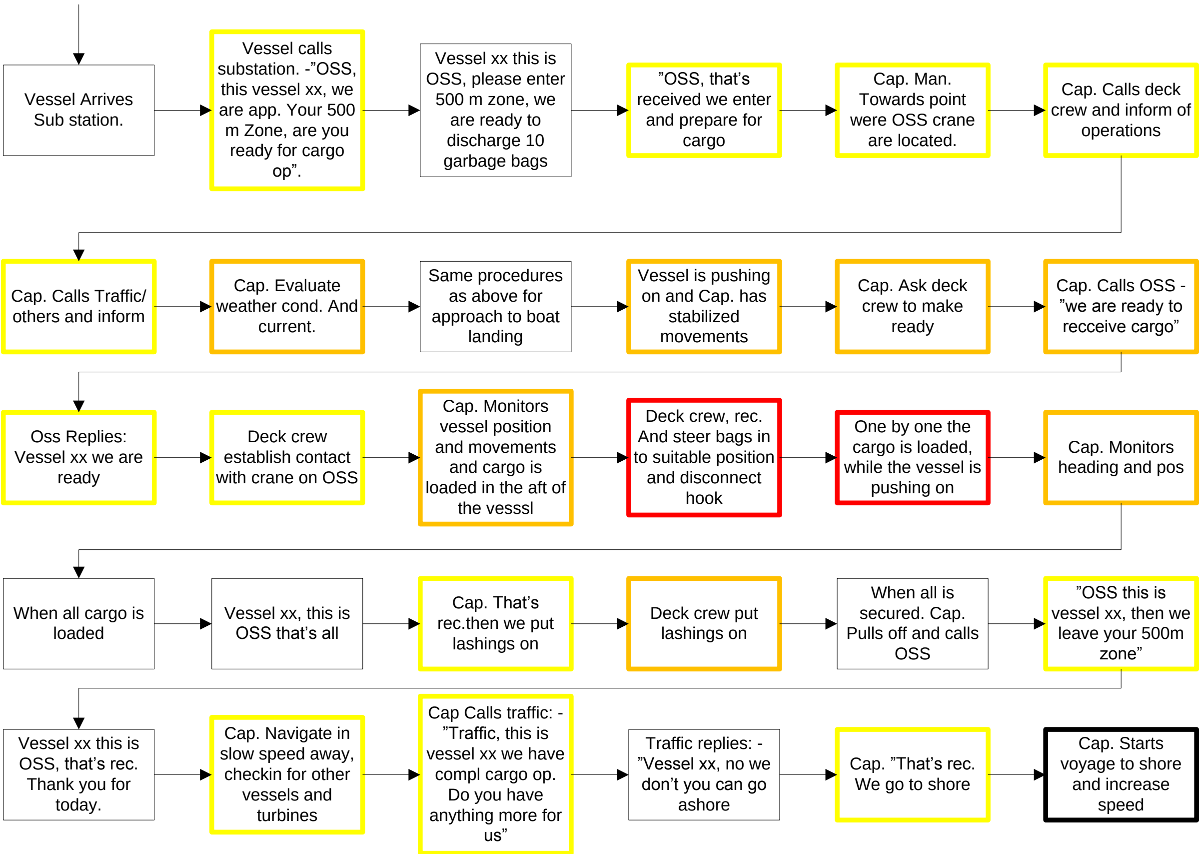
As mentioned earlier, the complexity of the single operations was of relevance. Here "complexity" was scored based on the judgment of the observers, which were asked specifically about this aspect. To denote the complexity a colour coding of the HTA-tree cells was chosen. The colour represents how complex the task in the box is to perform. Since the HTA is an analysis of a normal operation with no errors, the colour also shows tasks that can go wrong and that might lead to complete other task needing to be performed. In that case it can also be demanding and increase the workload demands on the crew. An example in this analysis is if the vessel starts to move on the friction bars while the technicians are climbing up the ladder, this requires different actions by the crew to stabilize the vertical movements or by aborting the operations. The workload also increases with other factors such as communication, weather, wind and current etc, not to mention eventual breakdown and accidents.
The following colour coding has been chosen:

- *Black boxes represent "standard" tasks*
- *The yellow framed tasks are when the crew has to pay attention. It can be when the the captain is communication with other vessels or technicians in the wind farm*
- *The orange framed task boxes represent tasks with high workload but not as much as the red ones. Typical task marked orange are where the bridge coordinates the operation with both the deck crew and the technicians, and the same time as the bridge, captain has to keep the vessel in position and perform other tasks.*
- *The red framed tasks with high workload and during these tasks the crew has to be very observant on what they all are doing. Deck crew working on the deck is such a*

high complexity (and very risky) situation.




Approach to turbine
While approaching in 10-12 kn, call Traffic
- "Traffic/Turbine this is xx going to turbine xx are there any people on this turbine"
Traffic/Turbine: - "No, you can proceed"
Cap Replies: - "proceeding"
If Traffic replies yes. "from that vessel xx"
Cap calls that vessel and informs on VHF
Call:-"Vessel xx, do you have technicians on turbine xx"
Vessel xx Replies: - "yes we have xx persons"
Cap: Can you call and to inform them of our intentions
Vessl xx Replies "Please stn-by"
The other vessel calls: "Vessel xx you can proceed"
If go ahead to approach
Cap. Evaluating approach direction after weather conditions and important current
50-75m off redcue speed to 6-7kn, maintaining heading
By visual reference man. The vessel against boat landing spot
Maintains heading maily by throttles assist with rudders – reduce speed
5-10 m off: moving slowly ahead, keep heading- working with both throttles
1-2m off, positioning the vessel bow after push on point – Visual reference of speed and psoition of vessel
Push on spot should be in "in the middle" of the vessel fender
0-1 m off. Slowly moving fwd. Eye fixed on ladder and vessels fender – Working with throttle and rudder at the same time
Contact with fender – Increas to 80-100 %, while operating rudders to stabilize for best direction of fenders create friction with fneder then push on
After stabilization and no vertical movemnt on bars reduce to 70-80 % General rule: there should be no movement on 80% if it is: stop operations
On 80 % - if vessel is stable – go ahead for tech. – Maintain heading with rudders
Pushing on – Technicians disembark
Cap. Visually checks stabilization of vessels movements
Tech. Agree if conditions are safe
Deck hand approch bow, opens gate and take fall arrest line
Technicians approach with their equipment
Deck hand takes the line and give to technician who hooks up
Tech goes to the ladder and climbs up the first section, second tech gets ready and so on.
Cap. Checks that every thing goes right
If the vessel starts to move vertically increase throttles
All technicians up.
Technicians lower crane and deck crew preapre to hoist up equipment
Hook comes down crew quipmetn are hoisted up
All technicians and equipment are up
Deck hand signals to cap. "all are up"
Cap. Take notes on who went up and time
Call traffic on VHF: This is Vessel xx, xx tech went up on turbine xx
Traffic replies: That's received please go to xx or stnby
Cap. -"That's received, backing off"
Cap checks visually if any vessel astern
If not, pull throttles astern
Vsl goes of friction bars
Continue to back of to a safe location 20-30 off turn vessel and go ahead
Cap. Looks in chart for next turbine while man. Slowly forward
Bring Technicians back
Vessal are called up by tech. - "Vessel xx we are ready, pls come in
Vessel xx answers: "-That's rec. Comming in" Vessel calls traffic and inform
Same approach as above
When vessel is stabilized and pushing on. Deck crews prepare to rec. Technicians and equipment
Tech. Starts lower their equipment, deck ahdn assist and disconnets hook on deck
All equipment down
One by one crew disembark the tower
Tech. Come to ladder – hook up with fall arrest line
Tech. Starts to go down
Deck hand counts the last step before the boat – "5,4,3,2,1 -
Cap. Monitors operation and prevailing weather
Tech. Enters
When all are onbard cap. Backs off acc. To above
Cap. Calls traffic and others: -"xx tech. Off from turbine xx"
Traffic replies "That's rec. Please proceed to sub. Stn for cargo work
Cap. "-That's rec. Proceeding to sub. Station for cargo"


Vessel Arrives Sub station.
Vessel calls substation. -"OSS, this vessel xx, we are app. Your 500 m Zone, are you ready for cargo op".
Vessel xx this is OSS, please enter 500 m zone, we are ready to discharge 10 garbage bags
"OSS, that's received we enter and prepare for cargo
Cap. Man. Towards point were OSS crane are located.
Cap. Calls deck crew and inform of operations
Cap. Calls Traffic/ others and inform
Cap. Evaluate weather cond. And current.
Same procedures as above for approach to boat landing
Vessel is pushing on and Cap. has stabilized movements
Cap. Ask deck crew to make ready
Cap. Calls OSS - "we are ready to recceive cargo"
Oss Replies: Vessel xx we are ready
Deck crew establish contact with crane on OSS
Cap. Monitors vessel position and movements and cargo is loaded in the aft of the vesssl
Deck crew, rec. And steer bags in to suitable position and disconnect hook
One by one the cargo is loaded, while the vessel is pushing on
Cap. Monitors heading and pos
When all cargo is loaded
Vessel xx, this is OSS that's all
Cap. That's rec.then we put lashings on
Deck crew put lashings on
When all is secured. Cap. Pulls off and calls OSS
"OSS this is vessel xx, then we leave your 500m zone"
Vessel xx this is OSS, that's rec. Thank you for today.
Cap. Navigate in slow speed away, checkin for other vessels and turbines
Cap Calls traffic: -"Traffic, this is vessel xx we have compl cargo op. Do you have anything more for us"
Traffic replies: -"Vessel xx, no we don't you can go ashore
Cap. "That's rec. We go to shore
Cap. Starts voyage to shore and increase speed

4 ANALYSIS

In general, findings and analysis point to some core areas of interest. In the following, they will be listed and briefly discussed. Firstly and most importantly is to know who the user is. Offshore operations are often specific to a certain vessel, and to a certain company.

4.1 Accessibility

The issue of accessibility is determined by the percentage of that device can be accessed, are a major factor that will affect the operation of an offshore wind farm (Salzman et al, 2009). The access problem can be highlighted in the effect of device availability; availability is defined by the amount of time the turbine is operational to create electricity (Faulstich et el, 2009).

The concept of accessibility in these operations is affected by a lot of parameters mainly adjusted by implications from weather and sea; however in our analysis we saw that this concept is quite complex and also affected by other parameters such as vessel design, turbine design and further more by training and experience. All these parameters are affecting each other.

4.2 User Centered Design

To be able to operate the vessel in a safe and efficient manner, the vessel and its support systems should be designed according to a user centered design approach.. To be able to operate the vessel in marginal conditions, this design approach has a very important role to play. Limitations in design might limit the vessel crew in interacting with systems and controls, which affects decision making.

The system should provide good overview, both to an individual and a group of operators, as dictated by the task/s being performed. There should be support for team work, information sharing and communication.

This approach does not only affect the vessel but also the turbine itself. Therefore, o design a system that supports the user and the different tasks in an offshore environment is a very complex task. For example, the majority of the boat-landing points on the turbine pylons are designed to meet the highest wave heights, but the main factor that affects the vessels approach is actually the ocean current. Stated in the interview by the captain, the bridge design on this vessel is supportive in the task he is undertaken in these types of operations.

4.3 Procedures

There are procedures in place up to 1,5m significant wave height (Hs) which seems to be an industry standard, however as operations do occur in wave height above that which has no clear stated procedures, “Then you are on your own” as stated by one captain. The industry wants a higher accessibility but there are today limited procedures how to support this.

4.4 Training and experience

It’s obvious that the wind offshore industry needs a shared and developed industry training standard for the boat crews. The value of experience is an important matter as these

operations require more “hands on” training and in providing the necessary background but you can only prepare the crews to a certain level. *“Then you are on your own”* as stated by one captain, this issue is something that needs to be considered further.
However, from the technician point of view, it is also important that there exists a training standard for those who are going offshore, and experience gained from working in these conditions needs to be addressed further.

4.5 Considerations for the near future

- User centered design and its role in supporting operations in adverse weather conditions
- Further studies in the concept of accessibility
- Is it possible to incorporate rules and regulations? Local procedures?
- Considerations regarding language and communication skills.

5 CONCLUSIONS

The offshore wind farm industry is still in its early stage and experiences from different phases are still gained and further on implemented in new projects. What has also been mentioned through the interviews is that high cost is something that the industry is suffering from at the moment. This can be seen as a main challenge throughout the industry, however it is not covered in this analysis as the main focus was to investigate the operation from a human factor perspective in order to apply user cantered design.

There is also an increased focus on accessibility and in order to increase this, a lot of focus and development is targeting different technical achievements. However as discovered in this analysis, these operations have to be analysed from a broad prospective and another method could be to analyse this from a sociotechnical perspective in order to map how different parts affects each other.

It is also clear that O&M (Offshore & Maintenance) operations needs an approach of user centred design, not only focusing primarily on vessels, but also for turbine design and structures which have influence in creating a system that is designed for its operations and the user undertaken these.

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